Closed Circuit Anesthesia is Justified Despite Marginal Cost of Co2 Absorbent

Presenting Author: Christopher Lo, University of Pennsylvania – Wharton School, Philadelphia, PA

Co-Author: Jeffrey M Feldman, MD, MSE, University of Pennsylvania-Perelman School of Medicine, Children's Hospital of Philadelphia. Philadelphia, PA.

Introduction: Closed circuit anesthesia is a method of anesthetic administration where fresh gas flow (FGF) equals oxygen consumption and anesthetic vapors are completely rebreathed. It is the ideal approach to minimizing anesthetic consumption as all of the exhaled gas returns to the patient providing the greatest drug cost savings and minimizing the environmental impact of wasted anesthetic vapor. However, the closed circuit condition also maximizes the utilization of CO_2 absorbent since all of the exhaled CO_2 passes through the absorbent. Given the varying cost and efficiency of CO_2 absorbents, it is possible that the marginal benefit of reducing drug costs in a closed circuit condition is limited by the marginal cost of CO_2 absorbent. This project develops a mathematical model to determine the optimal FGF defined as that FGF where the marginal benefit of reducing anesthetic usage equals the marginal cost of absorbent utilization.

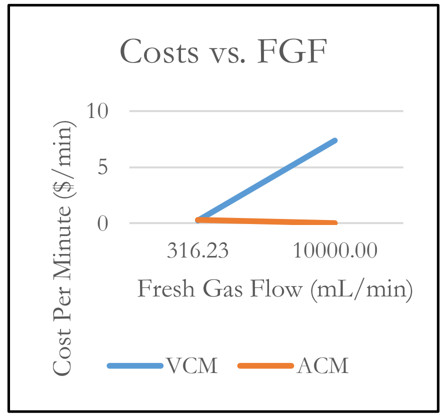
Methods: The mathematical model is designed to calculate the cost per minute of both anesthetic vapor (VCM) and CO_2 absorbents (ACM) as a function of fresh gas flow (FGF). Factors in the model include choice and cost of anesthetic drug, choice and cost of CO_2 absorbent formulation, patient weight and CO_2 absorbent efficiency. VCM is calculated as:

$$\text{VCM} = \text{VAP x FGF x VL x V\$}$$

where VAP is vaporizer setting in %, FGF is mls/min, VL is mls of liquid/mls of vapor and V$ is the cost of anesthetic in dollars per ml of liquid. The CO2 absorbent cost per minute (ACM) is calculated as:

$$ACM = \frac{CAM \times A\$}{CAG \times A_{eff}}$$

where CAM is the CO_2 absorbed per minute in mls/min, A$ is the absorbent cost in $/g, CAG is the CO_2 absorbed per gram of absorbent in mls/g, and Aeff is the efficiency of the absorbent in %. A closed circuit condition was defined as FGF equal to oxygen consumption (VO_2) as determined by the Brody equation. The maximum FGF was set at minute ventilation assuming this represented an open circuit condition. CAM was based upon CO_2 production (VCO_2) determined by oxygen consumption and a respiratory quotient of 0.8 and estimated as a linear relation from 100% of CO_2 absorbed for a closed circuit and 0% for an open circuit. Conditions that maximize the marginal cost of absorbent and minimize the marginal benefit of vapor savings were based upon cost data for anesthetics and absorbents from our hospital purchasing agent, and published data on absorbent capacity and efficiency.(1,2) Worst case assumptions that would maximize absorbent cost and minimize vapor savings included a 100 Kg patient, Isoflurane at $0.125/ml and MAC of 1.15%, A$ at $.05/g, CAG of 73 mls/g, Aeff of 50%.



Results: In this worst case scenario, the marginal cost of CO2 absorbent exceeded the marginal benefit of vapor savings by $0.11 per minute or $6.60 per hour when using a closed circuit anesthetic.

Discussion: This model is intended to determine the theoretical maximum cost of CO_2 absorbent and minimum vapor cost savings under closed circuit conditions and showed that the marginal absorbent cost is not very great. Real world results would yield lower absorbent costs and greater vapor savings indicating that closed circuit anesthesia is economically justifiable. There are strategies for minimizing absorbent cost including the choice of absorbent material, and delaying absorbent replacement until inspired CO2 is present. In addition to the economic benefits, the environmental benefits of closed circuit anesthesia are also compelling but are not addressed in this analysis.

References:

1) Knolle et. al. Anesth Analg 2002;95:650.
2) Hendrickx et al. J Clin Monit Comput 2016;30:193.