concentrations of an opioid does not markedly reduce the amount of the hypnotic or volatile anesthetic required to render the patient unconscious, but the opioid produces a marked, dose-dependent reduction of somatic, sympathetic, and hemodynamic responses to intense noxious stimulation. These observations call attention to specific, discrete pharmacologic effects of different drugs used in combination to achieve the overall spectrum of effects that may be desired during general anesthesia. Moreover, attention is drawn to the need to monitor individually the specific goals of general anesthesia.

The importance of the interactions of hypnotics and opioids is evident in this study. Given the existing knowledge of the concentrations of propofol and fentanyl alone that are required to suppress responses to noxious stimulation and to maintain unconsciousness (not consistently possible with an opioid alone) makes it highly likely that the interaction is a synergistic one. This means that relatively low doses of each drug can be used in combination to limit their individual side effects and accumulation in the body. It is important to note that relatively low concentrations of fentanyl, clearly within the analgesic range (fentanyl 1–3 ng/ml of plasma), reduced the requirement for propofol just as it does for inhalational agents by 30–50%.[3] Huge opioid doses are not needed to achieve satisfactory anesthetic conditions when the opioid is used in combination with hypnotic or volatile anesthetic.

Finally, the findings of this study are particularly relevant in this era of "fast tracking." To achieve rapid recovery from anesthesia, there is a growing tendency to limit the doses of hypnotic and analgesic drugs administered intraoperatively. This tendency may increase the risk of inadequate anesthesia, especially arousal in response to noxious stimulation, which may go undetected in the paralyzed patient. Given the widespread practice of administering amnesic drugs, the lack of recall of intraoperative events is no guarantee that the patient has not experienced pain or fear intraoperatively. In my opinion, amnesia does not fulfill the implied conditions of the contract that is established when the patient and anesthesiologist agree on general anesthesia. Again, the strategy of achieving unconsciousness with a hypnotic before administration of a muscle relaxant, maintenance of that level of hypnotic concentration, and supplementation with an opioid as needed to suppress sympathetic and hemodynamic signs of responsiveness to noxious stimulation goes a long way to achieving satisfactory fulfillment of the general anesthesia contract.

Carl C. Hug, Jr., M.D., Ph.D.
Professor of Anesthesiology and Pharmacology
Emory University School of Medicine
Department of Anesthesiology
Emory University Hospital
1364 Clifton Road, NE
Atlanta, GA 30322-1104
Electronic mail: chug@emory.org

References

1. Ausems ME, Hug CC Jr, Stanski DR, Burm AGL: Plasma concentrations of alfentanil required to supplement nitrous oxide anesthesia for general surgery. ANESTHESIOLOGY 1986;65:362–73

2. Zbinden AM, Petersen-Felix S, Thomson DA: Anesthetic depth defined using multiple noxious stimuli during isoflurane/oxygen anesthesia. ANESTHESIOLOGY 1994;80:261–7

3. Westmoreland CL, Sebel PS, Gropper A: Fentanyl or alfentanil decreases the minimim alveolar anesthetic concentration of isoflurane in surgical patients. Anesth Analg 1994;78:23–8

Anesthesiology
1997; 87:202–3
© 1997 American Society of Anesthesiologists, Inc.
Lippincott-Raven Publishers

Keep the Blood Red . . . The Right Way

All currently volatile anesthetics are degraded by carbon dioxide absorbents to compounds that are toxic. Desflurane, enflurane, and isoflurane are degraded to carbon monoxide (CO), which is neurotoxic and cardiotoxic. A 1-h exposure to 1,000 ppm CO will produce approximately 25% carboxyhemoglobin, sufficient to cause severe neuropsychiatric impairment, whereas 67% carboxyhemoglobin causes death.[1] The current Environmental Protection Agency limit for a 1-h exposure is 35 ppm. Signs and symptoms of CO toxicity are

Accepted for publication May 8, 1997.

Key words: Baralyme, calcium hydroxide, carbon dioxide, carbon monoxide, carboxyhemoglobin, complications, desflurane, hemoglobin, intraoperative monitoring, isoflurane, soda lime, sodium hydroxyide.

Downloaded from http://asa2.silverchair.com/anesthesiology/article-pdf/87/2/202/377413/0000542-199708000-00005.pdf by guest on 17 April 2024

masked during and after anesthesia, and carboxyhemoglobin cannot be detected by pulse oximetry.

In the past decade, case reports, abstracts, and newsletter articles have described various aspects of CO formation and poisoning. A gradual pattern emerged, in which most CO cases involved the first patient anesthetized on a Monday morning using an anesthetic machine idled for 2 days, the carbon dioxide absorbent was implicated in CO formation, and high inspired CO concentrations were associated with absorbent that had been used for a long time. This pattern was partially rationalized by the observation that relatively dry absorbent was required for CO formation,[2] which suggested a scenario whereby gas flowing through an anesthesia machine over a weekend could dry the absorbent and produce CO poisoning on Monday morning. Unfortunately, most of these reports never appeared as manuscripts in the peer-reviewed literature and received little attention. More importantly, several questions were left unanswered: What is the clinical incidence of CO exposure? What were the clinical effects of such exposure? Under what conditions might it occur? Is CO exposure a real concern or a "tempest in a teapot?" In this issue of ANESTHESIOLOGY are two investigations that address these issues.

Frink *et al.* studied the sequelae of absorbent drying in an anesthesia machine under plausible conditions of clinical use: oxygen (5–10 l/min) for 24–48 h through a circle system containing Baralyme® or soda lime with the reservoir bag in place or removed, followed by desflurane (1 minimum alveolar concentration) anesthesia. This is a Laboratory Report only because swine, not humans, were anesthetized. The results are startling and disconcerting. After drying Baralyme® at 10 l/min for 48 h without a reservoir bag, desflurane anesthesia caused extremely high inspired CO concentrations (37,000 ppm), and all animals had carboxyhemoglobin concentrations of more than 80%. Three pigs died, and the remaining animals remained hypotensive despite resuscitation with epinephrine. Clearly, physiologically devastating and unacceptable CO exposures can occur. Frink *et al.* also defined conditions in which significant CO formation did not occur (reservoir bag in place, lower gas flows).

Woehlck *et al.* studied the incidence of CO exposure in a teaching hospital and tested the hypothesis that educating operating room support staff (anesthesia technicians and housekeepers) to intervene to prevent absorbent drying could reduce CO exposures. Despite educating all anesthesia personnel about the factors predisposing to CO formation (specifically absorbent drying), the incidence of CO exposure was 1 in 200 first cases. After instructing OR support personnel to turn off anesthesia machines at the end of the day and to replace absorbent if gas was found flowing in the morning, the incidence was reduced to 1 in 2,000 cases. That operating room support personnel can contribute to patient safety is novel. Woehlck *et al.* also identified a previously unreported factor that promotes CO formation.

These two reports serve notice that clinical CO formation is not uncommon and can have serious sequelae. They further define and refine conditions under which CO formation occurs and can be avoided. Most importantly, they provide straightforward and readily implemented ways in which it can be prevented, both by anesthesia practitioners and nonpractitioners. In addition to those guidelines promulgated by the Food and Drug Administration to reduce CO exposure,[3] we now have additional ways to protect patients.

Evan D. Kharasch, M.D., Ph.D.
Professor
Departments of Anesthesiology and Medicinal Chemistry (Adjunct)
University of Washington
Box 356540
Seattle, Washington 98195

References

1. Stewart RD: The effect of carbon monoxide on humans. Ann Rev Pharmacol 1975; 15:409–23

2. Fang Z, Eger EI II, Laster MJ, Chortkoff BS, Kandel L, Ionescu P: Carbon monoxide production from degradation of desflurane, enflurane, isoflurane, halothane, and sevoflurane by soda lime and Baralyme. Anesth Analg 1995; 80:1187–93

3. Bedford RF: From the FDA. ANESTHESIOLOGY 1995; 83:33A

Downloaded from http://asa2.silverchair.com/anesthesiology/article-pdf/87/2/202/377413/0000542-199708000-00005.pdf by guest on 17 April 2024