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Local exhaust ventilation and exposure to nitrous oxide in ambulances

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Summary. Under extreme conditions, ambulance attendants and drivers could be exposed to nitrous oxide administered to transported patients in concentrations causing acute effects. Special arrangements are necessary to prevent such exposure, which is influenced by travelling speed, local exhaust ventilation and the use of an excess gas transfer tube evacuating expired air and overflow gas from the face mask to the outside. The separate eliminative effects of travelling speed and local exhaust varied considerably with the experimental conditions. The excess gas transfer tube reduced the levels of nitrous oxide in the air by 86 to 97% inside the ambulance at different experimental conditions. The combination of excess gas transfer tube and local exhaust resulted in a relatively constant reduction of the airborne nitrous oxide levels by about 98% when the ambulance was at a standstill and 99% when it was running.

Key words: Ambulance – Nitrous oxide – Pollutants – Transportation – Ventilation

Introduction

If special arrangements are not instituted, ambulance teams could be significantly exposed to nitrous oxide when this substance is administered to transported patients (Ancker et al. 1980). The problem is not negligible because these activities are performed under exceptional circumstances in motor cars in traffic. In the present study, the influence of different parameters on the airborne levels of nitrous oxide in an ambulance was investigated.

Materials and methods

A fullsize doll's head with an anatomic respiratory tract ("Resusci Anne", Laerdal) was coupled to a hand-driven suction pump constructed as a pair of bellows with a changeable volume. Between the head the the pump, two balloons, each with a volume of 1.5 liters, were connected in series. Between these two balloons and the pump a third balloon with the same volume was connected according to the scheme presented in Fig. 1. This balloon increases the capacity of the system, causing the expiratory air from the doll's head to retain some but successively decreasing amount of nitrous oxide when the administration of nitrous oxide is stopped. The system thus simulates a patient who has inhaled anesthetic gas.

The doll "breathed" at a frequency of 15 breaths per minute. One third of the respiratory cycle was occupied by inhalation, and two thirds by exhalation. A mixture of 50% nitrous oxide and 50% oxygen (Entonox, Alfax) was administered during three subsequent respirations, each with a volume of 1.2 liters. Between these three breathings, the mask was lifted from the doll's face and the head "breathed" pure air with a tidal volume of 0.5 l/min. Each parameter studied was examined for three separate periods, and each exposure period was repeated six times.

Air from the breathing zone of the ambulance attendant supervising the nitrous oxide administration was sucked through a probe located within 15 cm of the nose and analyzed with an IR-spectrophotometer (Miran 1-A, Foxboro/Wilks). The content of nitrous oxide was continuously registered on a chart recorder (Linear 142). The detection limit of the method was about 1 ppm (1.8 mg N_2O/m^3). Time-weighted averages of the airborne nitrous oxide levels for every breathing cycle were calculated by computerized curve integration including correction for the non-linearity of the calibration curve.

In an introductory laboratory study, the effects of varying the fan capacity and the distance between the doll's head and the outlet of the local exhaust were examined. In a following

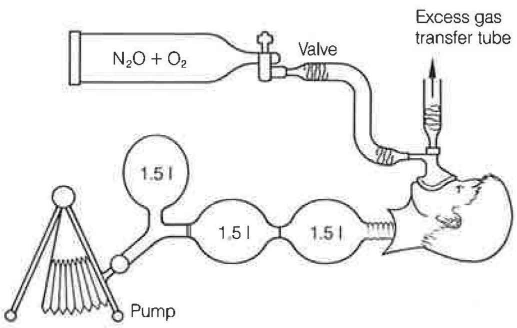

Fig. 1. Experimental set up of the "breathing" doll's head

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experiment, the capacity of the local exhaust was examined in an ambulance by systematic measurements, using the breathing doll's head and, for 25% of the measurements, a volunteer.

The laboratory tests were performed in a room with a volume of 40 m^3 and a ventilation rate of 6.2 air changes/h corresponding to an air flow of 4.1 m^3/min. A local exhaust was arranged with a flexible tube (∅75 mm) coupled to a fan and connected to the ventilation outlet in the room. All measurements of airborne levels of nitrous oxide were performed with a probe located in the breathing zone of the anesthetist and connected to the IR-spectrophotometer. The outlet air flow was measured with a pitot-static tube (Regin Vätskeanemometer IU 1 BG-2) and was either 112 or 145 m^3/h.

The air exchange rates in the ambulance (Mercedes Benz 190) were determined by measuring the decay rates of nitrous oxide in the ambulance coupé (Olander 1974). The IR-spectrophotometer and the fans used for mixing the air when performing the air-change registrations were connected to a battery set through a DC-AC-transformer (Valradio) transforming 24 V DC to 220 V AC.

An excess gas transfer tube evacuated expired gas from the expiration valve on the face mask to the outside of the ambulance. The adjustable roof hatch in the ambulance coupé was always half open, and the ordinary inlet fan in the driver's compartment was always switched on at maximal speed. This resulted in an air inflation rate of 78 m^3/h through the driver's compartment when the ambulance was at a standstill.

When the measurements were performed, the excess gas transfer tube was always connected to the expiration valve of the face mask, and the discharge of nitrous oxide was mainly due to leakage between the mask and the face. Guided by the results of the laboratory experiments, the outlet of the local exhaust was placed within 15 cm of the nose and mouth of the doll or volunteer (Fig. 2). The fan of the local exhaust was connected to a plate placed in one of the side windows of the ambulance and driven by the 12 V system of the vehicle.

Nitrous oxide mixture was administered with the same technique and the same scheme to both the doll's head and the volunteer. The effects of excess gas transfer tube (off and on), the exhaust ventilation capacity (0 and 130 m^3/h), and the ambulance speed (0 and 70 km/h) on the airborne concentration of nitrous oxide in the breathing zone of the anesthetist, time-weighted over each separate minute, were studied. The distribution of the nitrous oxide concentrations is skewed with a high frequency of low concentrations. However, the logarithms of the raw data demonstrate an approximately normal distribution, and the logarithmic values were used for computerized statistical analysis with the ANOVA design (HP 98820, A Statistical Library).

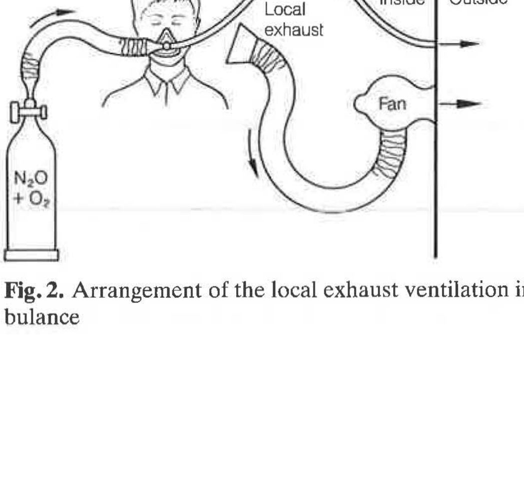

Fig. 2. Arrangement of the local exhaust ventilation in the ambulance

Results

The effect of the local exhaust rapidly decreases when the distance from the doll's head to the ventilation outlet exceeds 15 cm (Fig. 3). This phenomenon is apparent, irrespective of whether the exhaust airflow is 112 or 145 m^3/h.

Tables 1 and 2 illustrate the separate and combined effects of different eliminative measures on the nitrous oxide concentrations in the breathing zone of the ambulance attendant. The effect of the travelling speed varied considerably, depending on the excess gas transfer tube and local exhaust being on or off. Due to overflow phenomena, the capacity of the local exhaust diminished when the excess gas transfer tube

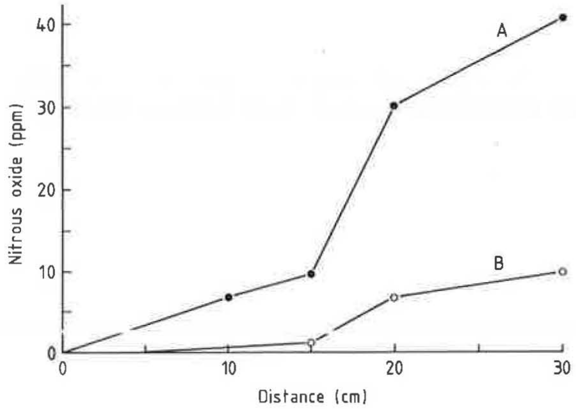

Fig. 3. Influence of the distance between face mask and outlet of the local exhaust at two different exhaust airflows (curve A 112 m^3/h; curve B 145 m^3/h)

Table 1. Airborne levels of nitrous oxide (ppm) in the breathing zone of the ambulance attendant (geometric means)

Excess gas transfer tube	Local exhaust ventilation	Travelling speed (km/h)	
		0	70
Off	Off	652	224
Off	On	401	198
On	Off	94	10
On	On	11	5

Table 2. Average reduction (%) of airborne levels of nitrous oxide in the breathing zone of the ambulance attendant due to different types of eliminative measures

Eliminative measure	Reduction (%)
Local exhaust	12–88
Increase of travelling speed from 0 to 70 km/h	51–89
Excess gas transfer tube	86–97
Excess gas transfer tube + local exhaust	98
Excess gas transfer tube + local exhaust + travelling speed 70 km/h	99

Table 3. Air exchange rates (air changes/h) in an ambulance

Local exhaust ventilation	Travelling speed	
	0 km/h	70 km/h
Off	36	138
On	40	148

was not in function and, used alone, the effect of the local exhaust was somewhat disturbed by turbulence phenomena caused by the travelling speed. The excess gas transfer tube reduced the airborne nitrous oxide concentration by about 86 to 97%, and in combination with local exhaust the reduction was constantly about 98%.

The air exchange rate in the ambulance coupé at two travelling speeds (0 and 70 km/h) and with the local exhaust system off and on, respectively, is shown in Table 3. The ordinary ventilation fan located in the driver's compartment induced 36 to 40 air changes/h, when the ambulance was not running. An increase of the speed from 0 to 70 km/h increased the air exchange rate inside the ambulance up to 3 to 4 times. As distinguished from the travelling speed, the local exhaust did not substantially affect the air exchange rate.

Discussion

A mixture of nitrous oxide and oxygen is perhaps the best analgesic for treatment of pain during ambulance transport (Baskett and Withnell 1970; Wright et al. 1972; Blomberg et al. 1978; Larcan et al. 1978; Thal et al. 1979; McKinnon 1981; Donen et al. 1982).

The ambulance coupé, however, is a unique workplace. It is a narrow moving sick-bay, and it is impossible for the attendants to anticipate the swaying and braking of the vehicle, especially in densely populated areas. Thus, administration of an analgetic gas to patients during ambulance transports could result in contamination not only of the ambulance coupé but also of the driver's cabin (Ancker et la. 1980; Bristow et al. 1986). At extreme conditions exposure peaks of up to 7.500 ppm have been registered in the breathing zone of the ambulance attendant supervising the patient (Ancker et al. 1980), indicating that staff members in extreme conditions could be exposed to nitrous oxide concentrations causing acute effects. The risk of obtaining such effects will be more pronounced if more potent anesthetic gases are used.

The air exchange rate inside an ambulance increases with increasing speed, especially when air inlets and outlets are open. This results in a tendency to decrease the airborne nitrous oxide levels. It is, however, essential to prevent the effluence of analgetic gas into the ambulance with an excess gas transfer tube (Ancker et al. 1980; Blomberg et al. 1980), which diminishes the airborne concentrations of nitrous oxide by about 90%, but other measures are necessary to prevent the spread of analgetic gas from leaks between the face and the mask. The excess gas transfer tube combined with an effective local exhaust reduces the airborne nitrous oxide levels inside the ambulance by about 98% when the ambulance is at a standstill and 99% when it is running.

It is essential that ambulances are furnished with adequate equipment for the evacuation of analgetic gasses. A combination of excess gas transfer tube and local exhaust provides reasonable security for extreme discharges of nitrous oxide around the face mask.

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