Efficiency of a circle system for short surgical cases: comparison of desflurane with isoflurane

D. J. H. Lee, D. L. Robinson and N. Soni

Summary

Patients undergoing short surgical procedures but requiring ventilation of the lungs were allocated randomly to receive either desflurane or isoflurane by circle absorption system, initially at a high fresh gas flow. The inspired and expired concentrations of the volatile agent were measured and the fresh gas flows reduced to low flow (500 ml min\(^{-1}\) total when \(F_{E}/F_{I} = 0.8\)), as measured on a multigas analyser. In patients receiving desflurane \((n = 32)\), the median time at which flows were reduced was 5 min (interquartile range (IQR) 1 min) while with isoflurane \((n = 32)\), the median time was 19 (IQR 12) min. After the reduction in flow, expired concentrations of volatile agent decreased in both groups. In the isoflurane group the concentration continued to decrease during anaesthesia. In the desflurane group the initial decrease was followed by a slow recovery. We conclude that the circle system can be used efficiently for short anaesthetics using desflurane. (Br. J. Anaesth. 1996; 76: 780–782)

Key words
Anaesthetics volatile, desflurane. Anaesthetics volatile, isoflurane. Equipment, breathing systems.

The advantages of circle systems compared with other breathing systems include conservation of gases, volatile agents, heat and moisture, and reduction in pollution [1]. These benefits are largely dependent on the use of low flows of gas. A large proportion of anaesthetics are of short duration and this does not lend itself to the use of low flows as traditionally it has been assumed to take 15–20 min at high flows to allow the achievement of adequate uptake of inhalation agent. Adequate uptake implies not only that an adequate alveolar concentration is achieved but that it is maintained at an acceptable level after flow reduction. While these initially high flows serve to reduce anxieties about nitrogen washout and nitrous oxide uptake, they also preclude efficient and effective use of the circle.

The advent of new agents with lower solubilities should enable more rapid uptake of agent and so potentially enable the flows to be reduced earlier [2]. Lower solubility also implies less ongoing uptake of the agent and so less risk of the alveolar concentrations decreasing progressively at the low flow rates. If the uptake of agent continues to be high, there is a risk that the alveolar concentration of volatile agent will diminish and result in a change in the depth of anaesthesia.

This study was undertaken to determine if an adequate end-expired concentration could be achieved earlier with desflurane than with isoflurane. We also wished to observe the changes in end-expired concentrations of volatile agents after reduction in flows.

Patients and methods

After obtaining approval from the Riverside Medical Ethics Committee, we studied ASA I or II patients, presenting for surgery, who required tracheal intubation and ventilation of the lungs for surgery. Patients were allocated randomly to receive either 8 % desflurane or 1.5 % isoflurane. These values were chosen as approximating to 1.5 MAC, so that at \(F_{E}/F_{I} = 0.8\), the values would be 6 % and 1.2 %, respectively, which were of adequate magnitude to preclude awareness even if the expired concentrations decreased significantly after reduction in fresh gas flow. No premedication was given as these were short anaesthetics expected to last 20–30 min. Anaesthesia was induced in the anaesthetic room with propofol 3 mg kg\(^{-1}\) and fentanyl 2 \(\mu\)g kg\(^{-1}\), and vecuronium 0.1 mg kg\(^{-1}\) was used to facilitate tracheal intubation. Anaesthesia was maintained with 66 % nitrous oxide in oxygen and intermittent propofol administration while patients were moved to theatre and the tracheal tube connected to the circle system. The initial gas flows were set at 6 litre min\(^{-1}\), with the vaporizers set to deliver 8 % desflurane or 1.5 % isoflurane. Initially the lungs were ventilated with a tidal volume of 10 ml kg\(^{-1}\) and a ventilatory frequency of 10 bpm. This was adjusted, as necessary, to maintain normocapnia.

The inspired and expired concentrations of desflurane or isoflurane were recorded at 1-min intervals. At the point where the expired concentration was 80 %, or greater, of the set inspired concentration \((F_{E}/F_{I} = 0.8)\), end-expired concentration/inspired concentration, the total
Desflurane vs isoflurane in a low-flow system

fresh gas flow was reduced to 500 ml min⁻¹ with a mixture of 50 % nitrous oxide and 50 % oxygen, and the time from connection to the circle absorption system was noted. The inspired and expired values of isoflurane or desflurane continued to be monitored until the end of anaesthesia. As this study was designed to evaluate short anaesthetics, a maximum time of 25 min was chosen arbitrarily. If the anaesthetic was shorter than 25 min and $F_i/F_t$ failed to reach 0.8, then the time at the end of the anaesthetic was taken as the end-point. If the anaesthetic progressed beyond 25 min yet failed to achieve an $F_i/F_t$ of 0.8, then 25 min was taken as the end-point.

The Mann–Whitney $U$ test was used to test the difference in times at which the flow rates could be reduced.

An Ohmeda RGM 5250 multigas analyser was used to determine end-expired values. Accuracy is described as ±0.2 % over the range 0–5 % for isoflurane and ±0.5 % over the range 5.1–10 % for desflurane. This study was approved by the Riverside Medical Ethics Committee.

Results

We studied 64 patients, 32 in the isoflurane and 32 in the desflurane group. Median age was 35 (interquartile range (IQR) 11) yr and median weight 61 (IQR 14) kg. There was no significant difference between the ages in the two groups.

All patients in the desflurane group achieved an $F_i/F_t = 0.8$ during anaesthesia. In the isoflurane group, eight patients failed to achieve $F_i/F_t = 0.8$ by 25 min and were given an arbitrary value of 25 min. There was one patient in the isoflurane group where the anaesthetic time on the circle absorption system was only 20 min and who failed to reach $F_i/F_t = 0.8$. In that situation and for the purposes of this study, the time to reach $F_i/F_t = 0.8$ was given the arbitrary value of 20 min.

The median time to $F_i/F_t = 0.8$ in the isoflurane group was 19 (IQR) 12 min and in the desflurane group 5 (IQR 1) min. The difference in the time to reducing flow was significant ($\text{P} = 0.001$, Mann–Whitney $U$ test). As nine patients failed to reach $F_i/F_t = 0.8$ and were given an arbitrary value of 25 min (except for one given 20 min), the

isoflurane values were artificially low so that the difference between the two agents was greater than indicated.

After reduction in flow rates, when $F_i/F_t = 0.8$ had been achieved, observations were made of the end-expired values of the volatile agents. The time at which the flow rate was reduced was termed time = 0 and the results plotted for isoflurane and desflurane at 1-min intervals (figs 1, 2).

Discussion

Previously it has been considered that the potential advantages of circle compared with non-rebreathing systems would be of benefit only in anaesthetics of long duration. In short anaesthetics, with the previous generation of soluble volatile agents, either high flows are required until the system has stabilized, negating the benefits of the circle, or complex and sophisticated techniques have to be used. The advent of new insoluble agents may enable the circle system to be used more efficiently in short anaesthetics, widening its effective application.

When $F_i/F_t = 0.8$ was used as an indicator to reduce the fresh gas flow into the circle system, the flows were reduced at a median time of 5 min with desflurane and 19 min with isoflurane. After the reduction in flows to a low flow of 500 ml min⁻¹, the pattern of change in the expired concentrations of desflurane and isoflurane were different. Desflurane decreased initially and then recovered while isoflurane decreased and then continued to decrease for the duration of time during which the concentration was measured, albeit a relatively short period of time in this study.

There are several aspects of this study which should be discussed. The time at which the flows were reduced was chosen in the absence of a specific indicator in the literature. An $F_i/F_t$ of 0.8 was chosen for two reasons. First, it is a value which, using a multigas analyser, is easy to apply clinically with any volatile agent. Second, as it equates to 2–3 half-lives, it is an appropriate point on the uptake curve for volatile agents; the exponential curve is flattening at $F_i/F_t = 0.8$, indicating that the uptake of agent is reducing at this point (fig. 3). Uptake of agent beyond this point should be considerably less than earlier in the anaesthetic. Maintenance of the expired concentration depends on whether or not the
The theoretical curve of $F_E/F_I$ against multiples of the half-life of a volatile agent assuming $F_I$ reaches $F_t$ eventually. $F_E/F_I = 0.8$ corresponds to the part of the curve with a reducing slope indicating a reduced speed of uptake.

In this study high initial flows were used. This is in keeping with standard practice with other breathing systems. Nitrogen washout occurs rapidly and the uptake of nitrous oxide is relatively unimportant as the volumes of either gas taken up or released are trivial compared with flows into the system. The concentration of volatile agent set on the vaporizer is the concentration intended, and with the vaporizer out of circuit the set concentration represents the inspired value at high flows. When flows are reduced there is no alteration in the vaporizer settings and there is no risk of high concentration of volatile agent. The risk is of decreasing expired concentrations of volatile agents with a reduction in depth of anaesthesia. At total flows of only 500 ml min$^{-1}$ (50 % oxygen: 50 % nitrous oxide) the oxygen concentration must be monitored closely as over long periods it is possible for the inspired oxygen to decrease to less than 30 %, even with a 50 % oxygen mixture, as oxygen delivery may be close to oxygen consumption in some circumstances.

The method used in this study was deliberately attuned to anaesthesia for short surgical cases with the circle system. In patients receiving desflurane, the use of $F_E/F_I = 0.8$ to determine when flows could be reduced allowed the circle to be used as a low-flow system at a very early part of the anaesthetic. Using even very low flows (500 ml min$^{-1}$) did not cause clinical problems with decreasing expired desflurane values. With isoflurane, high flows were in use for most of the anaesthetic.

It is difficult to avoid the economic issue when discussing the circle system, in particular when using expensive agents, the cost of which prohibits introduction into many hospitals. Assuming an anaesthetic time of 20 min with the volatile agent used throughout, and fresh gas flows being reduced at the times suggested by the values obtained in this study, the cost of the volatile agents can be calculated. In this institution isoflurane would cost £3.60 and desflurane £2.60 for a 20-min anaesthetic. (At a fresh gas flow of 6 litre, the cost of desflurane would be £8.60.) The 30 % difference, at low flow, has to be evaluated against the total cost of both the anaesthetic and the case [5, 6]. Of greater relevance to us is the ability to use the circle system efficiently and safely for day-case anaesthesia.

References