Failure to Detect CO$_2$-absorbent Exhaustion: Seeing and Believing

Diane Pond, M.D.,* Richard A. Jaffe, M.D., Ph.D.,† John G. Brock-Utne, M.D., Ph.D.‡

REBREATTHING during general anesthesia is defined as an increased inspired pressure of carbon dioxide above 2 mmHg.\(^1\) We report a case of rebreathing, with an unusual capnographic pattern caused by undetected exhaustion of the carbon dioxide absorbent.

**Case Report**

A 41-yr-old, 55-kg woman presented for nasal septoplasty, bilateral ethmoidectomies, and nasal scar revision. The patient's medical history was significant for anxiety disorder and prior cocaine abuse. Medication included lorazepam and amoxycillin. General anesthesia was induced with 425 mg thiotopental and 150 \text{mcg} fentanyl. The patient received 120 \text{mg} succinylcholine to facilitate tracheal intubation. Placement of the endotracheal tube was confirmed by auscultation and the presence of end-tidal carbon dioxide on the capnograph. Positive pressure ventilation was then instituted using the ventilator on our anesthesia machine (Narkomed 2B; Dräger Medical, Inc., Telford, PA). The initial end-tidal carbon dioxide value (40 mmHg) and the capnogram tracing were within normal limits, with an inspiratory carbon dioxide of zero. Fresh gas flow was increased to 2 L/min (2:1, N$_2$:O$_2$). Approximately 20 min into the procedure, the inspired end-tidal carbon dioxide value increased and the capnogram was noted to be abnormal (fig. 1). Shortly thereafter, the inspired carbon dioxide alarm sounded.

The carbon dioxide-absorbent canisters with soda lime were inspected visually. Both the upper and the lower canisters were not apparent, and the fresh gas flows were increased. The patient's lungs were manually ventilated while a machine exchange was performed. The remainder of the procedure was uneventful, and the patient was discharged the following day.

**References**

The first machine was disassembled, and the source of the problem was immediately identified as exhausted carbon dioxide absorbent in both compartments—the absorbent was uniformly and completely exhausted. The violet-blue dye indicator in the lower compartment had been filtered out by the yellow discoloration of the plastic canister, producing the appearance of fresh white carbon dioxide absorbent in that canister.

Discussion

Absorption of carbon dioxide by absorbent granules and fresh gas retrograde flow during the expiratory phase are the two methods of eliminating carbon dioxide from an anesthetic circle breathing system. Carbon dioxide absorption is achieved by a chemical reaction with water and alkaline hydroxides in absorbent granules. The reaction results in the formation of carbonic acid. Accumulation of carbonic acid results in the lowering of the pH of the granules and changes the color of the ethyl-violet pH-sensitive dye to violet-blue. The color change is readily apparent at visual inspection; however, nearly depleted soda lime can regain its white color when not used for many hours. This color reversal is the result of subsurface regeneration of active hydroxides at the granular surfaces. If used again, the soda lime quickly reverts to the violet-blue color.

In this case, the color change was not detected because of the yellowing of one of the two transparent plastic absorbent canisters. The yellowed plastic filtered out the blue-violet wavelengths, giving the granules the appearance of the original white color, especially when compared with the blue granule color in the smoky clear plastic upper compartment. It was not until the canisters were opened that we discovered the intensely purple color of the completely and uniformly exhausted lower-canister absorbent. The original plastic canisters for the absorbers were made of acrylic, but because they could not be autoclaved, they were replaced in approximately 1984 with a yellowish polysulphone compound (part #410-5852) that could be autoclaved. In 1992, North American Dräger Medical, Inc. released a smoky clear polysulphone canister (part #410-5852). The yellow-tinted and smoky clear canisters manufactured by Dräger Medical Inc. After this case, we replaced all yellow canisters with the smoky-clear variety. Dräger Medical has been informed of our observation, and concurs with our solution. In our case, we think that a technician “cannibalized” a yellow-tinted canister from an older machine for use on the newer machine. By eliminating the older canisters, we think that this potential disaster will not occur again.

The expected capnogram tracing resulting from exhausted carbon dioxide absorbent is seen in figure 3. Our tracing had an additional second peak that delayed diagnosis of the problem. We propose the following explanation for the unusual second peak. At inspiration
If the problem is an incompetent expiratory valve, increasing the fresh gas flow minimally affects the amount of $P_{\text{CO}_2}$.

If the absorbent is not properly packed in the canister, channeling of gases may occur. Channeled gases bypass the bulk of the absorbent, resulting in carbon dioxide rebreathing. In our case, the absorbent in both canisters was uniformly and completely exhausted, which is inconsistent with channeling.

In conclusion, if an abnormal capnogram waveform is seen with increased amount of $P_{\text{CO}_2}$, that decreases when the fresh gas flow is increased, one should consider opening the absorber compartments and inspecting the soda lime. One should not rely on the color of the absorbent as seen through the canister. You cannot always believe what you see.

References

1. Pond D, Jaffe RA, Brock-Utne JG: Failure to detect CO$_2$ absorbent exhaustion: Seeing and believing. ANESTHESIOLOGY 2000; 92:000-0

In Reply—Draeger Medical Inc. recommends establishing a routine schedule with a sufficient safety margin for replacing absorbent. Reliance on color change alone is not a foolproof method of assuring that carbon dioxide absorbents have not been depleted because of the possibility of channeling or color reversion, as mentioned in the case report of Pond et al.

One purpose of the tandem configuration of the canisters in the Narkomed absorber system is to allow the upstream canister to be refilled when it becomes exhausted. The downstream canister that is only partially exhausted can then be moved upstream, and the refilled canister can be placed in the downstream position. Use of this rotation technique ensures that fresh absorbent is always present.

If either of the above practices had been followed, we think that the problem reported by Pond et al. would have been avoided. Additionally, our experience has been that the color change can be seen in both varieties of canisters described by the authors. Placing both varieties in the same absorber system may have caused confusion regarding the color of the absorbent.

James J. Brennan
Director, Regulatory Affairs
Draeger Medical, Inc.
Telford, Pennsylvania

References

1. Pond D, Jaffe RA, Brock-Utne JG: Failure to detect CO$_2$ absorbent exhaustion: Seeing and believing. ANESTHESIOLOGY 2000; 92:000-0