J Clin Monit Comput (2015) 29:601–604
DOI 10.1007/s10877-014-9639-6

ORIGINAL RESEARCH

Reliability of the volatile agent consumption display in the Draeger Primus^{TM} anesthesia machine

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Received: 22 July 2014 / Accepted: 7 November 2014 / Published online: 12 November 2014

Abstract Knowledge of the consumed amount of volatile anesthetic (VA) expressed in liquid agent is necessary to enable agent sparing dosing measures and for billing purposes. The widespread Draeger Primus^{TM} anesthesia machine displays in its logbook the amount of consumed VA at the end of each anesthesia, but the reliability of this parameter is yet unknown. The objective was to evaluate the precision and reliability of the inbuilt VA consumption display in Draeger Primus^{TM} anesthesia machines as compared with the gold standard of weighing the vaporizer before and after anesthesia. In this prospective laboratory investigation we compared the VA consumption displayed by the Draeger Primus^{TM} anesthesia machine with measured vaporizer weight differences before and after 10 sevoflurane and 10 desflurane anesthesias. We assessed the average difference and spread of values between the predicted (displayed) and measured (control) values for VA consumption. The displayed sevoflurane consumption overestimated the measured values by 4.3 ± 5.4 ml (7.6 %). The displayed desflurane consumption underestimated the measured values by -3.5 ± 6.3 ml (6.2 %). Nine from 10 sevoflurane pairs of values and all desflurane pairs of values were within ± 1.96 SD. The displayed VA consumption calculations for sevoflurane and desflurane in the Draeger Primus^{TM} are sufficiently reliable to estimate the pharmacoeconomic impact of VA delivery during inhalational anesthesia.

Keywords Consumption · Volatile anesthetics · Pharmacoeconomics · Sevoflurane · Desflurane

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1 Introduction

The consumption of volatile agents (VA) during anesthesia and its pharmacoeconomic implications gain increasing attention [1, 2]. Therefore the knowledge of the consumed amount of VA expressed in milliliters of liquid agent at the end of each case becomes relevant and represents useful information to apply agent sparing dosing measures. The knowledge of the VA consumption per case also might be used for billing. To satisfy this need, the popular anesthesia machine Draeger Primus^{TM} (Draeger AG & Co. KGaA, Lübeck, Germany) is equipped with an inbuilt ability to calculate the ongoing VA consumption which at the end of anesthesia is displayed on the screen in a logbook [3, 4]. This feature is not yet commonly used and should therefore be tested in clinical routine regarding its precision and reliability.

The gold standard for VA consumption assessments for a specific period is to weigh the vaporizer before and after anesthesia and to take the difference as the consumed amount. This method has been widely used for various anesthesia related pharmacoeconomic investigations [5, 6]. A certain technical problem derives from the necessity for a very precise balance that has a wide range of measurement. Usually the larger the measurement range, the less is the resolution for the differences between the measured objects. A customary vaporizer weighs up to 9 kg, while the differences found by the prevailing levels of the residual VA content varies in the range of a few grams. Besides, weighing of the vaporizer can be only adopted if this is planned in advance. Due to unavailability of such equipment as well as the necessity to plan the measurements individually in advance, this weighing method remains limited to a reduced number of cases. Therefore it is essential to know whether one can rely on the inbuilt

calculation feature for VA consumption alone. This investigation has the purpose to evaluate the precision and reliability of the inbuilt VA consumption display in Draeger Primus^{TM} anesthesia machines.

2 Materials and methods

As being a purely laboratory investigation without interference with patients and/or personnel, there was no need for approval by the local Ethical Committee. We collected data from twenty anesthesias of which ten were conducted with sevoflurane and ten with desflurane by using Draeger Primus^{TM} anesthesia machines in three different operation rooms that are maintained according prescribed standards. Since patients from the involved cases were irrelevant for this investigation, their biometrical and clinical data was not recorded. The primary measured parameters were: weight of the vaporizer before and after anesthesia and the displayed amount of consumed VA at the end of each procedure. As secondary results we calculated the average VA consumption per time unit and the actual costs that occurred for the used VA in absolute numbers and over time. The vaporizers' weighing was performed with a temporarily leased Mettler-Toledo balance that has been calibrated prior the investigation by the supplier (Mettler-Toledo GmbH, 8606 Greifensee, Switzerland).

To extract the correct volume of delivered/consumed VA by taking the weight of the vaporizer before and after anesthesia, we divided the difference in grams by the specific weight of the involved VA, which is 1.53 g/ml for sevoflurane, and 1.47 g/ml for desflurane [7, 8]. The accuracy (bias and variance) of the calculated VA consumption were determined by using Bland/Altman comparisons and linear correlations [9]. For cost calculations the VA local Swiss market price per milliliter has been adopted, which in our case was at the time of the investigation 0.91 Euros (EUR)/ml for sevoflurane and 0.49 EUR/ml for desflurane (based on a currency exchange rate of 1.0 EUR = 1.21 Swiss Francs).

3 Results

There was no interference between taking the measurements and the applied practice of anesthesia. Therefore the collected data represent the unaffected daily routine of delivering general anesthesia with VA in our department. When using sevoflurane the effective VA consumption resulted in 52.8 ± 40.5 ml (mean and SD), while the Draeger Primus^{TM} reading showed an overestimation of 4.3 ± 5.4 ml representing 7.6 ± 6.4 % (Fig. 1). When using desflurane, the effective VA consumption resulted in 66.4 ± 25.7 ml (mean and SD), while the Primus reading showed an underestimation of −3.5 ± 6.3 ml representing −6.2 ± 9.1 % (Fig. 2). Nine from ten pairs of measurements for sevoflurane were located in-between ±1.96 SD (90 %), while for desflurane all pairs of measurements were inside of ±1.96 SD (100 %). The linear correlations between the predicted and measured consumption values resulted for sevoflurane with an $R^2 = 0.997$ and for desflurane with an $R^2 = 0.947$.

In Table 1 the used average settings for FGF and vol% on the vaporizer are displayed for both evaluated agents. Additionally, the VA consumption results, as well as the average time duration of the analysed anesthesias and the final expenditure of liquid VA are listed (Table 1). The indicated VA costs over time as well as the absolute VA costs were calculated according recent market prices in Switzerland from October 2013.

4 Discussion

According to the user manual, the Draeger Primus^{TM} calculates VA consumption on a case by case basis.

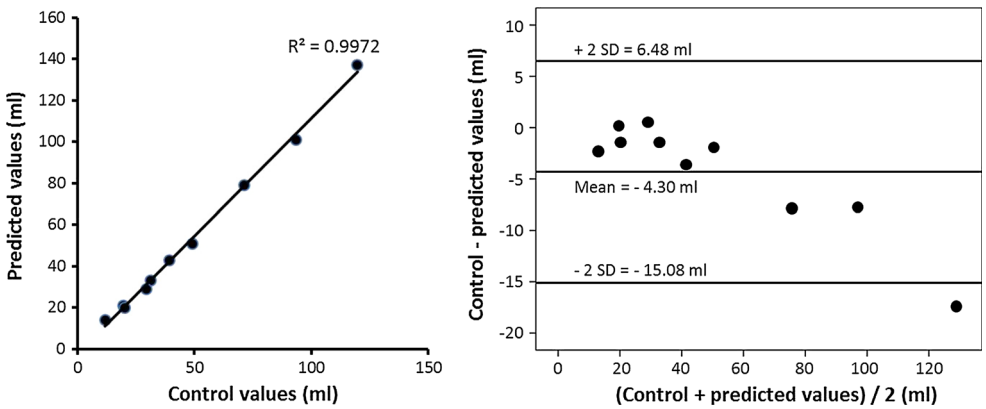

Fig. 1 Linear correlation and Bland/Altman analysis of pairs of measurements comparing the displayed (predicted) vs. control (measured) values from ten sevoflurane anesthesias. The displayed values show a systematic overestimation (positive bias) by 7.6 %

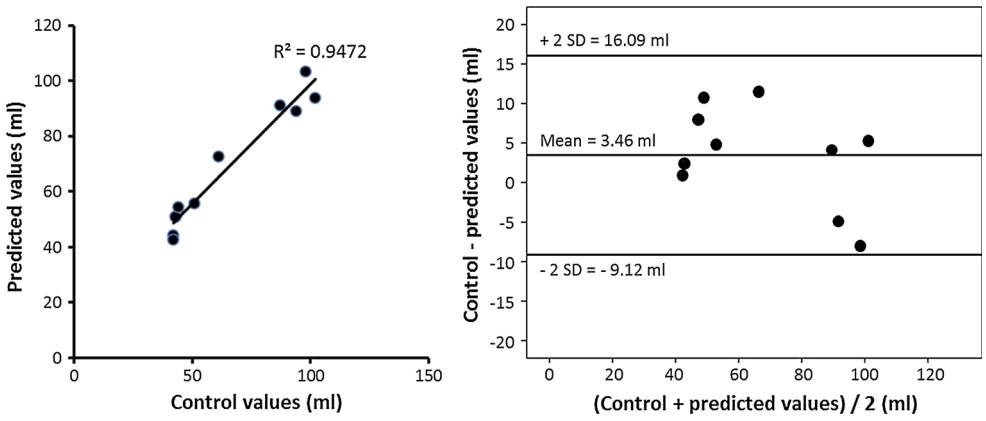

Fig. 2 Linear correlation and Bland/Altman analysis of pairs of measurements comparing the displayed (predicted) vs. control (measured) values from ten desflurane anesthesias. The displayed values show a systematic underestimation (negative bias) by −6.2 %

Table 1 Synopsis of results: overview of delivery settings, duration and consumption for sevoflurane and desflurane (n = 20; mean ± SD)

	Sevoflurane n = 10	Desflurane n = 10
Predicted VA consumption according the Draeger Primus™ display (ml)	52.8 ± 40.5	66.4 ± 25.7
Measured VA consumption = control (ml)	48.5 ± 35.5	69.9 ± 22.9
Difference to control (ml)	4.3 ± 5.4	−3.5 ± 6.3
Difference to control (%)	7.6 ± 6.4	−6.2 ± 9.1
Average VA concentration setting at the vaporizer (Vol %)	2.1 ± 0.3	6.8 ± 1.7
Average fresh gas flow (l/min)	2.1 ± 0.8	1.0 ± 0.3
VA delivery duration (min)	217 ± 219	187 ± 66
VA delivery over time (ml/h)	15.7 ± 5.6	22.1 ± 4.8
VA costs (EUR)	44.46 ± 32.23	34.62 ± 11.32
VA costs over time (EUR/h)	14.21 ± 5.04	10.90 ± 2.40

VA volatile agent

When ending anesthesia and the ventilator is set to "standby" mode, the logbook presents the amount of delivered VA in milliliters. This parameter is calculated by an inbuilt undisclosed proprietary method [10]. The found overestimation of sevoflurane consumption averaged to 7.6 %, and the underestimation of desflurane consumption resulted in −6.2 ± 9.1 %. In contrast to oxygen and carbon dioxide, the VA sensors are not subjected to automatic calibrations during each use, and therefore may present by time a certain drift.

We consider the differences between predicted and measured VA consumption data as tolerable from clinical point of view. This is in accordance with similar to findings by Lockwood et al., who found their predicted values to lie within the 95 % confidence intervals of the measured data [11]. When translating these average differences to resulting costs, we may have an error per case of about 3.94 EUR too much for sevoflurane and 1.75 EUR too low for desflurane, which should not pose serious objections against the reliability of the displayed values. However, due to the metrological background of these differences, one may not take the herein reported biases as constants. Instead, for each VA and anesthesia workplace the mean bias has to be assessed by adopting the gold standard of the weighing method and then the found bias can be subtracted from the displayed readings.

The average FGF when using desflurane is usually set lower then with sevoflurane. This may have two reasons: one is a widespread assumption that desflurane is more expensive than sevoflurane, which is true when the comparison is done with equipotent dosing thus increasing the users' readiness to limit the FGF. This may be an explanation why in our case the average FGF with desflurane was with 1.0 ± 0.3 l/min less than half than with sevoflurane at 2.1 ± 0.8 l/min. These figures simply represent the usual average settings used by our anesthesia personnel, unaffected by this purely observational investigation.

From our results we can conclude that the displayed VA consumption calculations for sevoflurane and desflurane are reasonably useful for estimation of the pharmacoeconomic impact of VA delivery during inhalational anesthesia in a routine clinical setting.

Conflict of interest The authors declare that there is no financial interest involved.

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