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The effects of lowering fresh gas flow during sevoflurane anaesthesia: a clinical study in patients having elective knee arthroscopy

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Abstract

The potential for minimising anaesthetic gas consumption with a circle absorber system is related to fresh gas flow. This study measured the actual sevoflurane consumption during elective arthroscopy of the knee in 75 ASA I–II patients randomised to three fresh gas flow rates (6, 3, and 1.5 l/min) using sevoflurane and O_2:N_2O (1:2) after intravenous induction with fentanyl and propofol. A circle absorber system was used with a laryngeal mask airway. Anaesthetic duration, discharge time and postoperative pain did not differ between groups. Sevoflurane consumption was more than doubled with each doubling of fresh gas flow (0.07 ± 0.03; 0.16 ± 0.05; 0.41 ± 0.12 ml sevoflurane/min; for gas flow 1.5, 3, 6 l/min; $P < 0.01$). The hourly sevoflurane related cost decreased from 15.5 to 2.8 US$ when reducing the fresh gas flow from 6 to 1.5 l/min. Decreasing the fresh gas flow from 6 to 1.5 l/min provides good anaesthetic depth with effective reduction in anaesthetic consumption, cost and environmental burden.

Keywords: Volatile anaesthetics; Sevoflurane; Fresh gas flow; Health economy

1. Introduction

Day surgery has evolved under the continuing pressure of achieving good anaesthesia, no awareness, short emergence times and cost effectiveness. Lowered consumption of anaesthetic gases, in addition to reducing costs, is also of environmental concern both locally for personnel in the operating room and globally.

We have in a series of earlier studies looked at the consumption of anaesthetics associated with various standardised anaesthetic techniques used in day surgical procedures and found both clinical differences in emergence time and considerable differences in direct drug related costs [1–3]. The present study investigated the consumption of sevoflurane and clinical outcome when using three different rates of gas flow.

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2. Methods

Seventy-five ASA I–II patients scheduled for elective knee arthroscopy were studied after approval from the hospital ethical committee and informed consent. Cyclozine 50 mg was given orally prior to anaesthesia; no other premedication was given. Routine monitoring included ECG, pulsoximetry, heart rate (HR) and non-invasive systemic blood pressure.

2.1. Induction study protocol

Patients were preoxygenated ($FiO_2 = 0.7$) via a face-mask 3 min prior to induction with bolus doses of propofol and standardised dose of 0.1 mg fentanyl. Muscle relaxants were not used and a laryngeal mask airway was easily introduced in all patients and then connected to a circle absorber system (Q-2 system, Anmedic AB, Valentuna, Sweden). All patients received intra-articular lidocaine (5 mg/ml) with adrenaline and fentanyl (0.05 mg) at the end of surgery.

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Table 1
Patient characteristics and preoperative observations for three levels of fresh gas flow in patients anaesthetised with sevoflurane for arthroscopy of the knee[a]

	Group A (0.5:1 l/min)	Group B (1:2 l/min)	Group C (2:4 l/min)
Age (years)	53 ± 14	47 ± 10	46 ± 12 ns
Weight (kg)	77 ± 11	75 ± 12	81 ± 19 ns
Duration of anaesthesia (min)	24 ± 7	24 ± 12	22 ± 8 ns
Duration of surgery (min)	20 ± 7	17 ± 8	18 ± 7 ns
Sevoflurane consumed (g)	2.6 ± 1.0	5.7 ± 3.6	13.9 ± 5.4[b]
Sevoflurane consumed (ml/min) [range]	0.07 ± 0.03 [0.03–0.16]	0.16 ± 0.05 [0.04–0.24]	0.41 ± 0.12[b] [0.24–0.61]

[a] $N = 25$ in each group; mean ± S.D. ANOVA: ns, no significance.
[b] Indicates $P < 0.001$ between the three groups.

Maintenance anaesthesia consisted of an oxygen:nitrous oxide mixture (1:2) and sevoflurane. Patients were randomised (Table 1) to three different fresh gas flow rates from the start and maintained throughout the procedure. Group C received 6 l/min, Group B received 3 l/min, and Group A received 1.5 l/min fresh gas flow.[1] Sevoflurane concentration was varied according to clinical judgement. The anaesthetist was not blinded to gas flow. At the end of surgery, nitrous oxide and sevoflurane were discontinued and a fresh gas flow of 6 l/min of oxygen was used until removal of the laryngeal mask airway.

2.2. Gas consumption determination

The sevoflurane vaporiser was filled and weighed (scale type) prior to induction. The vaporiser was disconnected and re-weighed when anaesthesia was complete. Sevoflurane consumption per min was calculated individually for each patient.

2.3. Postoperative care

All patients received lornoxicam 8 mg and paracetamol 2 g orally as postoperative analgesia. Pain was assessed at 30 and 60 min after emergence according to the visual analogue scale (VAS). Criteria for discharge were standard hospital routines: ability to drink, ambulate, void and pain less than 3 on the VAS scale.

Cost for sevoflurane was taken from the Swedish pharmacopoeia, 1 581 SEK for 250 ml and the exchange rate 1 US$ = 9.6 SEK.

2.4. Statistics

All values are given as means and standard deviation unless otherwise stated. Assuming an alpha risk of 0.05, a beta risk of 0.20, and the sevoflurane consumption reduced by half by each reduction of the fresh gas flow, we calculated that 75 patients should be included in this study. Differences between groups, for weights before and after anaesthesia were studied by means of ANOVA, whenever appropriate, followed by Scheffe F-test. $P < 0.05$ was considered statistically significant.

3. Results

Patient data is shown in Table 1. The groups did not differ in age, weight, or duration of either surgery or anaesthesia. All surgery was uneventful, haemodynamics were well controlled in all patients and there were no clinical signs of inadequate anaesthesia nor was any awareness reported.

Pain was overall low and VAS at 30 and 60 min postoperatively did not vary with gas flow (Table 2). Emesis was only infrequently seen, and time to discharge as well did not differ between the groups.

The sevoflurane consumption more than doubled with each doubling of fresh gas flow rate. Huge individual differences were noticed in anaesthetic consumption and the range increased with increasing fresh gas flow (Table 2 and Fig. 1). The coefficient of variation for the sevoflurane consumption was 43, 31 and 29, respectively for the 1.5, 3 and 6 l/min group of patients.

The average cost associated with sevoflurane consumed during each procedure was totally 10, 22 and 54 SEK, respectively for the 1.5, 3 and 6 l/min fresh gas flow. The estimated cost per h being 5.5 times higher for the 6 compared with the 1.5 l/min patients (Table 2).

4. Discussion

This study has shown that by reducing fresh gas flow to low levels in a semi-closed ventilator system, equivalently good anaesthesia is provided but with a more than proportional decrease in the volatile anaesthetic. Our results are to some extent different from those of Weiskopf and Eger, who found that 'background flows'

[1] Under sevoflurane's labeling, a fresh gas flow rate as low as 1 l/m is permissible for short cases (2 MAC h or less).

Table 2
Postoperative observations and direct cost associated to sevoflurane consumed for three levels of fresh gas flow in patients anaesthetised for arthroscopy of the knee[a]

	Group A (0.5:1 l/min)	Group B (1:2 l/min)	Group C (2:4 l/min)
VAS 30′	1.3 ± 2.0	1.4 ± 2.2	1.4 ± 1.9 ns
VAS 60′	1.6 ± 2.3	1.2 ± 1.4	1.1 ± 1.4 ns
Rescue analgesia (no. of patients)	3	3	2 ns
PONV (no. of patients)	1	3	0 ns
Time to discharge (min)	61 ± 23	72 ± 23	68 ± 17 ns
Cost/h (sevo) SEK (US$)	27 (2.8)	57 (5.9)	149 (15.5)

[a] $N = 25$ in each group; mean ± S.D. ANOVA: ns, no significance.

from 1 to 2 and to 4.0 l/min changed desflurane consumption by only 68–82%. In that study, a fixed 1 MAC concentration was the end-point whereas in our study 'adequate anaesthesia' was the end-point used [4]. The sevoflurane concentration in the present study was adjusted according to clinical needs. Our results are, however, very similar to those of Pedersen et al. who looked at isoflurane consumption during clinical anaesthesia for longer in-hospital procedures [5].

In this study, each reduction by half of the fresh gas flow resulted in a somewhat greater reduction in total sevoflurane consumed. It is hard to give any absolute explanation for this finding. Our study is, as far as we know, the first investigating the actual sevoflurane consumption during clinical anaesthesia. One possible explanation could be that during the higher fresh gas flow, a somewhat deeper anaesthesia was established. The somewhat bigger individual variation of sevoflurane consumption in the higher fresh gas flow group may be an indication in that direction. The stability of the haemodynamics and equivalent anaesthesia times and time to discharge all suggest that the depth, and therefore quality, of anaesthesia in each group was more or less equivalent. An explanation in the same direction would be that the vaporiser is not entirely accurate at the lower fresh gas flows and therefore, a smaller quantity of sevoflurane than anticipated has been administered to the patients. The use of a more objective method for determination of anaesthetic depth, such as the BIS monitor or something similar may have been of value.

Cost effectiveness, particularly crucial in rapid day surgery, is a complex equation of many factors, of which drug cost is only one [6]. Induction/preparation time, duration of anaesthesia/surgery, time to discharge, factors influencing personnel related costs are at least as important [7]. We found a cost saving of a multiple of 2–5 by decreasing the fresh gas flow, however, put into the financial perspective the saving per patient was not more than 2–3 US$. Even if accounting for only a very minor part of the total cost associated with each surgical procedure, drug-related cost reductions should be seen in the perspective of the multiple of procedures performed. Even if cost saving may be rather small for an individual patient, the savings should be put into the perspective of number of procedures carried out. Patient-related factors such as postoperative pain and satisfaction should of course not be neglected or overruled by cost constraints. We could, however, see no differences between the three fresh gas flows studied regarding clinical outcome. The number of patients is of course low for the determination of more delicate differences in the clinical course. Whether our findings are applicable to longer procedures is hard to tell. Saturation of the patient and the circle system during the initial phase may make a difference.

Environmental concerns for local and global effects of both halogenated anaesthetic gases and nitrous oxide are in this case congruent with cost considerations. Even with effective exhaust systems, leakage of anaesthetic gases locally into the surgical theatre are unavoidable and can plausibly be argued to increase with increased fresh gas flow [8,9]. Not even the most modern exhaust systems do more than remove the anaesthetic gases from the local to the regional environment. While probably not a significant contributor to the

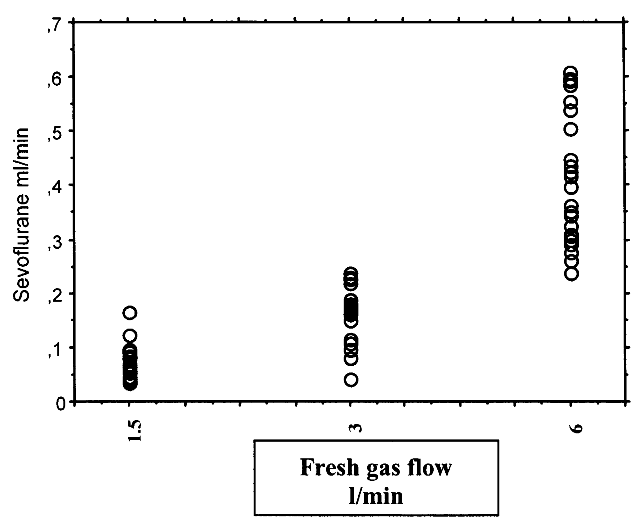

Fig. 1. The effect of fresh gas flow (l/min) on sevoflurane consumption (ml/min) in 75 patients undergoing knee arthroscopy ($r^2 = 0.7$).

total amount of halogenated gases released into the environment [10], our responsibility as health providers requires us to take those steps available to us. By reducing the fresh gas flow it is obvious that not only the amount of nitrous oxide is considerably lower but also the sevoflurane burden.

In conclusion, the simple reduction of fresh gas flow results in a slightly more than proportional decrease in sevoflurane consumption with a maintained standard of anaesthesia. The lowering of the fresh gas flow in the range between 6 and 1.5 l/min during ambulatory procedures such as arthroscopy of the knee is an effective cost-minimisation strategy.

References

[1] Jakobsson J, Hellquist E, Bastos M. Cost-effective anaesthesia for outpatient arthroscopic surgery, desflurane versus propofol? Ambul Surg 1997;5:67–70.

[2] Jakobsson J, Heidvall M, Davidson S. The sevoflurane sparing effect of nitrous oxide: a clinical study. Acta Anaesthesiol Scand 1999;43:411–4.

[3] Heidvall M, Hein A, Davidson S, Jakobsson J. Cost comparison between three different anaesthetic techniques for short out patient procedures. Acta Anaesthesiol Scand 2000;44:157–62.

[4] Weiskopf RB, Eger EI. Comparing the costs of inhaled anesthetics. Anesthesiology 1993;79:1413–8.

[5] Pedersen FM, Nielsen J, Ibsen M, Guldager H. Low-flow isolfurane-nitrous oxide anaesthesia offers substantial economic advantages over high- and medium-flow isolfurane-nitrous oxide anaesthesia. Acta Anaesthesiol Scand 1993;37:509–12.

[6] Fischer D, Macario A. Aconomics of anaesthesia care. A call to arms!. Anesthesiology 1997;86:1018–9.

[7] Kendell J, Wildsmith JAW, Gray IG. Costing anaesthetic practice. An economic comparison of regional and general anaesthesia for varicose veins and inguinal hernia surgery. Anaesthesia 2000;55:1106–26.

[8] Gilly H, Lex C, Steinbereithner K. Anaesthetic gas contamination in the operating room: an unsolved problem? Anaesthetist 1991;40:629–37.

[9] Kanmura Y, Sakai J, Yoshinaka H, Shirao K. Causes of nitrous oxide contamination in operating rooms. Anesthesiology 1999;90:693–6.

[10] Radke J, Fabian P. The ozone layer and its modification by nitrous oxide and inhalation anesthesia. Anaesthesist 1991;40:429–33.