The output of two sevoflurane vaporizers in the presence of helium

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Background. Modern vaporizers are designed to deliver accurate and stable concentrations of volatile anaesthetic agents. Carrier gas composition may adversely affect the output from vaporizers. No previous study has tested helium in combination with sevoflurane vaporizers, a clinically useful combination especially in anaesthesia for upper airway obstruction.

Methods. This study evaluated the effect of increasing helium concentrations, carrier gas flow rates and varying the vaporizer dial setting on the output from Blease Datum® and Drager Vapor 19.3® sevoflurane vaporizers.

Results. The presence of helium in the carrier gas had negligible effects on the output from both of the sevoflurane vaporizers tested. Carrier gas flow rates had the greatest effect on output but changes were within ±10% of baseline.

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Conclusion. Helium/oxygen mixtures can be used with these vaporizers without adversely affecting their performance.

Br J Anaesth 2002; 88: 711–13

Keywords: anaesthetics volatile, sevoflurane; equipment, vaporizers; gases, nonanaesthetic, helium

Accepted for publication: January 2, 2002

Most modern vaporizers cope well with variations in temperature and flow rates within normal working ranges. The output from anaesthetic vaporizers is affected by the physical characteristics of the carrier gas. Nitrous oxide, for example, is known to produce clinically significant changes at the extremes of flow rates and dial settings. Helium is a useful adjunct in upper airway obstruction because of its low density, which reduces turbulent flow. Inhalation induction of anaesthesia with sevoflurane is an accepted technique in the management of actual or potential upper airway obstruction. If inhalation induction of anaesthesia for the treatment of upper airway obstruction using a sevoflurane and helium/oxygen combination is planned, it is important to know if the output from the vaporizer is affected by the addition of helium to the carrier gas.

Methods and results

Two models of sevoflurane vaporizers were studied: Blease Datum® and Drager Vapor® 19.3.

For each vaporizer, the effects of increasing helium concentrations, carrier gas flow rates and varying the vaporizer dial setting on the sevoflurane vaporizer output was investigated using a 4×4 factorial design based on a previous vaporizer output study by RG Loeb. A standard anaesthetic machine (Cavendish 460) was used to deliver the fresh gas flow of oxygen metered through a bobbin flow meter. Helium was provided from a cylinder of medical quality helium and added to the circuit via a T piece connection 30 cm proximal to the vaporizer inlet to allow for adequate mixing of gases before entering the vaporizer chambers.

A Datex Ultima® Gas Monitor was used to measure sevoflurane concentrations 50 cm downstream from the vaporizer outlet. This was calibrated according to the manufacturer’s specifications before each series of readings. The manufacturer quotes an anaesthetic agent identification accuracy of 0.2 vol%.

Helium flow was calibrated using the same Datex Ultima® Gas Monitor (oxygen analysis function) by balancing the relative flow rates of oxygen and helium against the desired helium concentration. Helium concentrations were calculated as 100 minus measured oxygen concentration. The vaporizers were drained and flushed to remove any possible contaminants and refilled with fresh liquid sevoflurane.

Measurements were taken at dial settings of 2, 4, 6, and 8% sevoflurane from both the Blease Datum® and Drager Vapor® 19.3 vaporizers. Helium concentrations of 0, 25, 50, and 75% were studied at carrier gas flow rates of 1.5, 3, 6, and 12 litre min⁻¹. Measurements were made in a random fashion so that temperature effects would be distributed over all the measurements. Each measurement was made after a period of 30 s of stable vaporizer output.

The data were analysed using the SPSS statistical package. Stepwise multiple linear regression analysis was used to investigate the effects of helium, carrier gas flow rate, dial setting, and vaporizer model on sevoflurane output. A P value of <0.01 was accepted as significant.

The multiple linear regression model explained 98.9% of the variation in output (the coefficient of determination $R^2 = 98.9\%$, $P < 0.001$). On further analysis, the dial setting explained 97.9% of output variation whereas the effects of increasing helium concentrations, carrier gas flow rates and machine type accounted for just 1% (helium concentration $R^2 = 0.01$; flow rates $R^2 = 0.08$; machine type $R^2 = 0.01$).

To allow graphical comparative analysis (Fig. 1), the measured sevoflurane output concentration was converted to a percentage deviation from baseline. An increase in helium concentration resulted in a minor increase in sevoflurane output. All changes were minimal and while statistically significant on regression analysis ($P < 0.005$) were within ±10% of baseline output. The flow rate of the carrier gas had the greatest effect on output. Increasing the flow rate reduced the output of sevoflurane from both the Blease Datum® and Drager Vapor 19.3® vaporizers. Incidentally, the Blease Datum® vaporizer produced a statistically significant higher output than the Drager Vapor 19.3®.

Comments

The combination of sevoflurane with helium plus oxygen mixture as carrier gas is clinically useful in anaesthesia for the management of upper airway obstruction. During inhalation induction of anaesthesia it is important to be able to rely on the vaporizer dial settings rather than on volatile agent monitors which are not always available. The aim of this study was to determine if the presence of helium in the carrier gas affects the output from two modern sevoflurane vaporizers—the Blease Datum® and Drager Vapor 19.3®.
Vaporizer output is modulated by the ratio of carrier gas flow bypassing the vaporizing chamber to that which is diverted into the vaporizing chamber. Differences in density and viscosity of the carrier gases may affect the bypass splitting characteristics and final performance. Helium has a low density and high critical velocity. We would expect less turbulent flow and generated resistance in the channels and less impact on vaporizer output. Sevoflurane has a low saturated vapour pressure of 21.3 kPa at 20°C and, therefore, requires greater flow through the vaporizing chamber compared with other volatile agent vaporizers, e.g. isoflurane. This characteristic makes sevoflurane vaporizers more sensitive to high flow rate inaccuracies. The low MAC requires higher dial settings, which also impacts on the splitting ratio characteristics.

Of the variables measured, helium concentration had the least effect on output from either of the vaporizers. An increase in helium concentration did, however, result in a small increase in sevoflurane output. All changes were minimal and while statistically significant on regression analysis ($P<0.005$), were well within $±10\%$ of baseline output. Similar minimal effects of helium on vaporizer output have been reported for isoflurane and enflurane vaporizers.\(^1\)\(^4\)

Increasing the dial setting resulted in a statistically significant increase in output above the expected dial value. Conversely increasing the flow rate of the carrier gas reduced the output of sevoflurane from both the Blease Datum\((\text{®})\) and Drager Vapor 19.3\((\text{®})\) vaporizers. This phenomenon is most noticeable at very high flow rates. These changes cannot be extrapolated to all vaporizers as different designs and calibrations impact on performance.\(^1\)

Reductions in output have been reported in a Sevotec 5\((\text{®})\) vaporizer at high flows in association with a low fill state and a high (8\%) dial setting.\(^6\)

In conclusion, increasing helium concentrations and dial settings increased output while increasing flow rates decreased output in both vaporizers, but variations in output delivery were all within the manufacturers’ quoted accuracy and not clinically significant. The clinician can be reassured that helium/oxygen mixtures can be used in conjunction with the Drager Vapor 19.3\((\text{®})\) and Blease Datum\((\text{®})\) sevoflurane vaporizers without adversely affecting either vaporizer’s performance.

**Acknowledgements**

Kevin Hopkins, Head ODA and Ian Walton, Medical Technical Officer (Royal Devon and Exeter Hospital) for their technical help and Dave Wright (Statistics Department, Plymouth University) for his input into the statistical analysis.

**References**