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**How Closed is Automated Closed-Circuit Anesthesia?**

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## Introduction

True closed-circuit anesthesia (CCA) should reduce agent and carrier gas usage to just those amounts needed to prime the anesthesia circuit and the functional residual capacity and to replace the amounts taken up by the patient or lost via leaks. Gases sampled by the gas analyzer are redirected to the anesthesia circuit. It was previously shown that the Zeus® (Lübeck, Dräger, Germany), the only commercially available CCA machine, failed to provide true CCA conditions. This was attributed to suboptimal algorithms that steer fresh gas flows (FGF) and agent usage [1]. We now examined how closed the Zeus works with the latest software version SW 4.03 MK 04672-00.

## Methods and Materials

IRB approval and informed consent were obtained. In 13 ASA I-III patients presenting for abdominal or breast surgery, the Zeus® was used in target control mode to administer desflurane in O<sub>2</sub>/air with a target inspired O<sub>2</sub> (FIO<sub>2</sub>) and end-expired desflurane % (FAdes) of 50 and 6.0%, respectively. The desflurane cassette was weighed before and after 1 hour with a high precision weighing scale (Mettler-Toledo, Columbus, OH). A correction was applied for the loss of a small amount of desflurane that results from removing and replacing the cassette, determined to be 790 ± 100 mg by removing and replacing the cassette 10 times. To determine how closed the system worked, a 5L balloon was attached to collect the gases exiting from the exhaust. After 1 hour, the volume contained in the balloon was measured with a 250 mL glass syringe, and the contents analyzed by the Zeus's gas analyzer. From volume and content, the amount of desflurane wasted via the exhaust valve was determined. In addition, the O<sub>2</sub> and air FGF were downloaded in a spreadsheet every 10 min. Data are presented as average ± standard deviation.

## Results

Age, height, and weight were 62 ± 13 years, 169 ± 10 cm, and 80 ± 13 kg, respectively. FAdes was 6% within 4 min in all but 1 patient (6.5 min). Median FGF was 150-170 mL/min; FGF ranged from 100 to 200 mL/min (Figure 1). After 30 min, there were 5 short lived high FGF spikes when FIO<sub>2</sub> decreased below 50%. The amount of liquid desflurane used was 14.2 ± 2.2 mL, of which 0.13 ± 0.19 mL had exited via the exhaust valve.

## Discussion

The latest software version SW 4.03 MK 04672-00 has succeeded in making the Zeus work in CCA mode such that under the conditions specified in this study, it is unlikely that any further meaningful reduction in agent waste can be made.

## References.

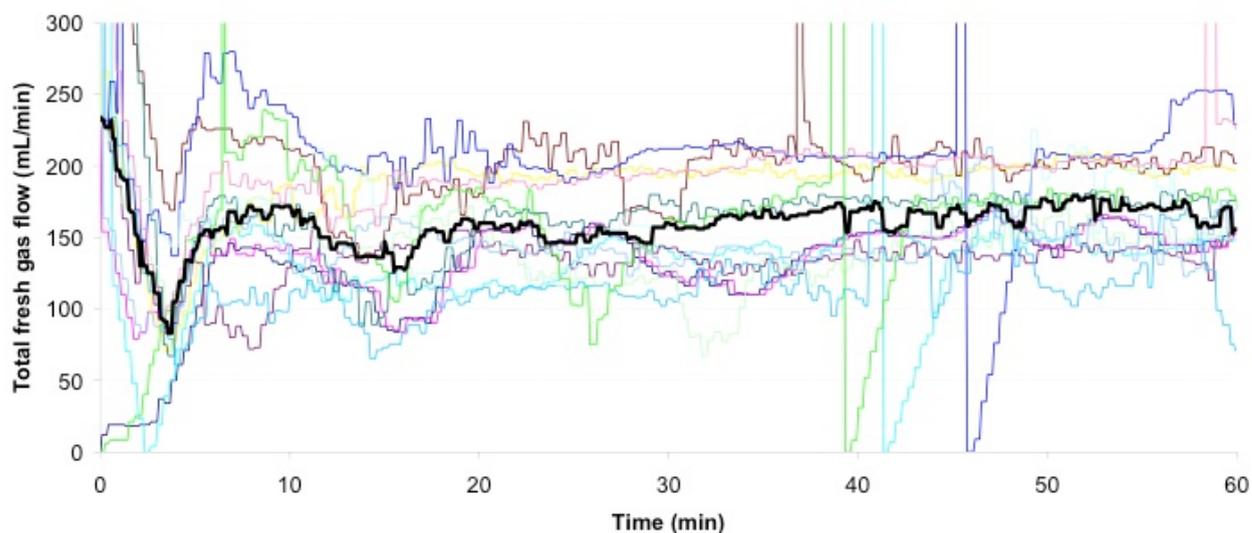
BMC anesthesiology. 2008;8:4.

**Figure 1**

Patient number	Difference in vaporizer weight before/after anesthetic (g)	Amount lost from vaporizer by removing cassette (g)	Amount vaporized during anesthetic (g)	Amount used during anesthetic (mL liquid)	Total gas volume captured in balloon at exhaust (mL)	Desflurane % in balloon	mL desflurane vapor in balloon	mL liquid desflurane in balloon
1	19.42	0.81	18.61	12.70	0	0	0	0.000
2	21.53	0.81	20.72	14.14	90	0.8	0.72	0.003
3	22.93	0.81	22.12	15.10	160	0	0	0.000
4	23.27	0.81	22.46	15.33	3720	1	37.2	0.178
5	16.13	0.81	15.32	10.46	170	0.3	0.51	0.002
6	28.91	0.81	28.1	19.18	2380	2.8	66.64	0.318
7	23.9	0.81	23.09	15.76	610	0.5	3.05	0.015
8	21.68	0.81	20.87	14.24	4120	2.7	111.24	0.531
9	17.52	0.81	16.71	11.41	400	0.8	3.2	0.015
10	19.86	0.81	19.05	13.00	450	0.5	2.25	0.011
11	20.4	0.81	19.59	13.37	560	0.5	2.8	0.013
12	22.06	0.81	21.25	14.50	2340	4	93.6	0.447
13	23.37	0.81	22.56	15.40	1000	3.2	32	0.153
Av	21.61		20.80	14.20	1231	1.43	29.43	0.130
SD	3.19		3.19	2.18	1425	1.35	40.02	0.187

Table 1. The amount of desflurane lost via the exhaust (outer right column) constitutes only a very small fraction of the amount of desflurane vaporized during the anesthetic (fifth column from the left). See text for details on other columns.

**Figure 2**



**Figure 1. Total fresh gas flow in the individual patients. Black line = median**