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Elimination of waste anaesthetic gases from operating theatres

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At present, waste anaesthetic gases in the operating theatre are eliminated by room ventilation and by additional measures such as scavenging by a double-mask system and a local exhaust system. A simple technique is proposed for measuring the capture efficiency (E) of different scavenging systems. E is the ratio of the waste anaesthetic gases captured by a system to the total quantity of waste anaesthetic gases produced. In a field study on existing unmodified systems, E from a phantom pollutant source was measured using a portable measuring unit designed for displaying test results on location. The pollutant source was a leaking double-mask system. When scavenging from the double-mask system, E was 98% at an exhausted airflow of 28–33 m^3/h. Using a local exhaust system at an airflow of 30 m^3/h, E ranged from 20 to 96%, depending on the distance between the mask and the nozzle of the exhaust system.

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In recent years a great deal of attention has been focused on the potential occupational exposure to air pollution caused by waste anaesthetic gases (1). Without scavenging precautions the occupational exposure even in well-ventilated theatres may exceed the limits recognized by the health authorities (2). Acceptable air quality in an operating theatre may be achieved by the use of carefully designed scavenging equipment (3, 4), if only minor leaks occur from the anaesthetic system. To avoid pollution, an additional local exhaust system may, however, be necessary when air containing high concentrations of inhalation anaesthetics escapes from a patient disconnected from the breathing system (5). Leakage from badly fitting face-masks may also imply the need for a local exhaust system.

The performance of scavenging systems has previously been assessed by measuring the occupational exposure caused by waste anaesthetic gases (3). Using this approach, however, it is extremely difficult to compare alternative systems, as the air pollution is non-uniform with reference to time and spatial distribution (6). The purpose of the present work was to develop a technique to measure the capture efficiency of exhaust systems by field studies in operating theatres. The proposed technique is a supplement to the conventional technique of measuring the occupational exposure.

MATERIAL AND METHODS

The efficiency of an exhaust system is defined (7) as the ratio of the amount of pollution captured by the system to the total pollution produced. Measurement of the pollution captured can be accomplished by sampling in the duct of the system, but measurement of the total pollution produced is difficult. To overcome this problem, a tracer gas technique has been suggested (7).

With this technique the first step is to establish a reference concentration, CREF, in the exhaust duct (when all the tracer gas is captured by the exhaust). CREF corresponds to 100% efficiency. The volumetric release rate of the tracer is M, and the exhaust flow rate Q may be calculated from the equation

$$\mathrm{CREF} = M/Q$$

Next, a phantom pollutant source is placed on the site where the air pollution is normally generated. Provided the phantom source has a tracer release rate of M, a concentration CX can be detected in the duct. The capture efficiency, E, of the exhaust system then is

$$E = \mathrm{CX}/\mathrm{CREF}.$$

It is important that the tracer is homogeneously distributed in the exhaust duct at the point of sampling. The required distance from the releasing point is 10 times the duct diameter after a 90° angle. The phantom pollutant source in the present field study was designed as follows: a manikin (sealed mouth and nose) with soft skin (1-mm layer porous foam) was placed on the table in a selected theatre. A double mask was secured to the face of the manikin. Anaesthesia administration was simulated using a mixture of SF_6 and air (12%/88%) at an arbitrary but constant flow rate of 200 cm^3/min, and the fitting of the mask to the face was adjusted so that the pressure in the mask was arbitrarily fixed at 1.2 Pa.

The concentration of tracer gas was measured with a previously described (8) portable field measurement unit (Fig. 1). The concentration was sequentially measured (with a 45-s interval) in 3 positions (A, B, C), mounted as follows: A) exhaust duct; B + C) 1.3 m above the floor and 0.5 m from the face of the manikin. The theatre was ventilated (18 air changes per hour) by a cross flow, the air being supplied at 22°C from a diffusor in the wall and exhausted through a grill in the opposite wall. Position B was in the area between the table and the diffusor, and position C was in the area between the table and the grill.

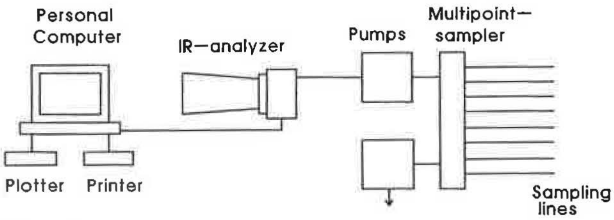

Fig. 1. Portable measurement unit.

The unmodified exhaust systems investigated included scavenging from the double-mask system (9) and a local exhaust system. Scavenging was performed by sucking air at a slight vacuum from the space between the inner and outer mask, and the capture efficiency was measured at two different flow rates. The local exhaust system was a 90 mm i.d. flexible hose positioned horizontally at the face of the manikin. The capture efficiency was measured at different distances (0.05 m, 0.10 m, 0.15 m, 0.20 m) between the inlet of the hose and the mask. This experiment was repeated fitting a perforated plate at the inlet of the hose.

Each experiment lasted for 20–40 min, and no persons were allowed in the theatre in order to minimize turbulence, but lamps were on during all the experiments.

RESULTS

As an example, Fig. 2 shows the results from the experiments using the local exhaust (without the perforated plate), the distance between the inlet and the mask being 0.15 m. The measured tracer gas concentrations at the positions A, B, and C are shown in the figure by the appropriately indicated curves. The data from curve A are used for estimating CX. Curve D in Fig. 2 represents the data from the introductory experiment where CREF was established. The results of all the experiments are summarised in Table 1.

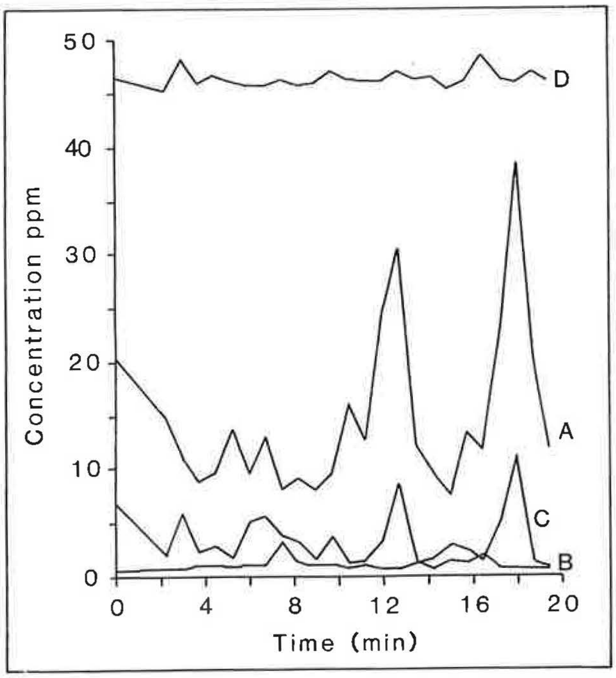

Fig. 2. The measured tracer gas concentration in dependence of time and sampling location.

DISCUSSION

Waste anesthetic gases may cause an unacceptable air quality even in well-ventilated operating theatres (2). The concentration may be non-uniform with time and spatial distribution (6). The data from the present study (Table 1) indicate a gradient of the concentration in a cross-flow ventilated theatre. The concentration at position B (close to the diffusor) was lower than at position C (close to the grill). It should be emphasized, however, that activity in the room may increase turbulence (3) and level out the spatial non-uniformity.

Althouth capture efficiency is the most meaningful characteristic of any exhaust system (10), the concept receives little attention in the standard ventilation text (11). Capture efficiency measurements have been made for specific operations such as laboratory fume hoods (12). In this study a quantitative method is presented for measuring the efficiency of exhaust systems in an operating theatre. The arbitrary but fixed leakage rate of our phantom pollutant source was estimated to be elevated (5–10 times) compared to a standard well-fitted single mask system. At the selected leakage rate the measured efficiency of scavenging by the double-mask system was 98% at an exhausted airflow of 28–33 m^3/h. At an airflow of 31–32 m^3/h the efficiency of the local exhaust system decreased from 96% to 20% as the distance between the inlet and the mask increased. A perforated plate at the inlet of the local exhaust may improve the performance of the system (12), but the present data indicate an improvement only close to the mask. The exhausted airflow, however, was less than 150 m^3/h, as previously recomended (13). It is recognized (14) that a flange at the inlet may improve the efficiency of an existing exhaust system.

As the design of the present study makes it invalid for studies carried out during normal activities in the operating theatre, the capture efficiencies reported here should not be considered conclusive. The proposed method, however, may be a useful tool in evaluating alternative exhaust systems.

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Table 1
The efficiency of local exhaust systems.

Exhaust systems	Distance between the mask and the inlet of the exhaust system m	Tracer gas concentration, ppm[a] Sampling position A	B	C	Capture efficiency %[a]
Local exhaust (32 m³/h) without a perforated plate	0[b]	46.5 ± 0.7	–	–	100
	0.05	35.3 ± 0.6	0.2 ± 0.03	0.7 ± 0.4	76 ± 1.4
	0.10	26.1 ± 2.6	0.5 ± 0.3	1.5 ± 1.3	56 ± 5.5
	0.15	14.6 ± 7.4	1.1 ± 0.5	3.6 ± 2.6	31 ± 16
	0.20	10.2 ± 5.6	1.1 ± 0.3	3.1 ± 2.5	22 ± 12
Local exhaust (31 m³/h) with a perforated plate	0[b]	47.9 ± 1.0	–	–	100
	0.05	46.7 ± 0.3	0.04 ± 0.00	0.4 ± 0.1	96 ± 0.7
	0.10	26.6 ± 4.1	0.8 ± 0.4	3.5 ± 1.6	56 ± 8.5
	0.15	10.8 ± 3.4	1.4 ± 1.0	4.0 ± 2.5	23 ± 6.7
	0.20	10.2 ± 5.6	2.0 ± 1.2	4.4 ± 2.8	21 ± 12
Scavenging from the mask (28 m³/h)	0[b]	53.1 ± 0.6	–	–	100
	–	52.1 ± 0.4	0.04 ± 0.00	0.4 ± 0.02	98 ± 0.8
Scavenging from the mask (33 m³/h)	0[b]	45.6 ± 0.3	–	–	100
		44.8 ± 0.3	0.04 ± 0.00	0.4 ± 0.02	98 ± 0.9

[a] mean ± standard deviation, [b] the introductory experiment where CREF is established.

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