Closed Circuit Anesthesia is Justified Despite Marginal Cost of Co2 Absorbent

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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 CO₂ absorbent since all of the exhaled CO₂ passes through the absorbent. Given the varying cost and efficiency of CO₂ absorbents, it is possible that the marginal benefit of reducing drug costs in a closed circuit condition is limited by the marginal cost of CO₂ 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 CO₂ 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 CO₂ absorbent formulation, patient weight and CO₂ absorbent efficiency. VCM is calculated as:

\[ VCM = VAP \times FGF \times VL \times V$\]

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 CO₂ absorbed per minute in mls/min, A$ is the absorbent cost in $/g, CAG is the CO₂ absorbed per gram of absorbent in mls/g, and A_eff is the efficiency of the absorbent in %. A closed circuit condition was defined as FGF equal to oxygen consumption (VO₂) 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 CO₂ production (VCO₂) determined by oxygen consumption and a respiratory quotient of 0.8 and estimated as a linear relation from 100% of CO₂ 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 CO2 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: