WAG Treatment and CO_2 Absorbers:
New Technologies for Pollution and Waste Prevention

Brian P. Barrick, M.D., D.D.S.
ASA Task Force on Environmental Sustainability

Elizabeth A. Snow, M.D.

All inhaled anesthetic agents are potent greenhouse gases, and nitrous oxide (N_2O) is additionally noxious to the ozone layer; thus they pose a threat to the environment when released into the atmosphere. Waste anesthetic gases (WAG) persist in the atmosphere anywhere from 1.1 years (sevoflurane) to 114 years (N_2O).[1] Methods for recapture and destruction are necessary to prevent environmental contamination. N_2O is a plentiful, cheap, unstable compound and reuse is not a practical option, while destruction is possible. Halogenated agents, however, are expensive and stable compounds, and reclamation of these agents for potential re-purification and reuse, or their destruction, are both possible. Waste reduction can be achieved by newer carbon dioxide (CO_2) absorber technologies that permit lower fresh gas flows without producing compound A. Prevention of WAG release to the environment should be pursued.

WAG Treatment

There are three potential methods for destruction of N_2O: oxidation, reduction or catalytic splitting. Oxidation produces NOx (x>0.5) species, which also impact the environment negatively. Reduction, on the other hand, removes oxygen to produce N_2 and another oxidized substance (depending on the catalyst). Catalytic splitting splits N_2O into N_2 and O_2. Catalytic splitting technology is currently used in Sweden to prevent waste N_2O release into the outdoor atmosphere from labor and delivery suites. It was adapted from Japanese technology and scaled up to facility-level scavenging system installation.[2] The Swedish technology treats 95 percent of collected N_2O. The word "collected" should be emphasized, as a significant amount of N_2O escapes due to the nature of delivery (patient-controlled face mask). N_2O used in the O.R. can have a much higher rate of collection when administered in a semi-closed circle system; however, leaving fresh gas flows on while intubating after mask induction, and mask anesthetics, are significant opportunities for pollution outside of the scavenging system. Destruction of N_2O could, in theory, be accomplished via a single catalytic splitting unit servicing multiple L&D rooms or O.R.s, and potentially PACUs if installed in HVAC systems.

Sequestration refers to a method to prevent release of anesthetic agents into the environment. Activated charcoal has been shown to effectively adsorb volatile anesthetics only. There has been some interest in its use as a reflector, meaning both adsorption and desorption of anesthetic gas. Along with the anesthetic gas, adsorption of methanol and acetone also occurs, and the potential for desorption and delivery of these waste products back to the patient is problematic.[3] If activated charcoal is used solely for anesthetic gas sequestration, there is still the problem of storage and disposal. Saturated charcoal will quickly desorb and release agents back into the environment, so its greatest utility is for indoor pollution control in settings that lack

Brian P. Barrick, M.D., D.D.S., is Professor of Anesthesiology, University of North Carolina, Chapel Hill.

Elizabeth A. Snow, M.D., is a CA-1 resident, Department of Anesthesiology, University of North Carolina, Chapel Hill.

scavenging systems; this technology is not, however, effective for outdoor pollution prevention. Desorption accompanied by destruction and/or reclamation is necessary for activated charcoal to be truly effective at preventing the release of volatile anesthetic gases into the atmosphere. Cold trap condensation is another form of sequestration. It recaptures agents in liquid form by cooling them to below their dew point. This could potentially allow for reclamation of the volatile anesthetic gases for destruction or reuse.

Blue-Zone Technologies Ltd. (Toronto, Ontario, Canada) produces the Deltasorb® canister system for use on a single machine, and Centralsorb® is a more centrally located system for collecting halogenated agents. Both utilize honeycomb-shaped silica zeolite crystals (Deltazite®) to maximize surface area. Deltasorb canisters were found to be effective for 100 percent adsorption of isoflurane for up to eight hours.[4] Deltazite® allows for desorption of halogenated agents as liquids for potential processing and reuse.[4] Reuse of halogenated ethers is not currently approved by the FDA, and storage of collected wasted volatiles is an issue. This technology is not suitable for N_2O waste handling.

Standard scavenging systems consist of vacuum technology that limits indoor occupational exposure to anesthetic gases, though eventually releases these directly to the outdoor environment. The most common systems are continuously on, even if the anesthesia machine is not in use. This greatly increases energy consumption. The Dynamic Gas Scavenging System (Anesthetic Gas Reclamation, Inc.) provides a more efficient scavenging system that can be installed on any anesthesia machine.[5] The use of a pressure valve/switch ensures that the system operates only when the anesthesia machine is in use. This reduces room air entrainment, energy use and the cost of running the scavenging system.

CO_2 Absorbers

Carbon dioxide absorbers in semi-closed circuits allow for use of fresh gas flows well below minute ventilation, unlike historic open-circuit systems. One need only replace the oxygen consumed by the patient. Low-flow anesthesia allows for reduction in the amount of anesthetic gas used and therefore wasted into the atmosphere. Low-flow sevoflurane presents its own challenge due to the theoretical risk from the formation of compound A. Newer CO_2 absorbers have calcium hydroxide, as opposed to historic sodium hydroxide or potassium hydroxide (Amsorb®, Armstrong Medical Ltd). These produce compound A only when desiccated, thus permitting low-flow sevoflurane without the concern for compound A toxicity.[6,7]

> ***"WAG pollution is a concern. In addition to behaviors that limit its impact (namely, careful selection of least-polluting drugs and close attention to lowest fresh gas flows), new technology can help limit WAG release into the atmosphere."***

Lithium hydroxide is a promising CO_2 absorbent that also does not produce compound A (Litholyme™, Allied Healthcare Products, Inc.). It was initially thought to undergo an exothermic reaction that produced too much heat to be clinically useful. A new formulation of lithium hydroxide, chemically bound to water (SpiraLith™, Micropore, Inc., Elkton, MD), was shown not to have a significant increase in temperature when compared to calcium hydroxide-containing absorbents.[8] Lithium hydroxide does not absorb volatile anesthetics, decreasing the amount of time necessary to reach equilibrium in the breathing system and thus the amount of volatile agents used.[9] It also does not undergo a significant weight change between its fresh and desiccated forms, signifying that it will perform similarly in both forms.[10]

Memsorb[11] is a new technology in development that does not rely on chemical reactions, but rather uses polymeric membranes similar to ones used in oxygenators for cardiac surgery. The membranes selectively allow CO_2 to leave the rebreathing circuit while maintaining anesthetic vapor, and no compound A is produced.

Continued on page 14

Continued from page 13

Conclusion

WAG pollution is a concern. In addition to behaviors that limit its impact (namely, careful selection of least-polluting drugs and close attention to lowest fresh gas flows), new technology can help limit WAG release into the atmosphere. Both WAG capturing and destruction technologies are already in limited use. WAG capturing technologies are effective for collecting volatile anesthetics, but do not handle N_2O, and storage is a concern. WAG destruction technologies are in routine use for N_2O in other nations, (e.g., Sweden); however, they would need to be modified to handle volatile agents. Newer CO_2 absorber technologies can permit lower fresh gas flows without concern for compound A. All such technologies are promising to aid in the prevention of WAG pollution.

References:

1. Sherman J, McGain F. Environmental sustainability in anesthesia: pollution prevention and patient safety. *Adv Anesth.* 2016;34(1):47-61.
2. Ek M, Tjus K. Decreased emission of nitrous oxide from delivery wards – case study in Sweden. *Mitig Adapt Strat Gl.* 2008;13(8): 809-818.
3. Leffler S. Storage of anesthetic gases on activated carbon. Lund University Department of Chemical Engineering website. http://www.chemeng.lth.se/exjobb/020.pdf. Received for review March 25, 2002. Last accessed February 8, 2018.
4. Blue-Zone Technologies Ltd. Where is your vented anesthetic waste going? http://www.blue-zone.ca/documents/BZCSDSOverviewC2CBro.pdf. Last accessed February 8, 2018.
5. Our key products. Anesthetic Gas Reclamation Inc website. https://www.gasrecycler.com/products/. Last accessed February 8, 2018.
6. Keijzer C, Perez RS, de Lange JJ. Compound A and carbon monoxide production from sevoflurane and seven different types of carbon dioxide absorbent in a patient model. *Acta Anaesthiol Scand.* 2007;51(1):31-37.
7. Di Filippo A, Marini F, PAcenti M, Dugheri S, Focardi L, Novelli GP. Sevoflurane low-flow anaesthesia: best strategy to reduce Compound A concentration. *Acta Anaesthesiol Scand.* 2002;46(8):1017-1020.
8. Hopkins T, Runyon S. Lucignano A. Ikeda L. MacLeod DB; Department of Anesthesiology, Duke University Medical Center. Comparison of temperature changes of three CO2 absorbents when exposed to three volatile agents. MicroPone Inc website. http://www.microporeinc.com/media/docs/DUKE%20Paper%202010%20Temperature%20Changes.pdf. Last accessed February 12, 2018.
9. MacLeod DB, Ikeda K, Runyon S, Hopkins T, Shaw A; Department of Anesthesiology, Duke University Medical Center. Comparison of absorption of volatile anesthetic agents by three different carbon dioxide absorbents. SpiraLith website. http://spiralith.com/wp-content/uploads/2013/10/DUKE_2010_Wash-in-Wash-out.pdf. Last accessed February 12, 2018.

A complete list of references can be found in the online version of this article at **monitor.pubs.asahq.org**.