In Vivo Performance of a Membrane CO_2 Filter during Target-Controlled Closed-Circuit Anesthesia

Co-Authors: S.A. Eerlings, M.D.[1,2], M. K. Bashraheel, M.D.[1,2,3], R. Carette, M.D.[1,2], G. Vandenbroucke, M.D.[1], A. M. De Wolf, M.D. [4], J. F.A. Hendrickx, M.D., Ph.D.[1]

Depts. of Anesthesiology of the OLV Hospital, Aalst, Belgium[1]; KU Leuven, Leuven, Belgium[2]; King Abdulaziz University,
Jeddah, Kingdom of Saudi Arabia[3]; and Feinberg School of Medicine, Northwestern University, Chicago, IL, USA[4]

Introduction: Currently used soda lime based CO_2 absorbents are safe [1] but not ideal for reasons of ecology (production and disposal), ergonomics (need to refill or replace), economy (discarded before used to full potential), and dust accumulation in sensitive machine parts. These issues are absent with the Memsorb™ (DMF Medical, Halifax, NS, Canada), a new device for gas-to-gas exchange and separation that uses technology similar to oxygenator membranes for cardiopulmonary bypass machines. A sweep gas flows through the lumen of semipermeable hollow fibers and adds or removes gases from the circle breathing system (whose gases pass in between the fibers) according to the prevailing partial pressure gradients across the fiber wall and the relative permeability of the gases. Because the permeability of CO_2 is higher than that of inhaled agents, the CO_2 transport rate and thus washout should be relatively higher than that of inhaled anesthetics. We tested the performance of the device during target-controlled closed-circuit anesthesia (TCCCA) with desflurane in O_2/air with the Zeus IE (Dräger, Lübeck, Germany).

Materials and Methods: After obtaining IRB approval and written informed consent, 8 ASA PS I-III patients undergoing robotic prostatectomy were enrolled. After induction of anesthesia and intubation of the trachea, TCCCA with the Zeus IE was used with the following settings: target inspired O_2 (F_IO_2) 39% in O_2/air; target end-expired (F_A) desflurane 5.0%; controlled mechanical ventilation, adjusted to F_ACO_2 4.5-6.0%; and 5 cmH_2O PEEP. An O_2/air blender (Scanatron Technics, Affoltern-am-Albis, Switzerland) delivered the sweep gas (40% O_2) to the inlet of the Memsorb™ canister. Sweep O_2% was set 1% above target F_IO_2. The sweep flow was titrated to keep $F_ICO_2 \leq 0.8\%$. RUGloop (DEMED, Temse, Belgium) collected the following data: F_IO_2, $F_A$desflurane, F_ICO_2, F_ACO_2, minute ventilation; O_2 and air FGF; sweep flow; and cumulative desflurane usage (Vdes). Only data of the first 2h are reported. Data are displayed as average (standard deviation) unless indicated otherwise. Vdes was compared (for $F_A$desflurane = 5.0%) with historical data of the Zeus IE used with soda lime (Dräger 800+) [2] and during conventional CCA [3].

Results: see Figure 1

Age (years), height (cm) and weight (kg) were 67(8), 173(5) and 78(10), respectively. A 14-25 L/min sweep flow maintained $F_ICO_2 \leq 0.8\%$ and $F_ACO_2 \leq 6.0\%$ combined with a minute ventilation of 5-7.6 L/min while a CO_2 pneumoperitoneum (CO_2PP) was applied. $F_A$desflurane and F_IO_2 targets were maintained within a very narrow range. Total FGF dropped to zero within 1.5-6 min, occasionally briefly increasing upon initially applying the CO_2PP, only to remain zero thereafter most of the time. Vdes was higher than during identical conditions with a soda lime absorbent with the Zeus IE during TCCCA [2] and during conventional CCA [3].

Discussion: During TCCCA, Memsorb™ removes CO_2 well under conditions of high CO_2 elimination (adult patient with prolonged CO_2PP). The small increase in F_ICO_2 is inconsequential because its effect on F_ACO_2 can easily be overcome by a small increase of minute ventilation. The amount of O_2 transferred from the Memsorb™ to the circle breathing system sufficed to cover patient O_2 consumption. In order to keep FGF low during TCCCA, the target F_IO_2 and the F_IO_2 in the sweep gas should be very similar in the target F_IO_2 mode. Liquid Vdes in the Memsorb™ group was 2.05 mL/h per 1% $F_A$desflurane higher than during historical CCA data, making Vdes with Memsorb™ during TCCCA after 1h equivalent to Vdes with a FGF slightly above 1L/min when a soda lime absorber is used [4]. The exact routes of carrier gas and agent losses need to be further defined.

References: [1] APSF Newsletter 122,210;Vol32, 3,February 2018 [2] Acta Anaesthesiol Belg 2009;60:35-7 [3] Anesth Analg 2003;96:356-62 [4] The Pharmacokinetics of Inhaled Anesthetics and Carrier Gases, Thesis, p.112, accessible at https://navat.org/downloads-2/

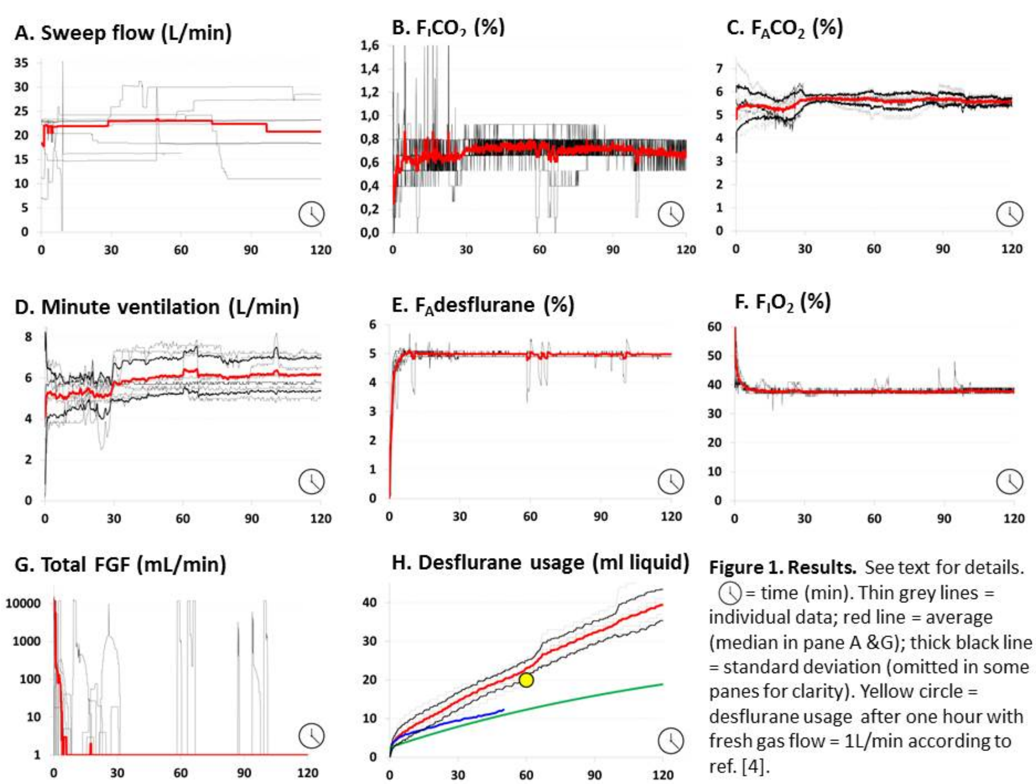

Figure 1. Results. See text for details. (clock icon) = time (min). Thin grey lines = individual data; red line = average (median in pane A &G); thick black line = standard deviation (omitted in some panes for clarity). Yellow circle = desflurane usage after one hour with fresh gas flow = 1L/min according to ref. [4].