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Effect of humidity in the circuit on the CO_2 absorption capacity of Amsorb and Sodasorb II

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Amsorb (Armstrong Medical, Coleraine, Northern Ireland), a new CO_2 absorbent that contains neither KOH nor NaOH, has been reported to demonstrate less reactivity with sevoflurane and desflurane than standard soda lime [1,2]. The reported CO_2 absorption capacity of Amsorb ranges from 40% to 90% of that of soda lime [1–6], but the designs of these previous studies have differed. Humidity in the circuit is one of the factors that might affect the CO_2 absorption capacity of absorbents. We previously reported that the CO_2 absorption capacity of soda lime was decreased by the addition of water [7,8], but recently Stabernack et al. [6] reported that the CO_2 absorption capacity of Amsorb was not affected by humidification. However, the values of 5 and 30 mmHg CO_2 that were used as the endpoints to define the CO_2 level at which CO_2 breakthrough occurs were different from those used in previous studies. The effect of humidity on the CO_2 absorption capacity of absorbents at each endpoint is of importance. The purpose of this study was to investigate the CO_2 absorption capacity of Amsorb and standard soda lime (Sodasorb II, W.R. Grace, Lexington, MA, USA) under normal and moisturized conditions. We studied the time course of CO_2 breakthrough under both conditions.

The Aestiva 3000 anesthesia system (Ohmeda, Madison, WI, USA) was used throughout this study. Amsorb or Sodasorb II was used as the absorbent, and each absorbent group was divided into two subgroups corresponding to normal and moisturized conditions. A 3-l latex bag connected to the Y-piece of the circuit acted as an artificial lung, and the CO_2 was delivered at a flow rate of $200\,ml{\cdot}min^{-1}$ into the distal portion of the bag. The artificial lung was ventilated at a rate of $10{\cdot}min^{-1}$ with a measured expired tidal volume of 500 ml. The inspiratory–expiratory ratio was set at 1:2. The anesthesia system was flushed for 30 min with 100% oxygen at a flow rate of $6\,l{\cdot}min^{-1}$ in the absence of the CO_2 absorbent. After this preparation period, 500 g of fresh absorbent was placed into the upper canister, and glass balls were placed in the lower canister as filler. The oxygen flow rate was reduced to $1\,l{\cdot}min^{-1}$, and the tidal volume setting was readjusted to maintain a volume of 500 ml. In the moisturized group, a heated respiratory humidifier (MR418 Humidification System, Fisher and Paykel, Auckland, New Zealand) was placed into the inspiratory limb, and the temperature of the humidifier was maintained at 37°C. Gas samples were obtained from the inspiratory limb just beyond the inspiratory valve. The CO_2 analysis was performed with a Capnomac (Datex, Helsinki, Finland). Each experiment was repeated three times for each group, and the studies were conducted in random order. The measured values are expressed as means ± SD. The total time of use (minutes), the time until each absorbent reached exhaustion, as defined by the occurrence of CO_2 rebreathing (1–5 mmHg), was compared between the groups by the Mann-Whitney U-test. A P value less than 0.05 was considered to indicate statistical significance.

The total time of use of the CO_2 absorbents is shown in Fig. 1. Humidification reduced the total time of use of Sodasorb II, but not that of Amsorb. Under normal conditions, the CO_2 absorption capacity of Amsorb was 55.7%, 73.5%, 75.5%, 78.1%, and 78.9% that of Sodasorb II at 1, 2, 3, 4, and 5 mmHg, respectively. Under moisturized conditions, the CO_2 absorption capacity of Amsorb was 66.6%, 80.6%, 84.8%, 87.3%, and 88.5% that of Sodasorb II at 1, 2, 3, 4, and 5 mmHg, respectively.

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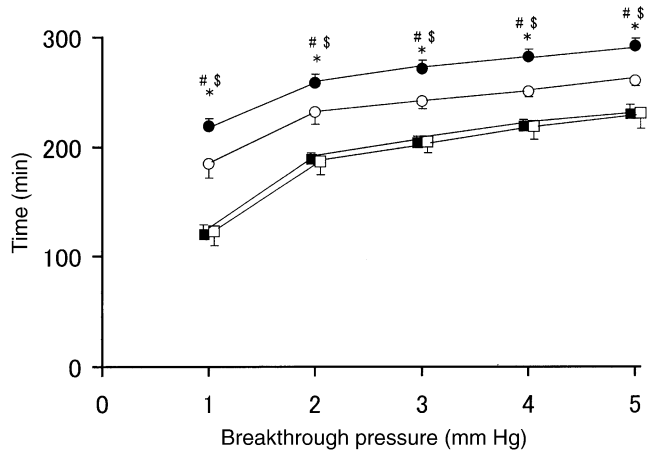

Fig. 1. Total time of use until each absorbent reached exhaustion. The total times until each absorbent reached endpoints (1–5 mmHg CO_2 breakthrough pressure) are expressed as means (SD). *Filled squares*, normal Amsorb; *open squares*, moisturized Amsorb; *filled circles*, normal Sodasorb II; *open circles*, moisturized Sodasorb II. $^{*}P < 0.05$, moisturized Sodasorb II vs normal Sodasorb II at the same endpoint. $^{\#}P < 0.05$, normal Amsorb vs normal Sodasorb II at the same endpoint. $^{\$}P < 0.05$, moisturized Amsorb vs moisturized Sodasorb II at the same endpoint

The CO_2 absorption capacity of Amsorb was less than that of Sodasorb II under both conditions and also at five different endpoints. This difference in CO_2 absorption capacity was smaller under moisturized conditions than normal conditions. Moreover, this difference was smaller at a breakthrough pressure of 5 mmHg than at a breakthrough pressure of 1 mmHg under both moisturized and normal conditions.

We previously reported that the CO_2 absorption capacity of Sodasorb II was decreased by adding water [7,8]. However, Amsorb was less affected by moisture than Sodasorb II at each data point. This result is consistent with that of Stabernack et al. [6] (at 5 and 30 mmHg breakthrough pressure). The initial moisture content of Amsorb is 14.1%, which is similar to that of Sodasorb II. The overall chemical process of CO_2 absorption is the same for both Amsorb and Sodasorb II (i.e., $CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$). However, the incorporation of calcium chloride as a humectant allows the calcium hydroxide to remain damp at all times, without the influence of the hygroscopic properties conferred by the presence of sodium hydroxide or potassium hydroxide in standard soda limes [1]. The difference in the humectant in each absorbent might contribute to the difference in the effect of adding water to each absorbent.

Our results also showed a difference in the time course of CO_2 rebreathing in the Amsorb group and the Sodasorb II group. CO_2 rebreathing started early with Amsorb; however, the point at which the CO_2 concentration reached 5 mmHg was late. The absence of strong bases such as NaOH or KOH might also explain this difference. As a mechanism of CO_2 absorption, strong bases contribute to a fast reaction that results in the formation of calcium carbonate. Some CO_2 may directly react with $Ca(OH)_2$; however, this reaction is much slower. Because Amsorb does not contain strong bases, the magnitude of the fast trap reaction might not be high.

In conclusion, the CO_2 absorption capacity of Amsorb was affected less by moisture than was that of Sodasorb II. The CO_2 absorption capacity of Amsorb was smaller than that of Sodasorb II. This difference was smaller under moisturized conditions than under normal conditions. Moreover, this difference was smaller at a breakthrough pressure of 5 mmHg than at a breakthrough pressure of 1 mmHg under both moisturized and normal conditions.

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