Technical Communication

The wide-range ejector flowmeter: calibrated gas evacuation comprising both high and low gas flows

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The wide-range ejector flowmeter is an active scavenging system applying calibrated gas removal directly to the anaesthetic circuit. The evacuation rate can be adjusted on the flowmeter under visual control using the calibration scale ranging from 200 ml·min⁻¹ to 15 l·min⁻¹. The accuracy of the calibration was tested on three ejector flowmeters at 12 different presettings. The percentage deviation from presetting varied from +18 to -19.4 per cent. The ejector flowmeter enables the provision of consistent and accurately calibrated extraction of waste gases and is applicable within a wide range of fresh gas flows.

Key words

ANAESTHESIA, EQUIPMENT: scavenging systems.

In the view of the evidence suggesting health problems with chronic exposure to anaesthetic gases,^{1,2,3} it seems rational to strive for implementation of effective antipollution measures, with due respect to resources and priorities, and thereby decrease the exposure to a minimum.

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Collection and disposal of excess circuit gases is a major factor among the measures which can be taken to control trace gas levels. But the introduction of a scavenging device adds complexity and thus presents risks to the patient. Therefore it is necessary to scrutinize carefully the benefits versus the risks.

Measures to protect the breathing circuit from harmful pressure alterations during scavenging should be of prime consideration. The effluent disposal tubing should be kink- and occlusion-proof. Active systems should be visually monitored for confirmation of operation, and the suction applied should be calibrated over a wide range of evacuation rates. An integral part of the system should be an interface providing positive and negative pressure relief and reservoir capacity allowing the mean extraction flow rate to be reduced.

The purpose of the present investigation was to design a scavenging system where such measures have been adopted, and present the results of an investigation of the accuracy of the predetermined calibration scale of that system.

Methods

Apparatus

The wide-range ejector flowmeter (Fig. 1) is an active scavenging system and a modification of a

FIGURE 1 The wide-range ejector flowmeter mounted on an anaesthetic apparatus.

device previously described.⁴ The major alteration is the inclusion of calibrated gas evacuation in the low flow range. With compressed air as the driving gas delivered through a reducing valve, the ejector (Fig. 2a) mounted at the upper end of an ordinary air rotameter flowmeter (Fig. 2b) generates sufficient negative pressure to extract waste gases from a closed reservoir through the rotameter tube. The evacuation rate will depend on the setting of the flow control valve at the inlet of the tube (Fig. 2c). The mixture of driving gas and entrained anaesthetic gases is vented through the kink and occlusion proof effluent tubing (Fig. 2d) and disposed of into the ventilation system or to the outside atmosphere. The closed reservoir may be situated outside the anaesthetic circuit, but most conveniently the anaesthetic circuit itself constitutes the reservoir.

By this method the waste gases are extracted at a constant rate directly from the circuit, receiving a constant inflow of fresh gas. Balance is achieved by equilibrating the gas evacuation rate to the fresh gas flow. An exhaust valve and a negative pressure relief valve,⁵ i.e., a valve preventing subatmospheric pressure in the anaesthetic circuit, are inserted in the circuit.

The evacuation rate can be adjusted on the

rotameter under visual control using the non-linear calibration scale ranging from 200 ml·min⁻¹ to 15 l·min⁻¹.

Experimental study

To determine the accuracy of the calibration, three ejector flowmeters were tested at 12 different presettings (Table) applying the bubble meter methods.^{6,7} This is an absolute method of measuring the volume flow rate of gases for which a variability within ± 1.8 per cent had been calculated beforehand.⁸

An excess of 50 per cent oxygen in nitrous oxide was delivered from a flowmeter unit; with a driving gas pressure of 4 kg·cm⁻² through the ejector nozzle the mixture was conducted from an open reservoir at ambient pressure to a soap bubble flowmeter and then through the ejector flowmeter. The bobbin of the ejector flowmeter was adjusted by eye; for the calculation of flow rates the mean of three independent measurements was used at each presetting to reduce the uncertainty in adjustment of the bobbin. Flowmeters are calibrated at a pressure of 760 mmHg and a temperature of 20°C; following correction for the vapour pressure of water the calculated flows were corrected to this temperature and pressure applying the formula for turbulent flows.

FIGURE 2 Schematic presentation of the wide-range ejector flowmeter.

TABLE Flowmeter setting and measured flow (760 mmHg, 20° C, dry gas) of three ejector flowmeters at twelve different presettings

Flowmeter setting (ml·min ⁻¹)	Measured flow (ml/min)		
	Flowmeter No.		
50% O ₂ /N ₂ O	1	2	3
200	227	236	171
400	411	411	337
600	583	581	484
800	732	756	645
1000	947	946	857
2000	1846	1890	1739
3000	2857	2975	2553
5000	4500	4713	4211
8000	6857	7273	6761
10000	8696	9302	8372
13000	10909	11803	10667
15000	13091	12698	12632

Results

At increasing flow rates the difference between flowmeter setting and the measured flow was increasing, but positive deviations were only shown at presettings of less than 600 ml·min⁻¹ (Table). The percentage deviation from presetting varied from +18 to -19.4 per cent.

Discussion

It has been almost dogmatic that scavenging of waste gases must take place after they have passed the exhaust valve. This is probably based on the erroneous assumption that gas extraction thereby does not influence the conditions within the anaesthetic circuit itself.

However, imbalance between the fresh gas input and the gas evacuation rate may often result from the fact that the gas supply is continuous while the waste gas flow through the exhaust valve is fluctuating. This problem can be avoided by applying calibrated evacuation of waste gases directly to the anaesthetic circuit by means of the ejector flowmeter instead of to the exhaust valve.

The rotameter incorporated in the ejector flowmeter is a variable orifice flowmeter,⁹ i.e., a rotameter where the size of the orifice varies for different flows, while the pressure difference on either side of the orifice is constant. Because the gas

flows are turbulent at most settings the density of the gas is the determinant of the rate of flow, when the rotameter is used for a gas different from that for which it was originally calibrated. If a gas A is passed through an orifice in a meter calibrated for gas B the following formula applies:⁹

$$\frac{\text{actual flow of gas A}}{\text{flow indicated on B-meter}} = \sqrt{\frac{\text{density of gas B}}{\text{density of gas A}}}$$

The densities for oxygen and nitrous oxide are 1.33 and 1.84 versus 1.20 for air. As the rotameter incorporated in the ejector flowmeter is calibrated for air, actual flows below the indicated flows were expected, when using a gas mixture of 50 per cent oxygen in nitrous oxide. The deviations found in this study are in accordance with this. It could be suggested that a flowmeter calibrated for oxygen or nitrous oxide would have been a better choice. Furthermore, in order to avoid any confusion between the fresh gas flows and the waste gases, the scale of the ejector flowmeter should be marked "waste anaesthetic gas," not "air."

For clinical purposes the accuracy appears to be satisfactory as the system is also monitored through the extent of filling of the breathing bag.

Thus the ejector flowmeter enables the provision of consistent and accurately calibrated extraction of waste gases from the anaesthetic circuit and is applicable within a wide range of fresh gas flows.

Standards for the trace gas levels which should be attainable with reasonable effort and currently available technology, and which may provide a margin of safety, have been laid down. Recent investigations have substantiated that these standards can be met by use of the ejector flowmeter.^{10,11} Furthermore, the ejector flowmeter functions silently.

This principle of scavenging has now been in use in our clinic since 1973, and no untoward effects have occurred. The ideal scavenging system should be safe, silent, easy to handle, economic, and give a continuous display of function. It appears that the ejector flowmeter fulfills most of these criteria to a considerable extent.

Acknowledgement

The ejector flowmeter is manufactured by DAMECA A/S, Islevdavej 211, DK-2610 Rødovre, Denmark.

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Résumé

Le débit-mètre éjecteur est un instrument qui, de façon active, permet de retirer du circuit anesthésique des quantités connues de gaz. Le taux d'évacuation peut s'ajuster sur le débit-mètre par simple contrôle visuel selon les données de l'échelle de calibration qui s'étend de 200 ml·min⁻¹ à 15 l·min⁻¹. La précision de la calibration a été vérifiée sur trois débit-mètres éjecteurs pour 12 réglages différents. Les déviations de part et d'autre du réglage ont été de +18 à -19.4 pour cent. Cet instrument permet donc l'extraction de quantités connues de gaz de façon précise et ceci pour des grands comme pour des petits débits de gaz frais.