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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.‡*

REBREATHING 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 loratidine and amoxicillin. General anesthesia was induced with 425 mg thiopental and 150 μg fentanyl. The patient received 120 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 3 l/min (2:1, N_2O: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 unduly warm, and no temperature difference was noted between them. Carbon dioxide absorbent in the upper compartment had a bluish cast, suggesting exhaustion of the carbon dioxide-absorbent granules. No color change was seen in the lower compartment (fig. 2). Because there was a dramatic color difference between the upper and lower canisters, the possibility that the carbon dioxide absorbent was exhausted in both canisters seemed unlikely. Other causes of the abnormal tracing were sought (*e.g.*, valve malfunction).

The expiratory and inspiratory valves were inspected and changed, without improvement in the capnogram. Rebreathing continued to be apparent, and the fresh gas flows were increased. The patient's lungs were manually ventilated while a machine exchange was performed. Although there was a decrease in carbon dioxide rebreathing with an increased fresh gas flow, we decided that changing the anesthetic machine would be the safest course of action because we were unsure as to the origin of the inspired carbon dioxide. The patient remained stable throughout this period, with normal blood pressure and a pulse oximetry reading of 100%. The capnogram was normal after the machine exchange. The remainder of the procedure was uneventful, and the patient was discharged the following day.

* Anesthesia Resident.

† Associate Professor of Anesthesia.

‡ Professor of Anesthesia.

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Address reprint requests to Dr. Brock-Utne: Department of Anesthesia, Stanford University Medical Center, Room 3580, 300 Pasteur Drive, Stanford, California 94305-5640. Address electronic mail to: brockutn@leland.stanford.edu

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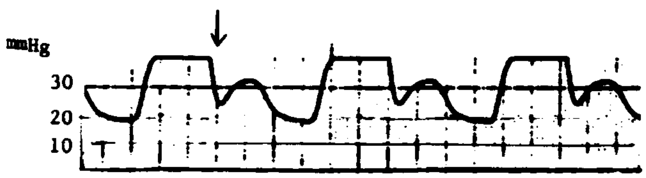

Fig. 1. Capnogram tracing approximately 20 min into the procedure. Note the dramatic increase in inspired end-tidal CO_2.

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.[2] This color reversion 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 used in this case were 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.

Fig. 2. Although this black and white photograph fails to demonstrate the dramatic color difference between the upper and lower compartments, carbon dioxide absorbent in the upper compartment is blue, suggesting exhaustion of the carbon dioxide–absorbent granules. No color change is seen in the bottom compartment because of the yellow tinting of the transparent plastic absorbent canister. The yellow plastic gives the granules a white appearance.

The expected capnogram tracing resulting from exhausted carbon dioxide absorbent is seen in figure 3.[1] 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

Fig. 3. Computer-assisted capnogram analysis showing the expected capnogram tracing resulting from exhausted carbon dioxide absorbent. Reprinted with permission from from van Genderingen *et al.*[1]

(fig. 1, arrow), gas enters the inspired limb from fresh gas flow from the anesthesia machine and the bottom of the canister. The dip in the trace seen at inspiration is most likely caused by dilution of the carbon dioxide with the fresh gas flow. The change in shape of the capnogram in these cases is also dependent on the tidal volume and the volume of the inspiratory limb.

The capnogram waveform seen in figure 1 could also have been caused by an faulty expiratory valve. The faulty valve and an exhausted carbon dioxide absorbent cause an increase in $P_{I_{CO_2}}$. When attempting to distinguish the cause of carbon dioxide rebreathing, it is recommended that one rapidly increase (*i.e.*, double or triple) the total fresh gas flow being delivered into the breathing circuit.[1,3] With an exhausted carbon dioxide absorbent as the cause, the high fresh gas flow rate should decrease the amount of carbon dioxide rebreathing. If this decrease occurs, there is no real danger of opening the absorber compartment during the administration of an anesthetic as long as one is quick and an Ambubag (Ambu Inc., Linthicum, MD) is readily at hand. If the problem is an incompetent expiratory valve, increasing the fresh gas flow will minimally affect the amount of $P_{I_{CO_2}}$.

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 summary, we report a simple case of absorbent exhaustion being masked by the color of a canister. Based on this experience, it is our recommendation that old yellow-tinted canisters (part #410-5854) be replaced with the new polysulphone canisters (also part #410-5854). Under no circumstance should the two types of canisters be used simultaneously on an anesthetic machine.

In conclusion, if an abnormal capnogram wave form is seen with increased amount of $P_{I_{CO_2}}$ 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.

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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.*[1]

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 ican 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

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