EVALUATION OF A NEW ANAESTHESIA MACHINE (IN LOW FLOW CONDITION)

Lt Col AK BHARGAVA*, Maj HK MAHAJAN⁺,
Maj BK GANDHI[#], Lt Col S SHARMA*

(Command Hospital (NC), C/o 56 APO)

ABSTRACT

The performance of a new anaesthesia machine was evaluated under low flow anaesthetic technique for 7 months. An assessment under low flow conditions over a definitive period can highlight the drawbacks or advantages of a machine under stringent conditions. The overall performance was satisfactory in the sense that it proved to be an efficient, reliable and safe machine. Minimum flows of oxygen and nitrous oxide that could be achieved at steady state were 0.4 L/min and 0.5 L/min respectively. At these flows the machine monitors were accurate and one could safely administer anaesthesia with a significant amount of saving of nitrous oxide. The requirement of nitrous oxide fell from 2 cylinders in a day to 2 cylinders in a week.

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KEYWORDS: Closed circuit anaesthesia; Low flow anaesthesia technique.

Introduction

Low flow anaesthesia is an inhalational anaesthetic technique in which a circle system with an absorbent is used with fresh gas flows (FGF) equal to the uptake of anaesthetic gases and oxygen by the system and patient. The carbon-dioxide expired is eliminated from the circuit by the absorbent (sodalime). It must be noted that no gases are vented through the adjustable pressure limiting (APL) valve as it is supposed to be completely closed. Generally the FGF is 3 L/min or less (flow being above basal but below the alveolar ventilation).

The respiratory gas monitor (RGM) fitted with the machine is necessary for the safe conduct of anaesthesia. When in this situation where only basal requirement of gases are being delivered it is essential to monitor the inspired/expired oxygen, carbon-dioxide, nitrous oxide, volatile anaesthetic agent, SpO₂ and minute volume.

The disadvantages of a low flow technique are that expensive sophisticated equipment with intense monitoring is required. Moreover a comprehensive knowledge of the pharmacokinetics and

physiology involved is essential before embarking on such a venture. Zbinden et al studied the fresh gas utilization of 8 circle systems under low flow conditions and observed wide variations in their efficiency, essentially due to the arrangement of the components of the circle components namely the APL valve, sodalime canister and FGF inlet [1].

Excel 210 Anaesthesia Machine has been introduced into the Armed Forces Medical Services hospitals recently. It is now over a year or so since its installation in most of the operation theatres. The following is a study using the low flow anaesthesia technique wherein minimal flow of gases as required by the patient are delivered to the breathing circuit. For such a technique it is mandatory to utilize an efficient anaesthesia machine by which one can administer anaesthesia on a scientific basis.

An exercise was undertaken to evaluate the performance of the Excel 210 anaesthesia machine. This could best be done by using the machine under conditions of low flow. Secondly, it was also used to ascertain the economics in the use of nitrous oxide and sodalime in our setting.

*Classified Specialist (Anaesthesiology), ⁺Graded Specialist (Anaesthesiology), [#]MO Anaesthesiologist, Department of Anaesthesiology, Command Hospital (NC), C/o 56 APO

Material and Methods

The study was undertaken from 01 September 95 to 31 March 96. All patients more than 30 kg in weight were included in the study and patients of both sexes and in various ASA grades. Various guidelines exist for the accurate calculation of the predicted requirement of oxygen, the carbon-dioxide production, ventilation desired for normocapnia and the uptake of volatile anaesthetic and nitrous oxide [2,3]. The clinical technique adopted was designed taking the above factors into consideration. The anaesthetic protocol followed was essentially the Liverpool technique using gas/oxygen/relaxant/narcotic sequence with traces of a volatile anaesthetic namely halothane or isoflurane. Intermittent positive pressure ventilation (IPPV) was performed using the Ohmeda 7000 ventilator incorporated in the closed circuit.

It is essential to administer a priming dose of oxygen for the denitrogenation of the breathing circuit, functional residual capacity of the patients and arterial circulation so that there is no interference with correct monitoring of the gases subsequently [4]. For this purpose preoxygenation using facemask with 100 per cent oxygen administration for 5 minutes was done using the closed circuit with the APL valve open. After induction with thiopentone and intubation, facilitated with suxamethonium, the patient was connected to the closed circuit and a mixture of nitrous oxide/oxygen was commenced. Initially 5 L/min of nitrous oxide and 3 L/min of oxygen, then 3 L/min of nitrous oxide with 2 L/min of oxygen, then 2 L/min of nitrous oxide with 1 L/min of oxygen was administered for 2 minutes at each setting with gradual closure of the APL valve. Subsequent readjustment of flow i.e., incremental decrease in flow was done after ensuring that FiO_2 fell in the range 0.3 to 0.4. The proportioning safety mechanism of the flowmeters were also helpful in ensuring that proportionate changes in oxygen and nitrous oxide were not too great when altering nitrous oxide or oxygen flows.

Duration of anaesthesia was measured from the time of introduction of nitrous oxide in the circuit till its discontinuation prior to end of surgery.

Anaesthetic depth was maintained by monitoring the BP, pulse, lacrimation, diaphoresis and

movement. Volatile anaesthetic agent (halothane or isoflurane) were introduced into the circuit as and when deemed necessary.

Results

A total of 202 patients were administered anaesthesia. Technically there was no difficulty in achieving a steady state and correct depth of anaesthesia with the flows of oxygen and nitrous oxide being reduced to as low as 0.4 L/min and 0.5 L/min respectively. At steady state the ratio of oxygen to nitrous oxide was 44.56 and was achieved, on an average, in 78 min. The duration of surgery in all cases had exceeded this average period. The consumption and requirement of nitrous oxide and soda lime during the period of study are shown in Table 1.

TABLE 1
Consumption and requirement of nitrous oxide and soda lime during study period

Total duration of anaesthesia (hours) with nitrous oxide	302
Total no of nitrous oxide cylinders (955L capacity) consumed	53
Life of one (955L capacity) cylinder	5.7 h of anaesthesia
Average duration of use of nitrous oxide per case (duration of surgery)	1 h 30 min*
No of cases per day	0.9 (1 case per day) #
MMF for nitrous oxide cylinders	7.5 (8 approx)
Total no of changes of soda lime (Canister capacity 2.7 kg)	4
Average life of soda lime (one filling)	75 h

$$* \frac{\text{Total duration of anaesthesia}}{\text{Total no of cases}} = \frac{302}{202} = 1.5$$

$$\# \frac{\text{No of cases}}{\text{No of days (7 months)}} = \frac{202}{212} = 0.9$$

The monthly maintenance figure (MMF) of nitrous oxide from earlier records for the particular operation theatre, prior to installation of the Excel machine, when semiclosed techniques were in use with the Boyle's Model F machine were calculated. This value was found to be 60 cylinders (995 L capacity) per month. This figure is significantly higher than the MMF calculated during the period of use of the Excel machine which was 8 (955 L capacity) cylinders per month.

The average life of one filling of soda lime was 75 h and a total of 4 fillings were required during

the study period.

Discussion

Excel 210 was the machine which was chosen to replace the Boyles Model F under the modernization policy. With the introduction of this newer machine in our armamentarium it was thought necessary to evaluate its performance in our setting. A closed circuit system in which carbon-dioxide is completely absorbed and the FGF reduced to the basal metabolic oxygen requirement (approximately 225 mL in an adult) plus the minimal anaesthetic gas would be the ideal and most logical design for an anaesthetic apparatus. The value in millilitres to which the nitrous oxide flow can be reduced is equal to a constant multiplied by the inverse of the square root of time (min). The constant as per the estimate of Severinghaus is 1000 [5]. In our study we could reduce the nitrous oxide consumption to 0.5 L/min after a period of approx 78 min. Some workers have worked on machines where nitrous oxide can be reduced to 350 mL/min at 100 minutes [6]. Theoretically by this formula after 100 minutes, 100 mL of nitrous oxide would be required. This actually never happens as nitrous oxide is lost via the skin and surgical wounds. A concern in the low flow technique is the potential build up of hypoxic mixtures due to a rise in nitrous oxide in the circuit after steady state is achieved and flows are not concurrently reduced further. In our study the steady state was reached in approximately 78 min and average duration of a case was 90 min; hence, this aspect could not be observed. It has been suggested by Spence that at steady state the oxygen/nitrous oxide mixture should be in a ratio of 50:50 in order to prevent any hypoxic event [7]. In our study, at steady state we were giving oxygen/nitrous oxide in ratio of 44:56.

It is well known that dissolved body nitrogen continues to be lost into the closed circuit with the passage of time. This interferes with the advanced gas monitoring and also dilution of the anaesthetic concentration. During the steady state, the sum total of oxygen, nitrous oxide, carbon-dioxide and volatile agent did not total to 100 per cent but around 98-99 per cent. This small discrepancy shown by the RGM is due to the nitrogen and other gases like CO, metabolites and volatile

agents such as CF_2CClBr , gases produced from the gut like methane, acetone and hydrogen. For a significant build-up of these unwanted gases in the circuit takes time and anaesthesia time lasting 4 to 6 hours would call for venting of these gases via the APL valve. The average duration of anaesthesia in the study was 90 minutes and such discrepancies were not really significant.

The advantages of a closed circuit low flow technique are that it conserves heat and humidity and decreases anaesthetic waste. It also increases safety as more intense monitoring is undertaken. Any anaesthesia machine which can be used effectively and safely under low flow anaesthetic technique qualifies for an excellence certification.

Very low consumption of nitrous oxide when low flow anaesthetic technique is used was proved. In the operation theatre where earlier two nitrous oxide cylinders (955 L capacity) were being used per day, now in the same theatre 2 cylinders are required in 1 week. Of course the cost of soda-lime has to be borne. Efficiency of soda-lime depends also on the closed circuit design. Conservation of soda-lime in the closed circuit is increased, if the spill valve is upstream of the soda-lime so that it is only the carbon-dioxide laden expired air that is vented whenever necessary. Secondly, if the FGF inlet is after the canister then the dry fresh gas does not dry the soda-lime. This arrangement which is considered ideal exists in the machine. One filling of soda-lime (2.7 kg) lasted for about 75 h. Considering the cost of soda-lime to be Rs 21/- per kg. The cost of use of soda-lime per hour of use would be around 75 paise. The economics of oxygen consumption was not worked out but theoretically requirements fall to one sixth when compared to semiclosed circuits. Under normal circumstances we have never felt the shortage of oxygen when compared to nitrous oxide, hence it was not considered in the protocol.

The consumption of volatile anaesthetics was not studied as only trace anaesthetic was being administered in the technique. Economy in the use of volatile agents arise when they are being used for anaesthesia during an inhalational technique with spontaneous respiration. The Tec 4 series vaporizers for halothane and isoflurane are placed in vaporizer outside circle (VOC) position in the

machine. At low flows vaporizers, particularly for halothane, which has a higher molecular weight tend to give less output than indicated on the dial setting. This aspect does not assume importance when we are monitoring the actual inspired and expired vapour concentration of the volatile anaesthetic. During controlled ventilation in a low flow technique with the APL valve completely closed the inspired concentration of the agent will steadily rise, hence inspired agent monitoring becomes mandatory in these circumstances. The RGM monitor has proved to be very reliable for this purpose. Desflurane, an agent desired to be used in closed circuit, is now being used in few centres abroad and may be available for use in the near future. As injector vaporizers for desflurane lend themselves to be utilized under low flow techniques [8] it would have been worthwhile to have had a provision of a desflurane vaporizer on the machine.

When oxygen flows are lowered near basal requirements the oxygen concentration in the expiratory limb starts assuming importance. Hence the facility to monitor fraction of oxygen in expired gas (FeO_2) is necessary, in fact an oxygraph similar to what a capnograph is for end tidal carbon-dioxide gives a better visual monitor of the changing trends and would be a more desirable feature than simple monitoring FeO_2 .

In this machine however, under no circumstances can oxygen delivery be lowered below 200 mL/min. Because of this mandatory oxygen flow which is slightly more or less greater than the metabolic oxygen requirement in adults, an inherent safety mechanism for prevention of delivery of potentially hypoxic mixtures exists.

Leaks are particularly important when a closed circuit anaesthesia system is under consideration. Modern machines have more than 20 potential sites of leak and can jeopardize the correct functioning of the machine more so when low flow techniques are being envisaged [2]. The washers in the soda-lime canister, faulty unidirectional valves in the breathing system and bag in bottle arrangement of ventilators are common sites of leaks in

other machines. Pulse oximetry is probably the only indicator to tell us that we are giving sufficient oxygen during the low flows supplied. The difference in FiO_2 and FeO_2 under low flows gives sufficient evidence that the body is utilizing the oxygen supplied to it. At high flows the difference becomes less marked.

Capnography was an excellent guide to ascertain whether hypo or hyperventilation was being resorted to. Since all our settings are aimed at normocapnia it forms the basis of conducting scientific anaesthesia. An elevated base line in the capnograph together with a raised inspired carbon-dioxide level is indicative of exhaustion of soda-lime. This was relied upon more than the change in indicator colour of soda-lime.

To conclude, the new anaesthesia machine introduced recently in our operation theatres has opened a new chapter. Additionally it has interfaces for being hooked up to computers to form database of monitored parameters and facility for incorporation in a servo-loop for computer aided anaesthetic techniques.

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