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Research Article

Washin of 8% Sevoflurane between Dräger Fabius GS and General Electric Avance: An in Vitro Observational Study

Juan Soliveres Ripoll[1*] and Carlos Docampo Sierra[2]

[1]Department of Anesthesia and Critical Care, University Hospital Dr. Peset. Valencia, Spain. Associate Professor. Department of Surgery. Universitat de Valencia, Spain; [2]Department of Anesthesia.University Hospital Quirón. Valencia, Spain

ABSTRACT

Objectives: To in vitro compare sevoflurane washin at FGF=6 l min^{-1}, 9 l min^{-1} and 12 l min^{-1} between the General Electric Avance® and the Dräger Fabius GS anaesthesia workstations. To know whether it is possible to reach an 8% sevoflurane concentration at each of the FGF studied.

Methods: In this observational in vitro study, three Avance (General Electric, Helsinki, Finland) and three Fabius GS (Dräger Medical, Lübeck, Germany) anaesthesia workstations were compared. A test lung was connected to the anaesthesia workstation and a sampling tube was connected from the Y piece of the breathing system to a Cardiocap S/5 gas analyser (General Electric, Helsinki, Finland). The gas analyser was connected to a computer and sevoflurane concentration and timeline were recorded every second. Mechanical ventilation was set to 500 ml tidal volume, 12 breaths per minute and FGF (fresh gas flow) of 6, 9 or 12 l min^{-1}. After checking a reading of 0.0 vol% of sevoflurane, the vaporizer was opened at 8% and data were recorded for 4 minutes (FGF of 6, 9 and 12 l min^{-1} for Avance and 12 l min^{-1} for Fabius) or 7 minutes (FGF of 6 and 9 l min^{-1} for Fabius)

Results: 90 test were recorded. Time to full washin was: FGF=6 l min^{-1}: 42.30 ± 2.49 s (Avance) and 223.42 ± 13.74 s (Fabius), p<0.001. FGF=9 l min^{-1}: 34.86 ± 2.54 s (Avance) and 122.40 ± 5.22 (Fabius), p<0.001. FGF=12 l min^{-1}: 29.67 ± 2.06 s (Avance) and 93.81 ± 5.93 (Fabius), p<0.001. 8% washin was only reached at FGF=6 l min^{-1} for Avance and Fabius. After plateau, a decay in sevoflurane concentration was observed at all FGF except for Fabius at FGF=6 l min^{-1}.

Conclusion: Avance is faster than Fabius at all FGF only at FGF of 6 l min^{-1} can be reached the 8% sevoflurane concentration. For high concentration sevoflurane inhalational adult anesthesia induction, it is advisable to use FGF=6 l min^{-1} and to purge the circuit for at least 42.30 ± 2.49 s (Avance) or 223.42 ± 13.74 s (Fabius).

Keywords: Sevoflurane; Anesthesia

INTRODUCTION

For adult patients who suffer needle fear or patients with difficult iv access, inhalational anesthesia is preferable to intravenous induction. Inhalational anesthesia is safe and reliable, may increase patient satisfaction, and is widespread used [1,2]. It is surprising that even 50% of adults prefer inhalational anesthesia induction when offered [3] but inhalational anesthesia induction is seldom offered.

One of the most used inhalational anesthesia induction in adults is initial high concentration of sevoflurane, where 8% sevoflurane in set on the vaporizer and the patient is allowed to breath until loss of conscientiousness [4]. For that technique, is mandatory to deliver 8% sevoflurane and purge the breathing circuit, although time to purge the circuit is seldom reported, if reported at all.

We hypothesized that the time needed to purge the breathing circuit (washin) depends on the anesthesia workstation and

Correspondence to: Juan Soliveres Ripoll, Department of Anaesthesia and Critical Care, University Hospital Dr. Peset. Valencia, Spain; Tel: +34 670 758 871; E-mail: soliveres_jua@gva.es

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minute ventilation, but not on the physical volume of the breathing circuit, as the gas does not mixes instantaneously inside the circuit. We also hypothesized that the cooling of the vaporizer at high fresh gas flow (FGF) could impede 8% sevoflurane delivery.

Our study aimed to in vitro compare sevoflurane washin at FGF=6 l min^{-1}, 9 l min^{-1} and 12 l min^{-1} between the General Electric Avance® and the Dräger Fabius GS anesthesia workstations. We also aimed to know whether it is possible to reach an 8% sevoflurane concentration for each of the FGF studied.

PATIENTS AND METHODS

In this observational in vitro study, we compared three Avance anaesthesia workstation units (General Electric Avance®, General Electric, Helsinki, Finland) and three Fabius anaesthesia workstation units (Dräger Fabius GS®, Dräger Medical, Lübeck, Germany) in clinical use. Each workstation had its own vaporizer attached (Dräger Vapor® 2000, Dräger, Lübeck, Germany) for Fabius, and General Electric Tec 7® vaporizer, General Electric, Helsinki, Finland, for Avance). Each workstation and vaporizer were serviced according to the manufacturer's instructions.

We connected an adult circle breathing system (1.6 m long Flexitube breathing system®, Intersurgical, Spain) to the anaesthesia workstation. The Y piece of the breathing system was connected to a breathing filter (Inter-Guard® breathing filter, Intersurgical, Spain) and to a test lung (Maquet adult 1 litre test lung 190®, Maquet, Spain).

A 3 m long sampling tube was connected from the luer lock port on the breathing system to a gas analyser (Datex-Ohmeda Cardiocap®/5 (General Electric, Helsinki, Finland). The Cardiocap monitor uses a nondispersive infrared analyser for inhalational agents with an of accuracy of ± 0.15 vol% or 5% and records two digit data resolution.

Fresh soda lime and brand new breathing system and filter were used for each test session. The monitor was zeroed prior to each test after a 30 minute warm up, according to the manufacturer's instructions in order to obtain the maximum accuracy possible. The monitor was only used for data collection during the time of this study, and was returned to clinical use afterwards. The sample flow was 200 ml l min^{-1}, not returned to the anesthesia workstation breathing circuit.

A standard RS232 to USB cable was connected from the RS-232 port on the I/O board of the monitor to computer's USB port. Numeric timeline and sevoflurane concentration at the Y piece were recorded every second with the S/5 Datex-Ohmeda S/5 Collect 4.0® software (General Electric, Helsinki, Finland).The exact vaporizer opening time was manually recorded.

After anaesthesia workstation self-text and monitor warm up and self-test, the vaporizer was filled to the maximum. Ventilation settings were set to match a standard adult ventilation (500 ml tidal volume, 12 breaths per minute, I:E of 1:2, 50% oxygen in air, no PEEP), and computer recording began.

After checking no sevoflurane reading on the computer for at last 60 seconds, the vaporizer was opened at its maximum (8 vol %) at an exact time point. To prevent an excessive cooling of the vaporizer after repeated tests that could affect the results, the minimum time between test was set to 30 minutes and the vaporizer was refilled prior to each one.

From a pilot study, we expected the maximum sevoflurane concentration to be reached at around 100 or 200 seconds for Fabius at FGF=6 l min^{-1} and 9 l min^{-1} respectively. So, we decided to record 4 minutes for each FGF, extended to 7 minutes for Fabius at FGF=6 l min^{-1} and 9 l min^{-1}, as a compromise between enough time recorded to asses plateau concentration and sevoflurane consumption.

Statistical analysis

Statistical analysis was performed with GraphPad Prism 8.1® (GraphPad, California, USA) and MedCalc 14.8® (MedCalc, Belgium). The normality of the distribution was evaluated by Q-Q plots. Normally distributed data are presented as mean ± standard deviation (SD).

Washin was defined as the time elapsed between opening the vaporizer and the time to reach the sevoflurane plateau concentration. Independent samples t test was used to compare time to reach plateau and time to reach 8% sevoflurane between Avance and Fabius at each FGF. ANOVA with Tukey-Kramer post-hoc test was used to compare time to reach plateau between FGF inside each workstation brand. Statistical significance was set to the 1% level.

Sample size calculation

We considered as clinically relevant a washin difference of 60 seconds or more between Avance and Primus. From a pilot study, we expected a SD of 30 seconds at FGF=6 l min^{-1}. To obtain an α error <0.01 and 99% power, we needed to include 13 test for each FGF and each workstation brand. To run the same amount of test on each workstation, we decided to run 5 test for each of the six anaesthesia workstations and each FGF studied, thus 15 repeats for each FGF and workstation brand were recorded.

RESULTS

We recorded 90 test, 45 for each brand: 15 test per FGF (Avance) and 15 test per FGF (Fabius). Two test at FGF=12 l min^{-1} (Avance) were discarded for excessive cooling of the vaporizer, and repeated. One data set (Fabius, FGF=6 l min^{-1}) was corrupted and repeated. Time recorded was 4 minutes for Avance at all FGF and Avance at FGF of 12 l min^{-1}. For Fabius at FGF of 6 and 9 l min^{-1}, 7 minutes were recorded.

Plateau sevoflurane concentration, time to washin and time to reach 8% sevoflurane are shown in Table 1. The concentration of 8% sevoflurane was not reached at FGF of 9 and 12 l min^{-1}

for Fabius nor Avance. The shape of the exponential washin curve is shown in the Figure 1.

Table 1: Sevoflurane washin.

		FGF			
		6 l min^{-1}	9 l min^{-1}	12 l min^{-1}	P (**)
Plateau (vol%)					
n=45	Avance	8.16 ± 0.10	7.19 ± 0.12	6.64 ± 0.16	<0.001
	Fabius	8.10 ± 0.09	7.18 ± 0.11	6.75 ± 0.14	<0.001
	P(*)	0,09	0,814	0,05	~
Time to washin (s)					
n=45	Avance	42.30 ± 2.49	34.86 ± 2.54	29.67 ± 2.06	<0.001
	Fabius	223.42 ± 13.74	122.40 ± 5.22	93.81 ± 5.93	<0.001
	P (*)	<0.001	<0.001	<0.001	~
Time to 8% sevoflurane					
n=30	Avance	29.30 ± 2.36	~	~	~
	Fabius	187.86 ± 3.87	~	~	~
	P (*)	<0.001	~	~	~

Data show mean ± SD. s: seconds. Plateau: plateau sevoflurane concentration. (*): P value between Avance and Fabius. (**): P value between FGF within Avance or Fabius. For FGF of 9 and 12 l min^{-1}, 8% sevoflurane was not reached.

DISCUSSION

In our study, the Avance has shown to be faster than the Fabius at all FGF studied with adult ventilation settings. Kern et al. [5] also demonstrated that Avance is faster than Fabius for toddlers and newborn mechanical ventilation settings. Nor Avance or Fabius have reached 8% sevoflurane at FGF above 6 l min^{-1}, probably due to the vaporizer cooling. With FGF over 6 l min^{-1} and 8% sevoflurane set, the vaporizers are likely to be beyond their own limits, not capable to deliver the sevoflurane concentration set [6].

Time elapsed between setting a sevoflurane concentration on a vaporizer and the presence of that concentration in the mouth of the patient not only depends on fresh gas flow (FGF) or the volume of the breathing circuit, but also on the type of anesthesia workstation [7]. As sevoflurane does not mix instantaneously inside the breathing circuit, the 8% sevoflurane kinetics inside the anaesthesia workstations is not well studied [8,9].

The difference of time demonstrated in our study to obtain 8% sevoflurane at the Y piece, can be easily explained by different circuit characteristics between Avance and Primus. Primus features a piston-driven breathing circuit, the FGF inlet is located between the piston and the soda lime canister, and includes a decoupling system to prevent barotrauma, which causes a delay in the time to reach the concentration set on the vaporizer [5]. The Avance is a traditional bellows driven circle breathing system where the FGF inlet is positioned between the inspiratory valve and the patient [10]. The position of the FGF inlet is likely to be the cause of the different kinetics inside the anesthesia workstations.

The decay in the sevoflurane concentration at high FGF can be also explained by the cooling of the vaporizer. Nevertheless, four minutes should be enough for an inhalational high flow anesthesia induction. For the Fabius at FGF of 6 l min^{-1}, no decay was observed within the 7 minutes recorded, which may be explained by the differences in the breathing circuit architecture inside the Fabius.

Time to purge the breathing circuit is seldom reported, if reported at all. The knowledge of the 8% sevoflurane washin time of the Fabius and Avance anesthesia workstations at FGF of 6, 9 and 12 l min^{-1} can help to choose the best combination of FGF for each anesthesia workstation for adult inhalational anesthesia induction and reduce costs [11].

LIMITATIONS

The anesthesia workstations were set to mechanical ventilation, whereas inhalational anesthesia is administered in spontaneous ventilation after the purge of the circuit, although in some occasions the patient is allowed to breath without previous circuit purge. We believe that the washin time is not too different in spontaneous and in mechanical ventilation, but this needs further investigation.

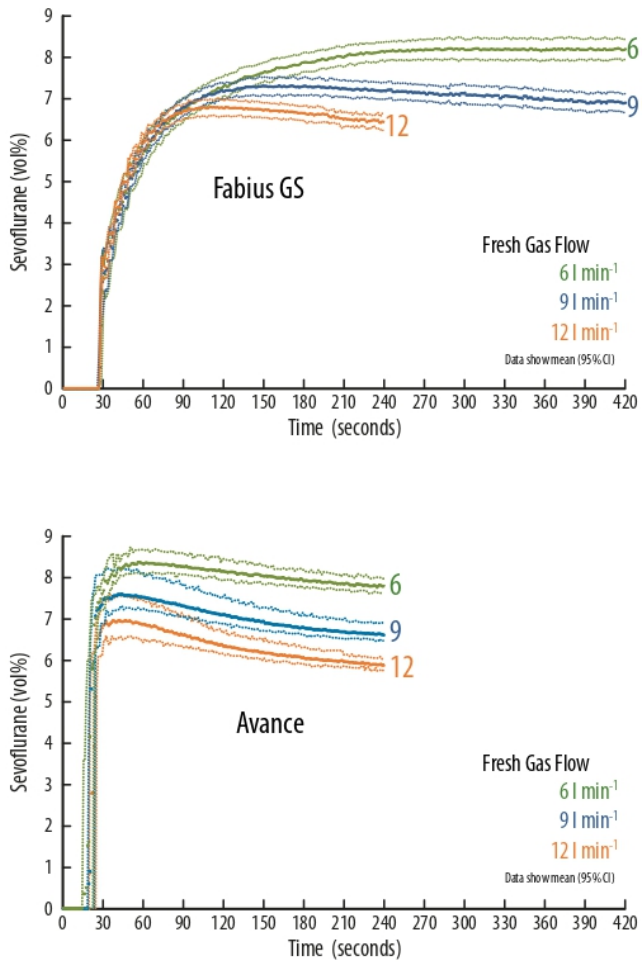

Figure 1: Sevoflurane washin follows an expected exponential curve. As FGF increases, time to washin shortens. Avance is faster than Fabius at all FGF. Only Fabius at FGF=6 l min^{-1} does not show a sevoflurane concentration decay along time. FGF: fresh gas flow. Time to washin: defined as time elapsed between the vaporizer opening and the time to reach the plateau. Data in the curves show mean ± 95 CI of the values. Data recording was cut at 4 minutes (240 seconds) or 7 minutes (420 seconds). After plateau, a decay was observed at all FGF except for Fabius at FGF of 6 l min^{-1} for the time recorded.

CONCLUSION

Avance is faster than Fabius at all FGF. Only at FGF of 6 l min^{-1} can be reached the 8% sevoflurane concentration. For high concentration sevoflurane inhalational adult anaesthesia induction, it is advisable to use FGF=6 l min^{-1} and to purge the circuit for at least 42.30 ± 2.49 s (Avance) or 223.42 ± 13.74 s (Fabius).

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