may be made by occluding the attachment with an experienced finger.

The system is open-ended and cannot transmit negative or positive pressures to the patient. The T-piece is easily sterilized or may be regarded as disposable.

REFERENCES

1. Vaisman, A. I. (1967): Eksp. Khir., **12**, 44.
2. Smith, W. D. A. *in* Langton Hewer, C. and Atkinson, R. S., eds (1976): *Recent Advances in Anaesthesia and Analgesia*, 12th ed., p. 167 Edinburgh: Churchill Livingstone.
3. Bain, J. A. and Spoerel, W. E. (1972): Canad. Anaesth. Soc. J., **19**, 426.

Comparison of three anaesthetic scavenging devices using cuffed and non-cuffed nasal endotracheal tubes during dental anaesthesia

D. MOYES, P. CLEATON-JONES, R. SHAW, J. AUSTIN, L. BONNER, H. FAIN, J. MALLETT

Summary

During maxillofacial and oral surgery the effect of three anaesthetic scavenging devices used with cuffed and non-cuffed endotracheal tubes was investigated. All the devices produced reductions in nitrous oxide concentrations in the breathing zone and peripheral air, ranging from 36% to 76%. Of the three devices evaluated, the Stellenbosch valve produced the greatest reduction in pollution compared with the control.

S. Afr. med. J., **59**, 180 (1981).

Since the cautionary advice of Vaisman[1] regarding the possible hazards of inhalation of trace anaesthetic gases, many devices to scavenge waste anaesthetic gas have been described.[2-4] Their function under clinical conditions has not been evaluated. We describe the use of three devices available in South Africa and compare their use with cuffed and non-cuffed tubes during maxillofacial and oral surgical operations.

MRC/University of the Witwatersrand Dental Research Institute, Johannesburg
P. CLEATON-JONES, B.D.S., M.B. B.CH., PH.D., D.A.
J. AUSTIN, B.A.SC.

Department of Anaesthesia, Baragwanath Hospital and University of the Witwatersrand, Johannesburg
D. MOYES, M.R.C.S., L.R.C.P., M.B. CH.B., F.F.A.
J. MALLETT, B.SC.
R. SHAW, B.SC.

Department of Anaesthesia, Johannesburg Hospital and University of the Witwatersrand, Johannesburg
L. BONNER, M.B. B.CH.

Department of Maxillofacial and Oral Surgery, University of the Witwatersrand, Johannesburg
H. FAIN, M.B. B.CH., D.A.

Date received: 12 June 1980.

Material and methods

The study was carried out in one operating theatre at the Oral and Dental Hospital, Johannesburg. The theatre has a volume of 138 m^3 and is ventilated at a rate of approximately 2 air changes per hour by 2 window-mounted air-cooling units (12 660 kJ/h). A previous study showed that the rate of elimination of nitrous oxide from this theatre is slow.[5]

The sampling method and gas chromatographic techniques have been previously described.[6] In summary, snatch air samples were taken by syringe at 10-minute intervals for 2 hours from (*i*) the breathing zone at the level of the surgeon's shoulder closest to the anaesthetic exhaust valve; and (*ii*) the peripheral air at the air conditioner intake. The samples were placed in airtight nylon storage bags and the nitrous oxide concentration in each sample was determined on a Pye Unicam model GCV gas chromatograph using a Kathorometer detector.

The scavenging methods used were the Gardner box (F. Gardner Co.), Stellenbosch[7] and Ventex (A. Cornish Co.) systems. Their function has been described previously.[5] The patients were all adults undergoing maxillofacial and oral surgery. They were induced with thiopentone and suxamethonium used to achieve nasal intubation. In all patients careful pharyngeal packing was done with moistened gauze or Tampax. After neuromuscular recovery the patients breathed spontaneously through a Magill circuit (Mapleson A) with a gas flow of 8 l/min. Nitrous oxide was given at 5 l/min and oxygen at 3 l/min. Halothane was added to achieve the appropriate level of anaesthesia. The standard Heidbrink valve was replaced by a Gardner hooded valve to allow attachment of the scavenging devices. As soon as the patient circuit was connected the scavenging system was attached to the hooded valve.

Patients were assigned by means of a table of random numbers to have either a cuffed (Shiley Group, California) or non-cuffed (Portex, Kent, England) nasal PVC tube. Similarly, the order of use of the scavengers was randomly assigned so that each device was examined on

4 separate days. Included in the investigation were control days when no scavenger was employed.

Results

A total of 832 nitrous oxide pollution measurements was made, 6 of which had to be discarded owing to technical malfunctions. In order to demonstrate the efficacy of the scavenging devices, only the 503 pollution levels recorded while nitrous oxide was actually being administered to patients were used in the subsequent analysis. Details of this nitrous oxide pollution are listed in Table I in parts per million (v/v).

Nitrous oxide pollution was higher in the breathing zone than in the peripheral air in all cases. On the control days, when no scavenger was used, the mean nitrous oxide pollution was higher when cuffed endotracheal tubes were employed. These differences were statistically significant in both breathing zone (t = 4,62; $P < 0,001$) and peripheral air (t = 2,21; $P < 0,05$). The same pattern was observed for each of the scavenging devices and was statistically significant in the breathing zone for the Stellenbosch (t = 7,67; $P < 0,001$) and Ventex scavengers (t = 5,06; $P < 0,001$). When the Gardner scavenger was used, mean nitrous oxide pollution levels in the peripheral air were almost identical, whether the endotracheal tubes were cuffed or not.

Comparison of mean nitrous oxide pollution levels of each of the scavenging devices revealed that pollution levels were similar. Statistical analysis employed the one-way analysis of variance and the Scheffe test for all possible comparisons. Statistically significant differences in nitrous oxide concentration in the breathing zone occurred, showing the Stellenbosch non-cuffed tube less than the Ventex with cuffed tube (F = 2,61; $P < 0,05$), and the Ventex cuffed tube more than the Ventex with non-cuffed tube (F = 2,77; $P < 0,05$). In the peripheral air the pattern was Stellenbosch with cuffed tube less than Ventex with cuffed tube (F = 2,23; $P < 0,05$), Stellenbosch with non-cuffed tube less than Ventex with cuffed tube (F = 4,47; $P < 0,01$), and Ventex with cuffed tube greater than Ventex with non-cuffed tube (F = 2,62; $P < 0,05$).

The coefficients of variation were high, ranging from 41% to 213% (Table I). Calibration measurements of standard concentrations of nitrous oxide, carried out before, during and at the end of each day's analysis showed a coefficient of variation of less than 5%, indicating that the majority of the variation seen was due to wide fluctuations in nitrous oxide concentrations in the operating theatre air.

To estimate the degree of reduction in nitrous oxide pollution produced by each scavenging device, the mean nitrous oxide concentration in each case was expressed as a percentage of the relevant control (Table I). This was then subtracted from 100% (Table II). In the breathing zone the Stellenbosch device with both types of endotracheal tube and Ventex scavenger used with a non-cuffed tube showed similar reductions in nitrous oxide pollution, approximately two-thirds. In the peripheral air the highest estimated reductions in pollution, some 75%, was produced by the Stellenbosch valve.

The scattergrams in Figs. 1 and 2 indicate the actual pollution recordings in the breathing zone and peripheral

TABLE I. DETAILS OF NITROUS OXIDE CONCENTRATIONS IN PARTS PER MILLION (v/v) IN THE BREATHING ZONE AND PERIPHERAL AIR

	Control		Gardner		Stellenbosch		Ventex	
	Cuffed	Non-cuffed	Cuffed	Non-cuffed	Cuffed	Non-cuffed	Cuffed	Non-cuffed
Breathing zone								
Number	26	36	34	26	23	36	31	38
Range	25 - 2 337	30 - 719	26 - 4 930	0 - 2 214	0 - 1 973	10 - 686	25 - 1 681	0 - 681
Mean	925	431	385	314	346	157	588	149
Standard deviation	596	177	823	425	516	139	503	142
Coefficient of variation (%)	64	41	213	135	149	89	86	95
% of control	—	—	42	73	37	36	64	35
Peripheral air								
Number	29	36	34	26	23	36	31	38
Range	35 - 1 026	7 - 564	0 - 384	0 - 510	0 - 426	0 - 230	32 - 403	0 - 333
Mean	445	331	139	143	106	84	191	110
Standard deviation	263	138	102	98	113	55	97	82
Coefficient of variation (%)	59	42	73	69	107	65	51	75
% of control	—	—	31	43	24	25	43	33

TABLE II. ESTIMATED PERCENTAGE REDUCTION IN POLLUTION

	Gardner		Stellenbosch		Ventex	
	Cuffed	Non-cuffed	Cuffed	Non-cuffed	Cuffed	Non-cuffed
Breathing zone	58	27	63	64	36	65
Peripheral air	69	57	76	75	57	67

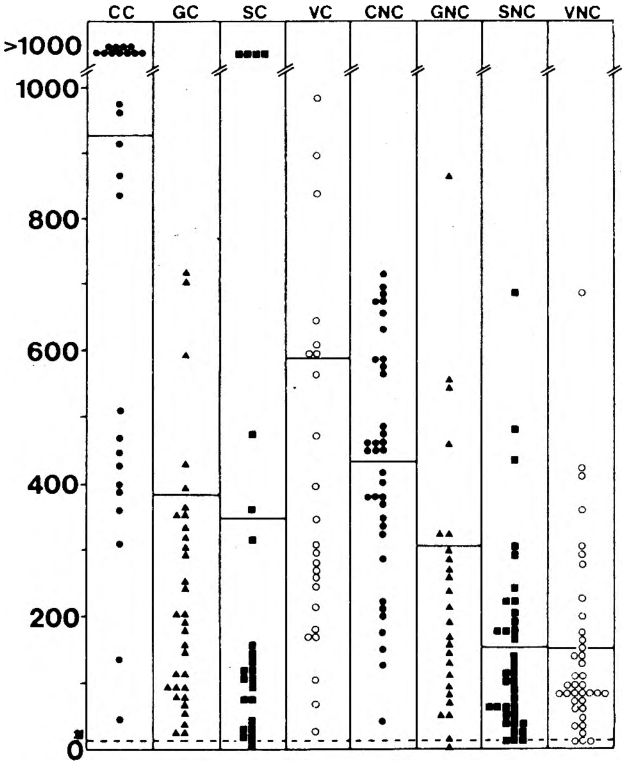

Fig. 1. Scattergram indicating individual nitrous oxide concentrations in the breathing zone. The solid horizontal line in each cell is the mean concentration and the arrowed interrupted line is the 30 ppm maximum pollution level recommended by NIOSH.[9] (CC = control and cuffed tube, GC = Gardner and cuffed tube, SC = Stellenbosch and cuffed tube, VC = Ventex and cuffed tube, NC = non-cuffed tube for the same scavengers.)

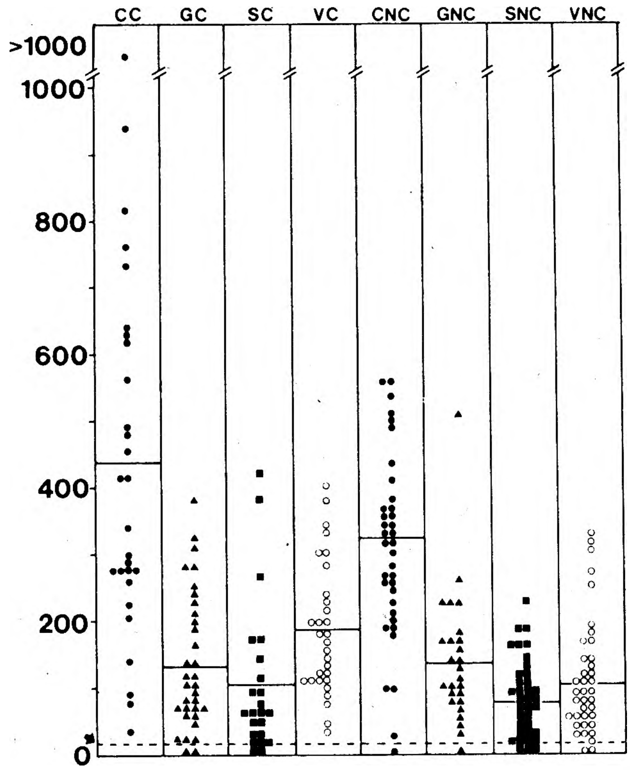

Fig. 2. Scattergram showing individual nitrous oxide concentrations in the peripheral air. The same abbreviations are used as for Fig. 1.

air, respectively. Both show the wide range of nitrous oxide concentrations recorded, but also indicate the downward trend when scavenging devices were used. Few concentrations were below the 30 ppm level recommended by the National Institutes of Occupational Safety and Health (NIOSH).[9]

Discussion

There are many factors determining the level of gaseous pollution in an operating theatre, but we have attempted to standardize this investigation as far as possible. The type of surgery, spontaneous breathing,[10] size of operating theatre,[11] presence of throat pack,[12] degrees of room ventilation,[13] suction and fresh gas flow[13] were similar in all instances. The time of exposure was also comparable in all groups.

The devices all produced satisfactory reductions in pollution levels, both in the breathing zone and in peripheral air. The higher pollution seen with cuffed endotracheal tubes than with non-cuffed tubes plus pharyngeal pack is probably due to different expiratory characteristics. Cuffed tubes probably allow less leakage into the oral cavity and thereby greater concentrations of nitrous oxide may be vented through the expiratory valve. The three scavengers may all be recommended, the Stellenbosch valve producing a slightly better all-round performance.

Although the scavenging devices produced a universal reduction in pollution levels, this was only occasionally below the NIOSH level of 30 ppm. There is a risk of first-trimester abortion in operating theatre personnel,[13] but the pollution level at which this is likely to occur has not yet been firmly established. The results of experimental studies that we have undertaken, in which gravid rats were exposed to concentrations of nitrous oxide of 1 000, 500, and 250 ppm,[14] suggest that the threshold lies between 500 and 1 000 ppm nitrous oxide. All the scavenging devices produced nitrous oxide concentrations mostly below 500 ppm (Figs 1 and 2), and we therefore recommend the use of scavenging devices during general anaesthesia.

Because of the wide fluctuation in concentrations of nitrous oxide observed in this study, we believe that the designs of scavengers need to be evaluated in the laboratory situation to reduce the large number of uncontrolled variables existing in operating theatres.

We are grateful to our operating theatre colleagues at the Oral and Dental Hospital for so readily assisting in the study, to Mrs J. Long for her expert typing, and Miss Cheryl Sam for the illustrations.

REFERENCES

1. Vaisman, A. I. (1969): Éksp. Khir., **3**, 44.
2. Steward, D. J. (1972): Canad. Anaesth. Soc. J., **19**, 670.
3. Lack, J. A. (1976): Anaesthesia, **31**, 259.
4. Smith, W. D. A. *in* Langton-Hewer, C. and Atkinson, R. S., eds (1976): *Recent Advances in Anaesthesia*, 12th ed., p. 131. Edinburgh: Churchill Livingstone.
5. Cleaton-Jones, P., Moyes, D., Shaw, R. *et al.* (1980): S. Afr. med. J., **58**, 120.
6. Austin, J., Shaw, R., Crichton, R. *et al.* (1978): Brit. J. Anaesth., **50**, 1109.
7. Foster, P. A. (1978): Paper presented at the South African Society of Anaesthetists Congress, Cape Town.
8. Moyes, D. G., Cleaton-Jones, P. and Foster, P. A. (1980): S. Afr. med. J., **58**, 79.
9. US Department of Health, Education and Welfare (1977): National Institutes of Occupational Safety and Health Publication No. 77, p. 140.
10. Smith, W. D. A. (1976): *Op cit.*,[4] p. 158.
11. Davenport, H. T., Halsey, M. J. and Wardley-Smith, B. (1976): Brit. med. J., **2**, 1219.
12. Vickery, I. M. and Burton, G. W. (1977): Anaesthesia, **32**, 565.
13. Whitcher, C. H. *in* Sperdijk, J., Feldman, S. and Maltie, H., eds (1976): *Anaesthesia and Pharmacology*, p. 304. Leiden: Leiden University Press.
14. Vieira, E., Cleaton-Jones, P., Austin, J. C. *et al.* (1980): Anesth. Analg., **54**, 175.