ISOFLURANE IN A CIRCLE SYSTEM WITH LOW GAS FLOW

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Isoflurane is not broken down by sunlight or soda-lime; thus it is suitable for use in low flow circle systems. Moreover, less than 0.2% of the administered dose of isoflurane can be recovered as urinary metabolites—compared with 2.5% of enflurane and 20% of halothane (Mazze, 1984). This minimal biodegradation may result in less nephrotoxicity and hepatotoxicity.

The cost of isoflurane is a disadvantage: at present, it is almost eight times as expensive as halothane by volume. The Goldman vaporizer has been used frequently in closed and low flow systems (Barton and Nunn, 1975; Robins, 1983). The aim of this study was to investigate the safety and efficacy of isoflurane when administered from a Goldman vaporizer into a low flow circle system.

PATIENTS AND METHODS

Forty-nine patients (ASA grades I or II) aged 18–70 yr took part in the study. They were undergoing orthopaedic, oral, plastic or general surgery likely to take 30 min or longer, in a general hospital. The local Ethics Advisory Committee approved the study and informed consent was obtained from each patient.

All patients were premedicated with an opioid (papaveretum or pethidine) and either hyoscine or atropine approximately 1 h before the induction of anaesthesia.

Anaesthesia was induced with sufficient thiopentone to obtund the eyelash reflex. This was followed by suxamethonium 1 mg kg⁻¹ to facilitate tracheal intubation. The larynx was sprayed with 10% lignocaine, unless contraindicated, and either a cuffed oral tube or a cuffed nasal tube inserted.

The tracheal tube was connected to the anaesthetic system shown in figure 1. A standard Boyle's machine (British Oxygen Company) and circle system were used. Isoflurane vapour was generated by a vaporizer-in-circuit (VIC). A Goldman vaporizer was chosen because it has a low resistance to gas flow. The oxygen analyser was an Analytical Instruments Teledyne fuel cell. The vapour analyser was a Datex Normac, which uses the principle of infra-red absorption spectrophotometry (Luff and White, 1985). Our analyser had a mean sampling rate of

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The system was flushed with oxygen at 1 litre min\(^{-1}\) for a minimum of 5 min before use, to reduce the concentrations of previous vapours. The glass bowl of the Goldman vaporizer was filled with 30 ml of isoflurane liquid, using a glass syringe to measure the volume accurately.

The patient's lungs were ventilated manually during the period of apnoea following the administration of suxamethonium. A fresh gas flow of 3 litre min\(^{-1}\) was used with the vaporizer set at either the second or the fully-on notch. The 3-litre fresh gas flow was found to fill the reservoir bag rapidly and permit manual ventilation. The vaporizer was adjusted to maintain a steady state of anaesthesia with appropriate isoflurane concentrations.

Oxygen alone was the fresh gas supplied to the first 19 patients (group A). In order to decrease the use of isoflurane further, nitrous oxide was incorporated to the inspired gas mixture in a second group of patients (group B). There were 30 patients in group B whose lungs were ventilated initially with nitrous oxide 2 litre min\(^{-1}\) and oxygen 1 litre min\(^{-1}\). Fresh gas flows were reduced to oxygen 300 ml min\(^{-1}\) and nitrous oxide 200 ml min\(^{-1}\) (Virtue, 1974) when spontaneous breathing restarted. The electrocardiograph, and oxygen and vapour concentrations were monitored continuously for the duration of anaesthesia. The heart rate and arterial pressure were measured every 5 min. On completion of surgery, the vaporizer was switched off, the trachea was extubated and the patients were taken to the recovery room where they breathed oxygen-enriched air until awake.

The results were analysed by the Student's \(t\) test.

**RESULTS**

In table I, the mean ages, durations of anaesthesia and volumes of isoflurane used in the two groups of patients are compared. There were no significant differences in the age and duration of anaesthesia in groups A and B. However, isoflurane usage was significantly greater in group A \( (P < 0.001) \).

The mean concentrations of isoflurane delivered to the patients at each setting of the Goldman vaporizer—taken at 15-min intervals—are shown in table II. The vapour concentration settled rapidly after changes in vaporizer setting. The
differences between these two groups were found to be non-significant. Carrier gas can affect vaporizer output, as has been demonstrated previously (Stoelting, 1971; Diaz, 1976).

Nitrogen concentration in the system was calculated for patients in group A at 30-min intervals using the formula:

\[ \text{Nitrogen} = 100 - (\% \text{oxygen} + \% \text{isoflurane}) \]

The results are shown in table III. Nitrogen concentrations decreased gradually after 30 min as a result of sampling by the Normac vapour analyser and loss through the expiratory valve.

Inspired oxygen concentrations at 30 min and after 30 min are shown in table IV. Oxygen concentrations at 30 min did not differ significantly from those observed after 30 min in group B.

**Effect on cardiovascular system**

The heart rate and arterial pressure tended to decrease in both groups; however, no treatment was required. An arrhythmia was noted in one patient having orthopaedic surgery, but it was present before surgery also. None of the nine patients undergoing extraction of wisdom teeth had arrhythmias.

**Recovery**

Recovery was rapid. All of the patients were conscious and able to return to their wards within 30 min of completion of anaesthesia. No difference in recovery time was noted between groups A and B.

**DISCUSSION**

The Goldman vaporizer has been evaluated previously as a draw-over vaporizer for halothane and enflurane in closed breathing systems (Mushin and Galloon, 1960; Barton and Nunn, 1975; Bushman et al., 1977; Jordan and Bushman, 1981; Robins, 1983). In this study, isoflurane was used in a similar breathing system in 49 patients. Nitrous oxide was used to decrease the amount of isoflurane needed to maintain anaesthesia in group B. As a result, the oxygen flow was reduced to 300 ml min\(^{-1}\). This value approaches the basal consumption of 200 ml for an average adult, making it essential to monitor the inspired oxygen concentration.

In this study the nitrogen concentration decreased below expected values as a result of sampling by the Normac vapour analyser and loss through the expiratory valve.

The vapour concentrations for each setting on the Goldman vaporizer were not significantly different in the two groups. The Datex Normac infra-red vapour analyser is not affected by nitrous oxide or nitrogen and so gives similar values for the two groups. The volume of isoflurane used per hour was significantly greater in group A. Each 10\% of nitrous oxide is known to reduce the required minimal alveolar concentration of an anaesthetic vapour by 10\% (Eger, 1981). As there was no significant difference in the mean duration of anaesthesia between the two groups, the increased usage in group A was attributed to the higher vaporizer settings required to maintain anaesthesia in that group.

The advantages of low flow re-breathing systems include increased humidification and reduced heat loss (Edsall, 1981). The risk of atmospheric pollution is decreased: it has been shown previously that the halothane concentration in the operating theatre was 500 times lower when a closed, rather than a semi-closed, system was used (Barton and Nunn, 1975).

Isoflurane is almost eight times more expensive by volume than halothane in this hospital (Q.M.H.) (table V). When used in a low flow breathing system, with nitrous oxide, it is still about twice as expensive as using 1.5\% halothane in a Magill breathing system with a fresh gas flow of 7 litre min\(^{-1}\). It is almost five times cheaper to use this closed system with nitrous oxide than to use isoflurane at 1.5\% in a Magill breathing system at 7 litre min\(^{-1}\) fresh gas flow.

The use of soda-lime and the use of additional monitoring are extra expenses in low flow systems. The approximate hourly cost of soda-lime can be calculated. In a 70-kg man using closed systems, the 1.13-kg cannisters of soda-lime last about 4 h (Edsall, 1981). In this hospital, the cost would be about 35p per hour. The cost of monitoring depends upon the initial price and the maintenance of the equipment. The Datex Normac cost £1,780, plus VAT. Two cannisters of calibration gas are used monthly, at £5.40 each. Servicing is performed by our departmental technician. The oxygen analyser could be justified for use in conventional or low flow systems. Isoflurane in a low flow circuit when compared with the conventional type (table V) would have to be used for about 430 h before it becomes more economical.
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REFERENCES
