DE GRUYTER OPEN

Acta Medica Marisiensis 2015;61(1):4-6 DOI: 10.1515/amma-2015-0023

REVIEW

The CO_2 Absorber Based on LiOH

Zilberman P*

Hadassah University Medical Center, Har Hatzofim Campus, Anesthesia Department, Jerusalem, Israel

Carbon dioxide absorbers have been used in anesthesiology for many years. However, this process is not limited to this field of medicine. Removing carbon dioxide from human environment is used in other areas as well: mining industry, submarines, scuba diving, space travel and many others. The rationale to remove carbon dioxide from confined spaces is that cannot be eliminated otherwise. Anesthesia practitioners are well aware of this component of the circle system, the carbon dioxide absorber. In daily practice the clinician is less concerned with what kind of substance fills the dedicated canister, as this is usually in the care of the maintenance personnel. The appearance of Sevoflurane and Desflurane, with their own chemical characteristics, prompted the clinician to dedicate new attention to these absorbents. The classical substances used for this purpose are different combinations of limes. The practical concern of the anesthesiologist is to notice when the absorbent is consumed and call for its replacement. Still, many other aspects remain: compound A formation with Sevoflurane, carbon monoxide formation with Desflurane and dry absorbent for instance. The latest member of these products in the medical field is the LiOH carbon dioxide absorbent. Although used for many years in the space exploration, its way into the operating room is a rather recent achievement. Special-chemical properties and high absorptive capacity make this new type of absorbent an attractive option for modern anesthesia practice. The article below invites the reader through a short journey on the history of the CO2 absorbents and anesthesia circuits, Lithiumas a chemical element and, finally, to this new type of absorbent.

Keywords: carbon dioxide absorbent, anesthesia circle system, lithium, traditional and proprietary absorbents, absorptive capacity, Apollo 13 story, recycling

Received: 25 December 2014 / Accepted: 15 January 2015

Short history of the carbon dioxide absorbents in anesthesia

The history of carbon dioxide removal from the gases returning to the patient goes back many years. As early as 1850 John Snow (1813-1858) recognized that ether and chloroform were exhaled unchanged with the expired air (1). He built a "to-and fro" rebreathing system in which the carbon dioxide was absorbed by an aqueous solution of caustic potash.

Alfred Coleman (1828-1902) was the first to use a to-and-fro system with carbon dioxideabsorption in clinical practice. It was absorbed by a slaked lime. The idea was similar to Snow's, reusing the anesthetic gases (at that time mostly nitrous oxide) while preventing carbon dioxide from returning to the patient.

Other researchers like Carl Sauer (1835-1892) (2), Franz Kuhn (1866-1929) (3), were also involved in the development of different rebreathing techniques with carbon dioxideabsorption.

The first report of prolonged anesthesia in animals by means of a closed circle system with volatile anesthetics, nitrous oxide and oxygen was done by Dennis E. Jackson (1879-1980) in 1915 (4).

A German chemist, Herman D. Wieland (1877-1928) and a German gynecologist Carl J. Gauss (1875-1957) in cooperation with the German engineer Bernhard Drager (1870-1957) built the first anesthetic apparatus equipped with an anesthetic circle rebreathing system. It was operational and put in clinical practice in 1924 (5,6).

Modern carbon dioxide absorbents use similar chemical reactions. Several formulations are available today, the most common being the soda lime and calcium hydroxide lime. The absorption process follows several steps:

1. $CO_2 + H_2O \rightarrow H_2CO_3$
2. $H_2CO_3 + 2NaOH \rightarrow Na_2CO_3 + 2H_2O$ + Heat
3. $H_2CO_3 + 2KOH \rightarrow K_2CO_3 + 2H_2O$
4. $Na_2CO_3 + Ca(OH)2 \rightarrow 2NaOH + CaCO_3$
(or K_2CO_3) (or 2KOH)

A novel carbon dioxide absorbent was created in 1999. Calcium hydroxide lime (Amsorb) is composed of calcium hydroxide (70%) and several other components to improve hardness. Water is 14.5%. With removal of strong alkali calcium hydroxide lime has potential benefits, including decreased formation of compound A with sevoflurane, minimal formation of carbon monoxide when exposed to desflurane or isoflurane, and minimal destruction of inhaled agents (7). Detailed description of the various combinations and producers of CO2 absorbents can be found in any anesthesia textbook.

Lithium

Its name derived from the Greek word "lithos" (stone). It was discovered din 1800 by the Brazilian chemist Bonifacio de Andrada e Silva in a mine on the Swedish island of Üto, probably from here derived its name. Extensive data

* Correspondence to: Paul Zilberman
E-mail: paulzi60@yahoo.com

on lithium can be found elsewhere. In this article we only remind some of its main uses: air industry lubricants (in fact its first use), medicine (as a mood stabilizing drug), nuclear technology, ceramic and glass industry, electronics (in high quality batteries), pyrotechnics, air purification in spacecraft and submarines and others.

Its use in anesthesia as carbon dioxide absorbent seems to be documented for the first time in 2010 (8-10). The relative novelty of this type of absorbent as well as the long time familiarity and market availability of previous absorbents make this new type of absorbent still difficult to implement in practice.

Traditional vs. premium CO_2 absorbents (11)

All carbon dioxide absorbents use a catalyst, $Ca(OH)_2$ and water which react with carbon dioxide to form $CaCO_3$, water and heat. During this cyclical process, $Ca(OH)_2$ is continually re-moistened during the exothermic reaction of CO_2 absorption until it becomes fully exhausted and converted to $CaCO_3$. While all absorbents undergo the same basic process to capture carbon dioxide, there lie important safety differences between traditional and premium absorbents which stem primarily from the catalyst used in the formulation.

Traditional carbon dioxide absorbents use Na or K catalysts to facilitate carbon dioxideabsorption reaction. Under desiccated conditions NaOH and KOH catalyst preferentially bind and process inhaled anesthetic agents into toxic compounds. Additional to this potential for generation of harmful substances NaOH and KOH usedin traditional carbon dioxide absorbents remain in the exhausted material regenerate after use, causing the reversion of the pH based dyes that are used to indicate exhaustion. Indicator dye color reversion renders this safety mechanism unpredictable and increases the probability of inadvertent re-use of exhausted absorbent.

Premium carbon dioxide absorbents do not use NaOH or KOH. They incorporate proprietary formulations containing catalysts that do not react with common inhaled anesthetic agents, even under desiccated conditions. The absence of NaOH and KOH catalysts also eliminates the potential for the regeneration of the indicator dye, thus providing the benefit of a permanent color change. To date, carbon dioxide absorbents that confer these enhanced safety characteristics also carried a premium price, limiting their adoption. It must be specified that the irreversibility of the indicator dye once its color has changed is characteristic of one of the two LiOH carbon dioxideabsorbents existing on the market today, Litholyme (Allied Healthcare Products Inc.). The other product, Spiralith (Micropore. Inc) does not use any dye; the exhaustion of the absorbent is noticed by the elevation of the $FiCO_2$. Every hospital should have its own limits, but usually when the $FiCO_2$ reaches 0.5% (or 760 mm Hg x 0.05 = 38 mm Hg) the absorbent must be replaced.

Despite the additional expense of the premium carbon dioxide absorbents, the Anesthesia Patient Safety Foundation (APSF) considers them the best practice in the market due to their increased safety, especially in low-flow systems where gases are subject to longer exposure to the carbon dioxide absorbent (12).

The simplified chemical reaction (without the heat produced at different steps) in these proprietary absorbents is described here:

$LiOH + H_2O \rightarrow LiOH{\bullet}H_2O$
$2LiOH{\bullet}H_2O + CO_2 \rightarrow Li2CO_3 + 3H_2O$
$2LiOH + CO_2 \rightarrow Li_2CO_3 + H_2O$ (13)

No strong alkalis appear in these reactions. In fact several papers demonstrated that this characteristic practically eliminates the production of compound A (14,15).

Other works also concentrate on the, production of carbon monoxide of different carbon dioxide absorbents. They show the minimal, if at all, production of carbon monoxide with Amsorb and LiOH ones, in the desiccated state (16,17).

The carbon dioxide absorbent capacity has been also evaluated. Traditional formulations absorb carbon dioxide usually in the range of 26 L / 100 g absorbent (soda lime). Other compositions range around 10.2 L/ 100 g absorbent (calcium hydroxide lime). However, in the traditional pellet form, due to channeling, the absorptive capacity can decrease (18). The absorptive capacity of the LiOH absorbents can range from similar to Sodasorb, to more than Amsorb and even to 5 times more (19).

This high absorption capacity has led many years ago the space exploration to adopt the LiOH carbon dioxide absorbers as the preferred solution that fit the crew production of this metabolic gas (20). A simple calculation demonstrates the high absorptive capacity of the LiOH.

The theoretical binding capacity of LiOH is 0.92 kg CO_2/kg LiOH.This value has been calculated in chemistry and is called stoichiometric limit of the reaction (21). In anesthesia the absorptive capacity is expressed in liters of CO_2, not kg. The equivalent between kilograms and liters for carbon dioxide is approximatively 0.5 m3/1 kg (22). The carbon dioxide production of a 70 kg human in resting state is theoretically 282 L/day (3.5 ml oxygen/kg/min x 24 h = 352800 L/day. Respiratory quotient = 0.8). This brings us to the conclusion that, stated in another way, 2 kg of LiOH can remove one person's daily carbon dioxide from the cabin environment.

In fact the LiOH carbon dioxide absorbers became more known to the general public due to the Apollo 13 accident. It was exactly this high absorption capacity that saved the life of the entire crew (23).

It is probably too early at this stage to evaluate the impact of this new carbon dioxide absorbent in the daily practice. As any new product it must get to be known and understood. Price issues must be overcome as well. A comprehensive perception balancing comfort, safety, financial issues and environment concerns will give the answer.

A possible boost to the implementation of this type of absorbent might be the renewed interest for the low flow anesthesia technique. It is this type of general anesthesia that consumes the most the carbon dioxide absorbent together with all the other abovementioned problems. The LiOH carbon dioxide absorbers may be the answer to all these problems.

Two major actors on the stage

At present there are only two producers of this type of absorbents. The chemical process is roughly similar, but there are differences too. They will be reminded here briefly.

Litholyme is produced as pellets, the way all the anesthesiologists are used today with, both as filling bags and prefilled canisters. This conditioning brings with it the usual concerns related to channeling during use and dusting. Its big advantage, however, is the non-reversible color change once the active substance is consumed. Thus, the so called "Monday morning syndrome" seems to be eliminated.

Spiralith has a novel way of appearance: the active substance is disposed on a polymer matrix base and rolled as a fixed spiral in a cylinder, thus maintaining its tridimensional shape and, consequently, itsabsorptive properties all during the lifetime of the absorber. It has no dye, thus requiring the anesthesiologist to follow the $FiCO_2$ on the monitor. Its main disadvantage is that exactly this conditioning requires sometimes special housings, depending on the type of the anesthesia machine used. However, the big advantage, and seemingly total novelty, is that once the absorbent consumed, it can be returned to the producer for recycling.

Conclusion

The LiOH carbon dioxide absorbent is a new type of component in the breathing circuit. Its chemical properties make it a very attractive option for the future of volatile anesthesia. As any new appearance in medicine it must pass a certain learning curve on behalf of the clinician. Once the experience with this new product will grow its penetration into clinical practice will extend. But at this stage it is too early to predict where and when it will happen.

Disclosure

Nothing to declare.

References

1. Baum J., Snow John: Experimentelle Untersuchungen zur Rückatmung der in der Ausatemluft enthaltenen Narkosegase. Anästesiolo Intensivmed Notfallmed Schmerzther 1995; 30, 37-41
2. Sauer C., Vorläufige Mittheilung der weiteren Versuche, mit Stickstoffoxydul-Gemischen zu anästhesieren. Berliner Klinische Wochenschrift 1869; 6, 366-367.
3. Kuhn F., Die perorale Intubation mit und ohne Druck. III. Teil. Apparat zur Lieferung des Druckes für die Überdrucknarkose. Deutsche Zeitschrift für Chirurgie 1906; 81, 63-70
4. Jackson DE., A new method for the production of general analgesia and anaesthesia with a description of the apparatus used. J Lab Clin Med 1915; 1, 1-12.
5. Gauss CJ., Die Narcylenbetäubunung mit dem Kreisatmer. Zentralblatt für Gynäkologie 1925; 23, 1218-1226.
6. Forreger R., A question of priority: who introduced the CO2 absorption method with the circle breathing into anesthesia practice? Anaesthetist 1995; 44, 917-918.
7. Walker SG, Smith TC, Sheplock G, Acquaviva MA, Horn N, Breathing Circuits, Elsvier Saunders, Second Edition, ANESTEHSIA EQUIPMENT, Philadelphia, PA, 2013, pg. 103.
8. www.wikipedia.org, Pethalite Mineral Information, in www.mindat.org/min-3171.html, Retrieved 10 August 2009
9. www.wikipedia.org, in Lithium Historical Information, www.webelements.com/lithium/history.html, Retrieved 10 August 2009
10. Weeks M (2003), Discovery of Elements, Whitefish, Montana, United States: Kessinger Publishing, p. 124. ISBN 0-7661-3872-0 Retrieved 10 August 2009
11. Litholyme: A safer and more Cost Effective CO2 Absorbent, www.litholime.com/images/wp.pdf, 2013
12. APSF Newsletter, Vol. 20, No. 2, pg. 25-44
13. www.wikipedia.org/wiki/Carbon_dioxide_scrubber
14. Ikeda K, Ph.D., MacLeod DB, F.R.C.A., Hopkins T, M.D., Runyon S, M.D., Shaw A, F.R.C.A., Comparison of Compound A Production by Three Different Carbon Dioxide Absorbents, 2010 ASA Abstract 451475
15. Dahms TE, Ph.D, Statzer N, B.A., Haynes GR, M.D., Ph.D, Evaluation of a New Carbon Dioxide Absorber: Litholyme, Abstract A 717, ASA Meeting, Oct 17, 2010
16. Stabernack CR, Brown R, Laster MJ, Dudziak, Eger EI II, Absorbents Differ Enormously in Their Capacity to Produce Compound A and Carbon Monoxide, Anesth Analg 2000;90;1428-35
17. Dahms TE, Ph.D, Statzer N, B.A., Haynes GR, M.D., Ph.D, Dehydrated Litholyme Does Not Produce Carbon Monoxide When Exposed to Inhalational Agents, Abstract A 718, ASA Meeting, Oct 17, 2010
18. Riutort KT, Eisenkraft JB, Cap.24, The Anesthesia Workstation and Delivery Systems for Inhalled Anesthetics, Lippincott Williams and Wilkins, Clinical Anesthesia 7th edition, Philadelphia, PA, USA, 2013, p. 675.
19. Dorsch MP, CRNA Ph D., The Anesthesia Gas Machine (www.udmercy.edu/crna/agm/07.htm), Revised July 2012.
20. Bacal K, Beck G, Barrat MR, Cap. 22, Hypoxia, Hypercarbia and Atmospheric Control, Principles of Clinical Medicine for Space Flight, Springer, 2008, p. 460.
21. Norfleet W, Horn W," Carbon Dioxide Scrubbing – Capabilities of Two New Non-Powered Technologies", Naval Submarine Medical Research Laboratory, Report No. TR1228, 27August2003
22. www.uigi.com (Universal Industries Gas, Inc.): Measurement Conversions/Product Wight & Weight Conversion Factors/Carbon Dioxide
23. www.howequipmentworks.com, "Most famous CO_2 absorber in the world: The Story of Apollo 13"