CLINICAL PRACTICE

Modification of a draw-over vaporizer for use with sevoflurane

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Editor’s key points
- Draw-over vaporizers are still widely used but are not calibrated for sevoflurane use.
- A modified draw-over for use with sevoflurane is evaluated here.
- Acceptable concentrations were achieved over a range of flows and temperatures.
- In a continuous flow mode, concentrations suitable for induction can be achieved.

Background. Draw-over anaesthesia is widely used throughout the developing world, in disaster areas and in military anaesthesia when the supply of pressurized oxygen is unreliable. To date, no draw-over vaporizer has been able to deliver sufficient concentrations of sevoflurane for use in inhalation induction of anaesthesia. A laboratory study to assess the performance of a new vaporizer (DDV2) to deliver sevoflurane in a wide range of situations is described.

Methods. In this study, the concentration of sevoflurane delivered at different dial settings (1–4%) and at different temperatures (20–40°C) in a draw-over mode was measured. The concentration of sevoflurane delivered at different dial settings with continuous flow (6 and 8 litre min⁻¹) at 20°C was measured. The maximum possible concentration of sevoflurane that can be delivered by the DDV2 was measured at a continuous flow rate of 8 litre min⁻¹ at 20, 30, and 40°C.

Results. Concentrations of sevoflurane delivered in the draw-over mode were within 0.5% of dialled setting up to 30°C. Above this temperature, higher levels of vapour were delivered. With continuous flow, concentrations of sevoflurane at 20°C were within 0.5% of dialled setting and were stable throughout the duration of the experiment. On the ‘induction’ setting, concentrations of sevoflurane of between 6.4% and 10.1% could be delivered with continuous flow.

Conclusions. The modifications to the DDV2 allow stable concentrations of sevoflurane to be delivered in draw-over and continuous flow modes over a range of temperatures. With continuous flow, concentrations of sevoflurane sufficient for induction of anaesthesia can be achieved.

Keywords: anaesthetics, inhalation; disaster medicine; military medicine; sevoflurane; vaporizers
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Although draw-over anaesthesia is now seldom used in modern well-equipped hospitals, it is still widely used throughout the developing world wherever the supply of pressurized oxygen is unreliable.¹ It is also used in military anaesthesia and after natural disasters when normal support facilities may be unavailable.²

There are a number of draw-over vaporizers currently in use including the Oxford Miniature Vaporizer (OMV, Penlon Ltd, Abingdon, UK)³ and the Diamedica Draw-over Vaporizer (DDV, Diamedica UK Ltd, Bratton Fleming, UK).⁴ They are designed for use with halothane, isoflurane, or trichloroethylene but none of these vaporizers has been calibrated for use with sevoflurane.

Sevoflurane possesses several properties that make it an attractive agent for use in remote locations. Its relative insolubility allows for rapid onset and offset of anaesthesia, while it is non-irritant and sweet smelling, greatly facilitating its use for inhalation induction.⁵ The use of sevoflurane in draw-over anaesthesia has so far been limited by the inability of existing vaporizers to deliver sufficiently high concentrations for induction of anaesthesia.⁶ ⁷ The DDV has been modified for use with sevoflurane for induction and maintenance of anaesthesia.

Laboratory studies to assess the performance of the new vaporizer (DDV2) over a wide range of situations are described.

Methods
The object of the study was two-fold:
(i) To measure the concentration of sevoflurane produced at different dial settings and temperatures in draw-over and continuous flow modes.
To measure the maximum concentration of sevoflurane that can be delivered by the DDV2 at an ‘induction’ dial setting.

Ethical approval was not required as this was an entirely laboratory-based study with no patient contact and was not carried out on NHS premises.

The vaporizer tested was the Diamedica Draw-over Vaporizer 2 (DDV2, Diamedica UK Ltd). This is a version of the original DDV vaporizer which has been modified for use with sevoflurane. The modification has entailed a resetting of the splitting ratio mechanism to increase the proportion of carrier gas passing through the vaporizing chamber at each division of the scale and thus deliver the higher concentrations required when using sevoflurane. This is necessary due to the lower vapour pressure of sevoflurane and the higher minimum alveolar concentration value. In addition to dial settings on a linear scale from 0% to 4% agent output, there is an additional setting marked ‘induction’. When the dial is in this position, the highest achievable volume of the carrier gas is diverted through the vaporizing chamber to increase the concentration of sevoflurane produced to a concentration suitable for gaseous induction (Fig. 1). This dial setting has been chosen to avoid cramping of numbers at the top end of the scale. In practice, concentrations of sevoflurane above 4% are seldom required for the maintenance of anaesthesia and would normally only be required for induction.

In addition, due to the higher outputs that the new splitting mechanism allows, an agent-specific filler for sevoflurane has been added. This is a novel connector supplied with the vaporizer. This eliminates the risk of accidental filling with other agents and allows filling without removal of the filler cap. The level of the filler agent should always be visible through the sight glass so that overfilling is avoided.

To simulate draw-over ventilation, a Glostavent anaesthetic machine (Diamedica UK Ltd) was used with the Diamedica AP ventilator capable of delivering tidal volumes from 35 to 1000 ml at a rate of 1–40 bpm (Fig. 2).

The accuracy of flow rates, tidal volumes, and respiratory rates was ensured using a calibrated gas flow and volume sensor (QA-VTM ventilator tester; Fluke Biomedical, Everett, WA, USA). This was calibrated to record air/oxygen carrier gas mix used in all experiments. Oxygen was used as the carrier gas in all calibrations and experiments. Flow rates and tidal volumes were adjusted so that the delivered rates and volumes were within 0.01 litre min\(^{-1}\) and 0.01 litre, respectively, of that required before each experiment.

The concentration of the sevoflurane produced in each setting was analysed using a Datex-Ohmeda gas analyser (Datex-Ohmeda, Madison, WI, USA). The calibration of the...
The主要集中器在实验之前和之后被检查，以确保精确度。所有实验均使用两个挥发器进行。

挥发器温度被维持在一个温度受控的水浴中。水浴温度保持在目标温度的±0.5 °C范围内。麻醉剂温度被监控在一个Datex-Ohmeda系列400温度探头中。水浴温度被保持在目标温度的±0.5 °C范围内。麻醉剂温度被允许在实验间隔内达到目标温度的±0.5 °C范围内。

这种方法通过使用水浴来模拟环境温度，它在早期的DDV和OMV的研究中被用于评价不同挥发器的输出。在某些情况下，保持准确的环境温度是非常复杂的，因为它必须在不产生显著气流的情况下进行，气流会导致挥发器周围的大气温度波动，从而影响结果的准确性。

作为比较性测量，挥发器的性能在2.3%的拨号设置和6升/分钟的持续流量下在21 °C的空气中测量了一小时。在21 °C的温度下，挥发器的输出温度从21.3 °C降低到18.2 °C，而七氟烷浓度输出从2.4%降低到2.1%。

实验是在20–40 °C的温度范围内进行的。在军事应用中，可以在低于此温度的条件下工作，输出可能低于指示浓度。在这种情况下，Diamedica生产的温度稳定器被推荐。这是一款小型电池驱动的加热垫，可以提供温度调节，以维持温度在20 °C，可以与麻醉机一起提供。

三个实验被进行以评估新挥发器在不同情况下的性能。

实验1
测量在不同拨号设置和不同温度下的七氟烷浓度在吹吸模式下的输出。

此实验中，七氟烷浓度在3分钟内被测量，每15秒记录一次。呼吸机设置为600毫升Vt在10个呼吸/分钟。这在1%，2%，3%和4%的设置下重复了，水浴温度为20，30，和40 °C。

实验2
测量在不同拨号设置下的七氟烷浓度在持续流量模式下的输出。

此实验中，七氟烷浓度在20分钟内被测量，每5分钟记录一次。呼吸机关闭，持续流量率为6和8升/分钟。这在1%，2%，3%，和4%的设置下重复了，水浴温度为20 °C。

实验3
测量在不同温度下可以由DDV2提供的七氟烷最大浓度。

此实验中，七氟烷浓度在5分钟内被测量，每15秒记录一次。呼吸机关闭，持续流量率为8升/分钟。拨号设在 ‘诱导’设置。这在20，30，和40 °C的水浴温度下重复了。实验也在每4，6，和8升/分钟的流量下重复了。
ambient room temperature of 21.8°C to further investigate the effects of flow rate and cooling on high-concentration outputs.

Results

Experiment 1
The concentrations of sevoflurane delivered in a draw-over mode over 3 min at dialled concentrations of 1–4% at 20 and 30°C were within 0.5% of the dialled figure and remained stable throughout the time tested. At 40°C, the concentrations delivered were higher than the dialled figure, but the concentrations remained stable after the initial 30 s (Figs 3 and 4). The variation in the concentrations at 30 s and 3 min was 5.6%, 2.8%, 2.0%, and 10.5% for dial settings of 1%, 2%, 3%, and 4%, respectively.

Experiment 2
The sevoflurane output at 20°C with dial settings 1–4% in a continuous flow mode showed that all concentrations delivered were within 0.5% of the dialled concentrations between 1% and 4% at flow rates of 6 and 8 litre min⁻¹ (Table 1).

Experiment 3
The sevoflurane concentrations delivered at the ‘induction’ setting over 5 min at 20, 30, and 40°C showed that the initial concentrations delivered were between 8.4% and 10.1% and remained above 6.4% for the duration of the experiment (Fig. 5). At lower flow rates, the concentration of sevoflurane was slightly higher, with an output range of 6.3–8.6% at 6 litre min⁻¹ and 7.4–8.8% at 4 litre min⁻¹. As expected, the temperature decrease was less at lower flow rates: 1.1°C at 6 litre min⁻¹ and 0.6°C at 4 litre min⁻¹.

Discussion
Draw-over breathing systems are still widely used in those parts of the world where the supplies of oxygen and electricity are unreliable and they have been used successfully in military conflicts for many years.² With the recent improvements in equipment for draw-over anaesthesia, it is likely to retain its popularity wherever anaesthesia has to be administered under difficult circumstances. The results found with this vaporizer correlate with similar behaviour in previous
Following a recent debate among British military anaesthetists, 39 out of 40 who expressed an opinion voted for the retention of draw-over equipment. Despite its continuing popularity, one of the most persistent problems of draw-over anaesthesia has been the difficulty in achieving a sufficiently high concentration of volatile agent for inhalation induction of anaesthesia. However, because of its physical properties, sevoflurane is now generally preferred for inhalation induction of anaesthesia in the UK and North America. A concentration of 8% is commonly used but this has not previously been achievable from a draw-over vaporizer. Even when two OMVs were used in series, the maximum concentration delivered was 5.9% under similar conditions.

The modifications to the DDV have facilitated its use with sevoflurane by increasing the proportion of carrier gas passing through the vaporizing chamber and therefore the concentration produced. The ‘induction’ setting greatly increases the concentration delivered to allow gaseous induction. This has, however, resulted in an increase in the resistance to breathing to a level which may be unacceptable to some patients, for example, the frail and elderly who may have difficulty generating sufficient negative pressures and in small infants. To overcome this difficulty, the DDV2 can be used in a continuous flow mode during the induction phase changing to a draw-over mode when induction is complete. If the continuous flow provided is greater than the patient’s minute volume, the resistance throughout the circuit is effectively zero. Intraoperatively, in the draw-over mode, resistances are acceptable for all patient groups. This scenario is readily achievable when the DDV2 is used with the Glostavent anaesthetic machine which has been specifically designed for use in either continuous flow or draw-over modes. Whenever the flow of supplementary oxygen exceeds the patient’s respiratory minute volume, the pressure within the reservoir increases, the gas flow to the patient becomes continuous, and the effect of the increased resistance is nullified. As soon as induction is complete and the high concentration of sevoflurane is no longer required, the supplementary oxygen flow rate can be reduced below the patient’s minute volume and draw-over anaesthesia is resumed.

In conclusion, modifications have been made to the Diamedica draw-over anaesthetic vaporizer to enable it to be used for both induction and maintenance of anaesthesia using sevoflurane. The high concentration required for gaseous induction can be achieved by using the continuous flow mode during induction and changing to the draw-over mode thereafter.

Declaration of interest
R.N. is the Managing Director of Diamedica UK Ltd.

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