Effects of oxygen concentrators on ventilator oxygen delivery

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To the Editor,

As previously detailed,^{1,2} there are more than 50 hospitals in Canada that utilize oxygen concentrators (OCs) as their primary source of oxygen supply. Furthermore, on evaluating OC technology as a primary oxygen source, the US Food and Drug Administration ruled in 2004 that hospital grade OCs were classed as a substantial equivalence to United States Pharmacopeia (USP) oxygen 93^A (O₂ 93) and therefore subject to compliance of all of the same federal statutes and regulations. *Guidelines to the Practice of Anesthesia*³ provides consideration for the use of OCs with an anesthetic machine and includes topics such as anesthesiologists' awareness of the OC, monitoring circuit oxygen concentration, machine calibration with O₂ 99, and understanding the potential for argon accumulation at fresh gas flows < 1 L·min⁻¹. The increasing use of anesthesia workstations and computer-controlled patient ventilators prompted us to examine the circuit oxygen delivery of these systems with an OC as a primary source of supply.

As a benchmark study, we tested the following two anesthetic machines: the Aisys CarestationTM (GE Healthcare, Madison, WI, USA) and the Narcomed 2B (North American Drager, Telford, PA, USA). In spite of its age, we included the Narcomed 2B as it still functions in some local outpatient facilities. We also tested the following two patient ventilators: the Puritan Bennett model 840TM (PB 840) (Nellcor Puritan Bennett, Boulder, CO, USA) and the LTV® 1000 (Pulmonetics, Minneapolis, MN, USA). Oxygen 93 was obtained by pre-filling E-size oxygen cylinders with an OC filling station, Chad Total O₂

Delivery SystemTM (CHAD Therapeutics Inc., Chatsworth, CA, USA), and then the O₂ 93 was supplied to each system via a high pressure regulator. Oxygen 99 and medical air were supplied via a hospital wall outlet. Each system was tested for circuit oxygen levels at decreasing increments in the same sequence, O₂ 99 followed by repeat observations with O₂ 93. In addition to each system's built-in oxygen sensor (except for the LTV 1000 that utilizes a mechanical blender), oxygen was also monitored with an in-line monitor, Mallinckrodt PTS 2000TM (Nellcor Puritan Bennett, Boulder, CO, USA). A Smart LungTM 600 test lung (IMT Medical BuchoSG, Switzerland) was utilized. The standardized ventilator parameters were tidal volume 400 mL and a frequency of ten cycles per minute. Oxygen concentration measurements were made at machine settings of 30–100% oxygen in increments of 10%. At each increment, measurements were recorded only after attaining five minutes of steady-state values on the PTS 2000. Machine calibration, both manual and automatic, were from the hospital primary supply (O₂ 99) prior to each study.

The aim of this study was to observe any differences between the inspired oxygen settings of the ventilator or anesthetic machine and the actual circuit oxygen levels when using two different oxygen supplies (O₂ 99 vs O₂ 93). Secondly, we were interested in the general ventilator and alarm function with the presence of O₂ 93 as a primary source of supply. At each oxygen setting (30–100%, *n* = 8), the PTS 2000 recording was subtracted from the percent oxygen setting on the test machine. A negative value indicated that the machine setting overestimated the actual oxygen present. The mean differences between O₂

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^A The United States Pharmacopeia. The National Formulary. Rockville, MD, United States Pharmacopeia Convention Inc, 1998: IV/360.

Table 1 Inspired oxygen settings vs actual values

Machine	O ₂ 99*	SD	O ₂ 93*	SD	Student's <i>t</i> test
Drager 2B	-1.6	0.9	-1.6	1.1	$P = 0.450$
Aisys Carestation	-0.3	0.4	-0.5	0.4	$P = 0.237$
PB 840	-0.7	0.9	-1.7	0.9	$P = 0.322$
LTV 1000 [†]	-0.9	1.8	-3.1	2.8	$P = 0.004$

SD = standard deviation. * Difference between actual oxygen percent (PTS 2000) minus machine setting (mean values, $n = 8$); a negative value indicates a measured oxygen less than the machine setting. [†] LTV 1000 inspired oxygen setting (not an actual measured value). An oxygen blender meters oxygen flow by measuring oxygen inlet pressure

99 and O₂ 93 at each setting were compared for each machine and analysed by Student's *t* test.

Table 1 is a summary of the observed mean differences. Observations at the sequential oxygen settings were pooled, as each machine was tested in the same manner. Additionally, we noted that the contribution of O₂ 93 was more evident at higher F_IO₂s. The mean difference at a 30% oxygen setting was $0.1\% \pm 0.47$, while the mean difference at a 100% oxygen setting was 2.8 ± 1.9 ($P = 0.03$). In general, the machine settings slightly overestimated the actual circuit oxygen concentration, and, except for the LTV 1000, these were not statistically significant changes. All of the ventilators functioned within specification for either oxygen supply. No alarm functions were triggered by the use of USP O₂ 93 during any of the test runs. For the systems that provided in-line circuit oxygen monitoring, Aisys Carestation, Narcomed 2B, and PB 840, there was an insignificant difference between selected and actual oxygen concentration for either source of oxygen supply.

Although of minimal clinical significance, the LTV 1000 demonstrated $> 3\%$ negative difference between the actual measured circuit oxygen concentration and the ventilator setting. It would be prudent to monitor in-line

Table 2 Oxygen sensor performance specifications*

Machine	Oxygen Sensor [†]	Accuracy	Notes
PB 840	EnviteC – Wismar	$\pm 1.0\%$	
Aisys CareStation	Datex Ohmeda	$\pm 2.5\%$	FGF [‡] $> 1 \text{ L} \cdot \text{min}^{-1}$
Narcomed 2B	MaxTex TM (MAX 11)	$\pm 1.0\%$	FGF [‡] $> 1 \text{ L} \cdot \text{min}^{-1}$ 5 min equilibration
PTS 2000		$\pm 2.0\%$	Annual factory calibration

* Product manufacturers' information appears in the text. [†] All oxygen sensors specified calibration with 100% oxygen. Sensor components of a different model name than the actual medical device are listed here. [‡] Total fresh gas flow

oxygen concentration on all ventilators regardless of their source of oxygen supply.

The differences observed in this study fall within manufacturer supplied oxygen sensor specifications (Table 2).

In conclusion, we did not observe any adverse ventilator function utilizing either O₂ 93 or O₂ 99. Furthermore, there were no clinically significant differences between machine settings and actual measured oxygen concentration when using an OC as a primary source of supply.

Competing interests None declared.

References

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