

Sevoflurane Output in the Isoflurane/Halothane Diamedica Draw-over Vaporiser

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Abstract

Introduction: Draw-over anaesthesia remains an attractive option for conduct of anaesthesia in austere conditions. The Diamedica Draw-over Vaporiser (DDV) is a modern draw-over vaporiser and has separate models for isoflurane/halothane and sevoflurane. **Materials and Methods:** A laboratory study was done to measure sevoflurane output in an isoflurane/halothane DDV. We did 3 series of experiments with the isoflurane/halothane DDV. We measured anaesthetic agent output in both push-over and draw-over setups, and at minute ventilation of 6 L/min and 3 L/min. Series 1 experiment was done with isoflurane in the DDV at ambient temperature of 20°C. Series 2 experiment was done with sevoflurane in the DDV at ambient temperature of 20°C. Series 3 experiment was done with sevoflurane in the DDV and with the DDV placed in a water bath of 40°C. **Results:** The sevoflurane output was found to be two-thirds of the isoflurane/halothane DDV dial setting at ambient temperature of 20°C. With the DDV in a 40°C water bath, the sevoflurane output was found to be about the isoflurane/halothane DDV dial settings. **Conclusion:** In our experiment, we show that it is possible to use sevoflurane in an isoflurane/halothane DDV.

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Introduction

Draw-over anaesthesia is an attractive option in a resource poor environment.¹ The Diamedica Draw-over Vaporiser (DDV) by Diamedica UK is a modern reiteration of the venerable Oxford Miniature Vaporiser (OMV).² The OMV can be used with halothane, trichlorethylene, enflurane, isoflurane and sevoflurane. The DDV comes in 2 versions,³ one for isoflurane/halothane and one for sevoflurane. The isoflurane/halothane DDV is made of stainless steel and has a capacity of 150 mL/s. Its dry weight is 2.6 kg and allows a scale from 0% to 5% (Fig. 1). The purpose of this series of experiments was two-fold. Firstly, to examine sevoflurane output when utilising the isoflurane/halothane DDV and secondly, to examine whether this vaporiser could, if required, be used in clinical practice with sevoflurane.

The saturated vapour pressures at 20°C of the inhalational anaesthetic agents are: halothane 32.4 kPa, isoflurane 31.9 kPa and sevoflurane 21.3 kPa.⁴ The proximity of the

saturated vapour pressures of halothane and isoflurane explains why they can be used in a common DDV. The saturated vapour pressure of sevoflurane is about two-thirds of that of isoflurane/halothane. Saturated vapour pressure increases with increasing temperature. We did a series of experiments to measure sevoflurane output in an isoflurane/halothane DDV under varying conditions.

Materials and Methods

Three series of experiments were performed. The anaesthesia circuits used for the experiments are shown in Figure 2. We had different configurations for push-over and draw-over setups.

Standardisations

Ethical approval was not required as this was an equipment-based study with no patient involvement. The

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Fig. 1. Diamedica Draw-over Vaporiser (DDV) for isoflurane/halothane. It is a common vaporiser for halothane and isoflurane.

DDV used came from the Diamedica Portable Anaesthesia System (DPA 01) purchased by the Department of Surgery, National University of Singapore (NUS).

The schematic diagram of the set-up is as shown in Figure 2. The ventilator used is the Impact® 731 Series model EMV+® transport ventilator. Two-minute ventilation targets were chosen: 6 L/min (500 mL tidal volume x 12 breaths per minute) for simulation of an adult patient and 3 L/min (150 mL tidal volumes x 20 breaths per minute) for simulation of a paediatric patient. All experiments were run twice and the average values charted and plotted.

The isoflurane and sevoflurane were produced by Baxter Healthcare (Asia) and Abbott Laboratories, respectively. We did not examine halothane output as it is no longer available in Singapore. Anaesthetic agent output was measured using a CARESCAPE Monitor B850 system from GE Healthcare. A Draeger anaesthesia gas scavenging unit attached to the hospital's operating room active scavenging system was used to scavenge the expired gases.

The DDV was filled with 100 mL of anaesthetic agent before each run of the experiment and the temperature of the DDV was allowed to stabilise for 15 minutes before each run.

Series 1: Verification of Isoflurane Output at 20°C

We measured the DDV's isoflurane output at ambient

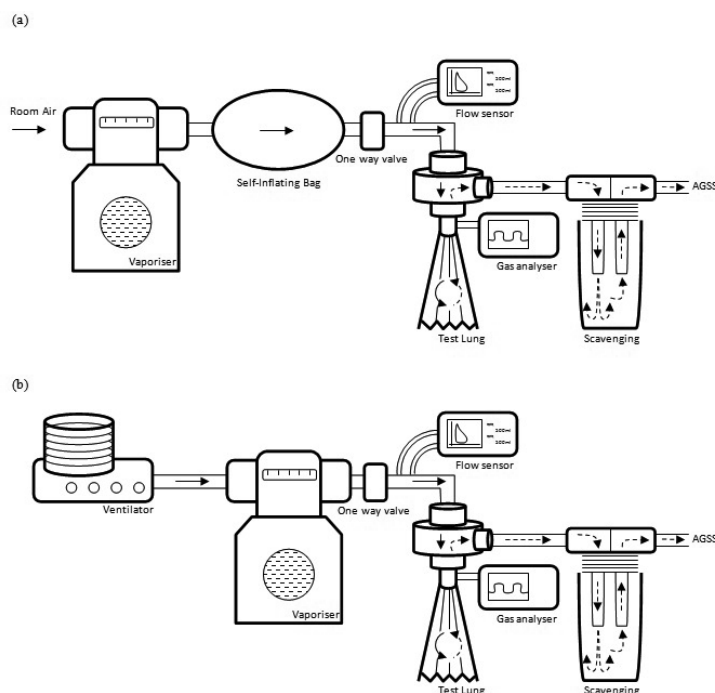


Fig. 2. Schematic diagram of the bench test set up of (a) draw-over circuit and (b) push-over circuit. The solid arrows (→) represents the theoretical inspiratory flow of gas, while the broken arrows (---→) represents the expiratory flow. AGSS: Anaesthetic gas scavenging systems.

temperature of 20°C using both push-over and draw-over setups. Isoflurane output was recorded at the 0.5- and 1-minute mark with dial settings of 3%, 4% and 5%, with minute ventilation of 6 L/min and 3 L/min at each dial setting.

Series 2: Sevoflurane Output at 20°C

In this experiment, we measured the sevoflurane output in both the push-over and draw-over setups at ambient temperature of 20°C. Sevoflurane output was recorded every 30 seconds over a 5-minute period at dial settings of 3%, 4% and 5% with minute ventilation of 6 L/min and 3 L/min.

Series 3: Sevoflurane Output in Water Bath at 40°C

In this experiment, we measured the sevoflurane output in both the push-over and draw-over setups with the DDV in a water bath of 40°C. Sevoflurane output was recorded every 30 seconds over a 5-minute period at dial settings of 3%, 4% and 5% with minute ventilation of 6 L/min and 3 L/min.

Results

Series 1: Verification of Isoflurane Output at 20°C

At an ambient temperature of 20°C, the isoflurane output from the isoflurane/halothane DDV was found to be within

0.5% (a standard as used by Payne et al)⁸ of its dial settings at 3%, 4% and 5% at minute ventilation at 6 L/min and 3 L/min (Table 1).

Series 2: Sevoflurane Output at 20°C

The sevoflurane output from the isoflurane/halothane DDV at ambient temperature of 20°C was found to be two-thirds of the dial settings. The push-over setup yielded similar results to the draw-over setup (Table 2). Within the push-over and draw-over groups, minute ventilation (6 L/min or 3 L/min) did not affect the output of sevoflurane.

Series 3: Sevoflurane Output in Water Bath at 40°C

When the isoflurane/halothane DDV was immersed in a water bath with a temperature of 40°C, the sevoflurane output concentration was found to be about the dial lever settings (Fig. 3). There were minimal difference in sevoflurane output for both draw-over and push-over setups and there was also minimal difference (<0.5%) in sevoflurane output between minute ventilation of 6 L/min and 3 L/min.

Discussion

Accuracy and Consistency of DDV

In Series 1 experiment, we attempted to verify the internal accuracy of the dial setting of the isoflurane/halothane DDV to its measured isoflurane output. At ambient temperature of 20°C, the output of isoflurane measured corresponded to the dial setting in both push-over and draw-over setups at minute ventilations of 6 L/min and 3 L/min.

In our experiments, we used both push-over and draw-over setups. Previous studies have shown no differences in concentration output between push-over and draw-over on

the OMV50 Vaporiser^{5,6} and Universal Portable Anesthesia Complete (PAC) vaporiser.⁷ These bench studies were conducted using halothane and different vaporisers. Payne et al⁸ compared the concentration using draw-over and continuous flow methods with a sevoflurane dedicated DDV. English et al² compared intermittent (draw-over) and continuous flow methods for isoflurane/halothane DDV. The results from our Series 1 experiment showed that there was minimal difference between push-over and draw-over setups when using isoflurane.

Using Sevoflurane in Isoflurane/Halothane DDV

In our Series 2 experiment, we placed sevoflurane into the isoflurane/halothane DDV. When operating at ambient temperature of 20°C, the output concentration of sevoflurane remained relatively steady over the time period of our experiment.

Sevoflurane output concentration was found to be around two-thirds the dial settings on the isoflurane/halothane DDV. This was consistent using either the draw-over or push-over setup at minute ventilation of 6 L/min and 3 L/min. The measured output concentrations were consistent with an expected two-thirds value as predicted from saturated vapour pressures (sevoflurane has a saturated vapour pressure value of approximately two-thirds that of isoflurane/halothane).

When set at 5% using the isoflurane/halothane DDV, the sevoflurane output was about 3%. This is 1.5 times the minimal alveolar concentration (MAC) of sevoflurane. This concentration of sevoflurane should be enough for maintenance of balanced general anaesthesia under intermittent positive pressure ventilation (IPPV). It should also be sufficient for general anaesthesia under spontaneous ventilation with generous amounts of opioids or

Table 1. Output Concentration of Isoflurane Using the Isoflurane/Halothane DDV in Push-over and Draw-over

	Dial Setting			
	Draw-over		Push-over	
	Time			
	0.5 min	1 min	0.5 min	1 min
Minute ventilation: 6 L/min				
Concentration				
3%	2.9	2.9	3.0	3.0
4%	3.9	3.7	3.9	3.8
5%	4.8	4.7	4.9	4.7
Minute ventilation: 3 L/min				
Concentration				
3%	2.8	2.7	2.8	2.8
4%	3.7	3.7	3.8	3.7
5%	5.0	5.0	5.1	5.1

DDV: Diamedica Draw-over Vaporiser

Table 2. Concentration of Sevoflurane Output at Different Minute Ventilation and Concentration, using Draw-over and Push-over*

	Time (Min)										
	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
Draw-over											
Minute ventilation: 6 L/min											
Concentration											
3%	0	2.3	2.2	2.2	2.1	2.1	2	2.1	2	2	2.1
4%	0	2.6	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.3
5%	0	3.5	3.3	3	3.1	3	2.9	2.9	2.9	2.9	2.9
Minute ventilation: 3 L/min											
Concentration											
3%	0	2	2	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.8
4%	0	2.7	2.7	2.6	2.6	2.6	2.6	2.5	2.5	2.5	2.5
5%	0	3.7	3.6	3.6	3.5	3.5	3.5	3.5	3.4	3.4	3.4
Push-over											
Minute ventilation: 6 L/min											
Concentration											
3%	0	1.9	1.9	1.8	1.8	1.8	1.8	1.8	1.8	1.7	1.7
4%	0	2.5	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.2	2.2
5%	0	3.1	3	2.9	2.9	2.8	2.8	2.8	2.7	2.7	2.7
Minute ventilation: 3 L/min											
Concentration											
3%	0	1.9	1.9	1.9	1.9	1.9	1.8	1.8	1.8	1.8	1.7
4%	0	2.6	2.5	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.4
5%	0	3.7	3.6	3.6	3.5	3.5	3.4	3.4	3.4	3.4	3.3

*All experiments were done at ambient temperature of 20°C.

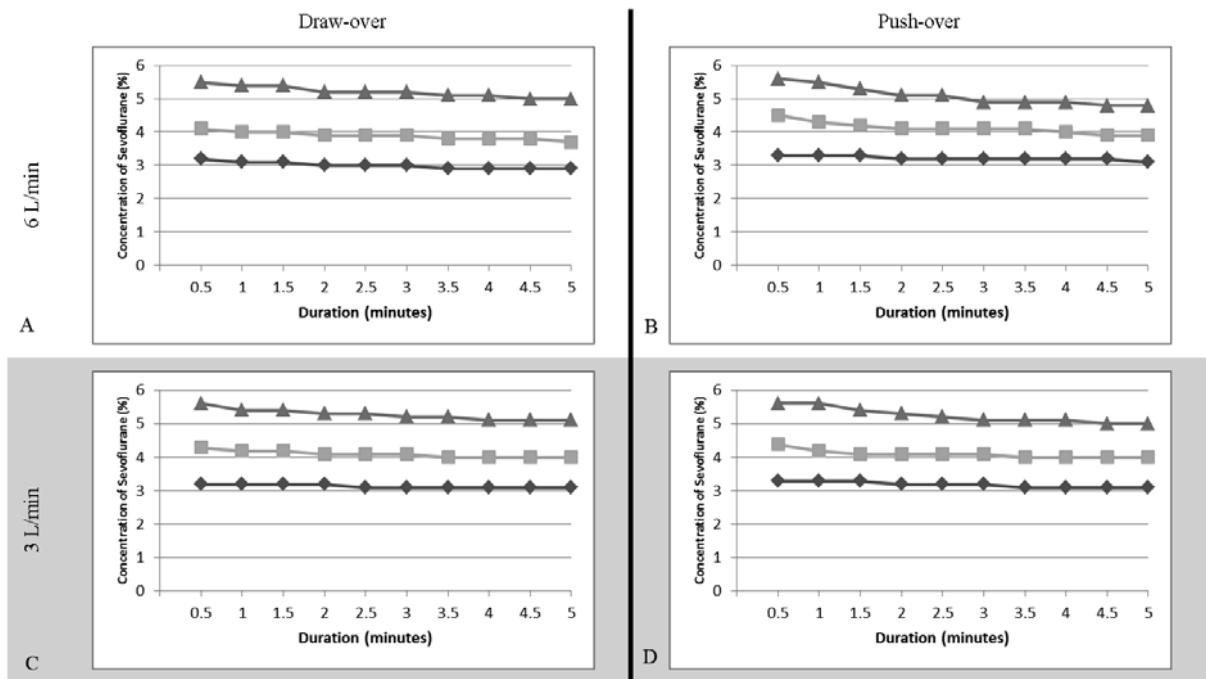


Fig. 3. Concentration of sevoflurane output at minute ventilation of 6 L/min (A and B) and 3 L/min (C and D) at concentration dial setting at 3% (◆), 4% (■) and 5% (▲). This was done with DDV in water bath set at 40°C using draw-over (A and C) and push-over (B and D) method.

premedication with benzodiazepines. However, the highest sevoflurane concentration of 3% would be insufficient to conduct routine inhalational induction. Pylman and Teiken encountered similar results with Ohmeda Universal PAC draw-over vaporiser, achieving a maximum concentration of 3.6%.⁹

To overcome the above problem, Diamedica UK has produced a dedicated sevoflurane DDV^{3,8} and as an alternative solution, some authors have experimented with connecting 2 draw-over vaporisers in series.^{10,11} We found that inhalational induction doses of sevoflurane (4% to 8% in adults¹²⁻¹⁵ and up to 12% in children)¹⁶⁻¹⁹ could be achieved by immersing the isoflurane/halothane DDV in a warm water bath of 40°C as shown in the Series 3 experiment. Under Series 3 experiment conditions, sevoflurane output concentrations are about the dial lever setting on the isoflurane/halothane DDV. This is because at higher temperatures, the SVP will increase and hence, the output will increase (20.9 kPa at 20°C, 26.2 kPa at 25°C, 42.3 kPa at 36°C)²⁰ compared to SVP of isoflurane (31.7 kPa at 20°C, 39.3 kPa at 25°C, 60 kPa at 35°C).²¹ With this setup, induction doses ($\geq 4\%$) of sevoflurane output were achievable.

Lastly, the authors must highlight safety concerns regarding the use of non-specified agent in a dedicated vaporiser. However, the same safety concerns also exist with the universal OMV, another vaporiser that can be used with a variety of different volatile agents. In these situations, clear labeling of which agent is being used is important. The use of end-tidal anaesthetic agent monitor will also help to improve the safety profile.

Conclusion

In our experiments, we have shown that it is possible to achieve clinically useful sevoflurane output in an isoflurane/halothane DDV. At ambient temperature of 20°C, the sevoflurane output was found to be two-thirds of the isoflurane/halothane DDV dial setting (as predicted from SVP). In a water bath at 40°C, the sevoflurane output was found to be approximate to the isoflurane/halothane DDV dial setting.

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