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Nitrous-oxide Analgesia During Ambulance Transportation. Airborne Levels of Nitrous Oxide

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A model experiment was performed for studying nitrous-oxide levels in the breathing zones of the different members of an ambulance team, viz. the anesthetist, the accompanying person in the ambulance coupé, and the ambulance driver. Without a functioning local exhaust coupled to the exhalation valve, the integrated average level of nitrous oxide in the breathing zone of the anesthetist was 650–1,700 ppm, with top concentrations up to 7,500 ppm. Under the same conditions, the accompanying person in the ambulance coupé was exposed to average concentrations of 58–280 ppm, with top concentrations up to 660 ppm. The mean exposure of the driver was 9–45 ppm (max. 81 ppm). However, the exposure to nitrous oxide was considerably decreased in all parts of the ambulance by an effective local exhaust system. A prerequisite for nitrous-oxide analgesia in ambulances is an effective local exhaust coupled to the exhalation valve or face mask. The ambulance coupé ought to be equipped with a motor-driven exhaust fan in the roof, the ordinary inlet fan of the ambulance should be switched on at maximum speed, and any additional heater or fan in the ambulance coupé should be placed inside the coupé and not behind the driver's seat.

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It is well-known from studies in operation theaters that high levels of anesthetic gases often occur in the breathing zones of the anesthesiological and surgical staffs during conventional anesthesia (HALLÉN et al. 1970, GÖTHE et al. 1976b), and that occupational exposure to anesthetic gases could induce both short-term and long-term complications (GÖTHE et al. 1976a, GÖTHE & HOFFMAN 1977). Therefore, before the introduction of large-scale use of nitrous-oxide analgesia during ambulance transportation, a model experiment was performed to study nitrous-oxide levels in the breathing zones of the different members of an ordinary ambulance team.

MATERIAL AND METHODS

Oxygen-nitrous oxide was administered to a simulated "patient" with standard equipment (Entonox). The patient was replaced by an ejector (Bird) which took 15 "breaths" per minute with a tidal volume of 0.6 liters. At the beginning of every minute the ejector made six "inhalations". This corresponds to a large dose, because patients, when they administer the gas to themselves, seldom make more than six inhalations of nitrous oxide-oxygen per minute. The concentration of nitrous oxide was 50% in the cylinder, but dilution of air in the ejector decreased the concentration to 33% in the gas that left the equipment.

Local exhaust was arranged through a plastic tube from the exhalation valve of the face-mask to the adjustable roof cover.

The airborne nitrous-oxide levels were examined in (see Fig. 1)

I. The breathing zone of the anesthetist;
II. The breathing zone of the accompanying person in the ambulance coupé;
III. The breathing zone of the ambulance driver.

Air from these three zones was sucked through a probe and analyzed with an IR-spectrophotometer (Miran-1A, wave length 4.5 μm, cuvette length 0.75 m, meter response 4), and the nitrous-oxide content was continuously registered on a chart recorder (Linear 142). The equipment was connected to a battery set through a DC-AC-transformer (Valradio), transforming 24 V DC to 220 V AC.

The accuracy of the method made it possible to determine nitrous-oxide concentrations in air down to about 1 ppm (1.8 mg N_2O/m^3). Time-weighted means of the airborne nitrous-oxide levels were calculated by curve integration with correction for the non-linearity of the calibration curve.

The air-change rates inside the ambulance (ambulance coupé and driver's compartment) were determined by measuring the decay rate of a trace gas (OLANDER 1974). Nitrous oxide was used as trace gas.

RESULTS

Two ambulance makes, Mercedes-Benz and Volvo, were studied. The integrated means of the airborne levels of nitrous oxide in the two ambulances are demonstrated in Tables 1 and 2. The levels varied considerably in different parts of the vehicles. The distance between zone I and zone II (Fig. 1) is only about 1 m, but the nitrous-oxide levels were up to ten times higher in zone I than in zone II when the gas was freely evacuated into the coupé. The local exhaust

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Table 1

Airborne levels of nitrous oxide (ppm) in ambulance (Mercedes-Benz). Effect of travelling speed and local exhaust coupled to the ejector. Ordinary inlet fan on, roof fan off, and roof cover in ambulance coupé open.

Travelling speed (km/h)	Local exhaust	Test zone I	II M° (min-max)	III
30	On	4 (<1-16)	<1	<1
70	On	<1 (<1- 7)	<1	<1
30	Off	1,700 (260-4,700)	280 (150-660)	39 (8-49)
70	Off	650 (47-7,500)	58 (13-190)	9 (5-19)

°M = Integrated mean (ppm) during analgesia.

Table 2

As Table 1. Volvo ambulance.

Travelling speed (km/h)	Local exhaust	Test zone I	II M° (min-max)	III
30	On	14 (1-46)	7 (<1-20)	2 (1-7)
70	On	2 (<1-14)	<1	<1
30	Off	970 (200-3,400)	260 (100-440)	45 (27-81)
70	Off	1,300 (200-4,200)	240 (100-410)	33 (9-75)

°See Table 1.

coupled to the ejector decreased the nitrous-oxide levels near to and below the lowest detectable level of 1 ppm.

Increasing the travelling speed tended to decrease the airborne levels of nitrous oxide, especially in the Mercedes ambulance. This phenomenon was, at least partly, coupled to rate-dependent variations in the air-change rates (Table 3). The effect of the travelling speed differed between the two ambulance makes, probably due to small differences in the ventilatory systems and inside fittings, affecting the air turbulence.

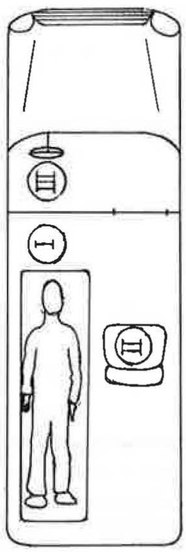

Fig. 1. Test zones in the ambulances.

The Mercedes ambulance had a motor-driven exhaust fan in the roof of the ambulance coupé. Table 1 demonstrates the airborne levels of nitrous oxide with the fan off, and Table 4 demonstrates the results with the fan on. A comparison between these two tables makes it evident that the roof fan decreased the nitrous-oxide levels by about 50% inside the ambulance. This phenomenon could partly be linked to an increase in the air-change rate (Table 3). However, it is probable that the roof fan also caused the air currents inside the coupé to be broken up and, thus, facilitated the evacuation of air pollutants. It should be noted that the adjustable roof

Table 3

Air-change rates (air-changes/h) in ambulance coupé and driver's compartment at two travelling speeds.

Travelling speed (km/h)	Roof fan	Mercedes-Benz Test zone II	Mercedes-Benz Test zone III	Volvo Test zone II	Volvo Test zone III
30	On	70	65	70	90
70	On	95	105	120	140
30	Off	35	45	70	75
70	Off	60	75	95	80

Table 4

As Table 1 (Mercedes-Benz), but roof fan on.

Travelling speed (km/h)	Local exhaust	Test zone I	II	III
			M° (min-max)	
30	On	<1	–	–
70	On	<1	–	–
30	Off	650 (120–5,600)	330 (220–470)	37 (9–68)
70	Off	140 (31– 480)	260 (77–640)	10 (1–24)

°See Table 1.

Table 5

Effect of additional heater in the ambulance coupé (Mercedes-Benz). Ordinary inlet fan on, roof fan off, and local exhaust off. Travelling speed 30 km/h.

Heater location	Heater fan	Communication window	Test zone II	III
			M° (min-max)	
See Figure 2A	On	Open	500 (220–750)	80 (68–97)
	Off	Open	450 (260–720)	79 (47–110)
See Figure 2B	On	Open	380 (220–510)	130 (100–160)
	Off	Open	320 (220–470)	71 (49–92)
	On	Closed	–	87 (66–100)
	Off	Closed	–	67 (39–90)

°See Table 1.

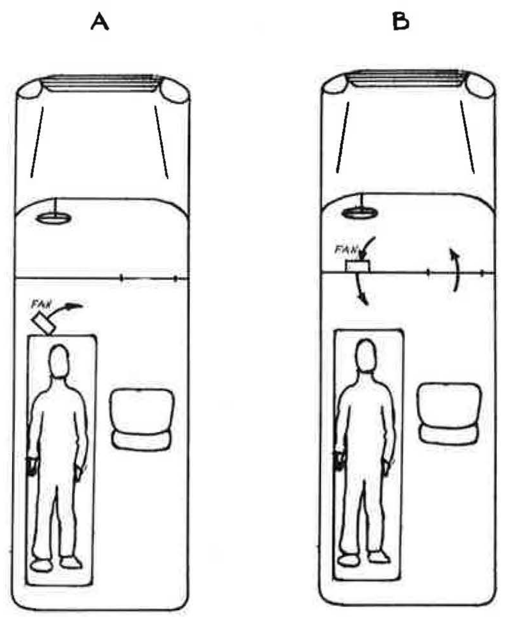

Fig. 2. Direction of the air-stream from the additional heater in the ambulance coupé.
A. Heater located inside the ambulance coupé.
B. Heater located behind the driver's seat.

cover was always open, even when the roof fan was not used.

When it is cold, the ambulance coupé is heated by a hot-water radiator equipped with a fan. The radiator is located either inside the ambulance coupé or behind the driver's seat. In the first instance (Fig. 2A) the airborne levels of nitrous oxide were not affected by the radiator fan. However, when the radiator was located behind the driver's seat (Fig. 2B), the fan elevated the airborne levels of nitrous oxide inside the driver's compartment (Table 5). This depends on an overflow of air from the ambulance coupé into the driver's compartment through the communication window between the two compartments. When this window was closed to a slit of about 2 cm, the nitrous-oxide concentrations in the driver's compartment were at the same level as when the radiator was placed inside the ambulance coupé (Table 5).

DISCUSSION

Examinations in Swedish hospitals in the early seventies showed nitrous-oxide levels varying from about 25 ppm up to well above 1,000 ppm in the work zones of anesthetist nurses during on-going operations (OLANDER 1974). Similar results have been reported by NIKKI et al. (1972) and by CORBETT (1973). In delivery rooms, nitrous-oxide levels in the breathing zones of midwives have been shown to be about 300–540 ppm (DAHLGREN et al. 1979) when the mothers were self-administering the analgetic gas.

In ambulances, the integrated average of the nitrous-oxide levels in the breathing zone of the anesthetist varied between 650 and 1,700 ppm, with top concentrations up to 7,500 ppm when local exhaust systems coupled to the ejector were not in operation and the gas was let off into the ambulance coupé before evacuation to the exterior. In such circumstances, the exposure of the anesthetist inside the ambulance will be similar to or higher than was common for staff in operating rooms in the early seventies, and higher than is common for staff in obstetrical wards. However, exposure to nitrous oxide inside ambulances will be considerably decreased when an effective local exhaust system is used.

The experiments with a local exhaust system represent a situation that could be described as "the best possible", because all administered nitrous oxide was evacuated through this exhaust system with very little leakage. The experiments without this local exhaust represent the opposite extreme, i.e., all administered nitrous oxide was let off inside the ambulance coupé before evacuation. Administration of nitrous oxide to a patient represents a situation between these two extremes, because it is not possible, even under ideal conditions, to avoid some leakage of the gas from the face-mask, and because the patient exhales the gas freely into the surroundings when he is not inhaling the gas.

It is evident that a prerequisite for nitrous-oxide analgesia during ambulance transportation is that the ambulances are specially equipped with exhaust systems. An essential demand is an effective local exhaust coupled to the face-mask. The ambulance coupé ought to be equipped with a motor-driven exhaust fan in the roof, and the ordinary inlet fan of the ambulance should be switched on at maximum speed. This is essential, especially at slow travelling speeds, and when the ambulance is parked. If the ambulance coupé is equipped with an additional heater, this should be placed inside the coupé and not behind the driver's seat. Otherwise an overflow of nitrous oxide into the driver's compartment could occur.

In the ambulances examined there was only an insignificant overflow of nitrous oxide from the ambulance coupé to the breathing zone of the driver. However, it must be remembered that even small changes in the construction and inside fittings of the ambulances could change this situation. It is essential for traffic safety that the air pressure in the driver's compartment is higher than in the ambulance coupé. To achieve this, all air inlets should be located in the driver's compartment, and all air outlets should be located in the ambulance coupé. The alternative is a total separation of these two compartments from each other. However, this is undesirable because it could disturb communications between the different members of the ambulance team.

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