Greening the Operating Room

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Disclosures

- Draeger Medical – consulting fees
- Covidien – consulting fees

Anecdote

- Malnutrition in Rural Vietnam – Jerry Sternin 1990
  - Language Barrier
  - Sanitation, Poverty, Lack of Clean Water
  - Given 6 months to effect change
- Engaged mothers to
  - Identify “healthy” kids in the population
  - Unique Eating habits – mixed crab/shrimp and greens into rice
  - Hold cooking classes with families to show these ingredients
- Results
  - 65% of kids were better nourished and stayed that way
  - Ultimately reached 2.2 million people through self education

Definitions

Greening (v): The act of greening involves incorporating "green" products and processes into one's environment, such as the home, work place, and general lifestyle.

- WIkipedia

Greening (n): An apple of a variety that is green when ripe.

- OED Online

Waste (v): Use or expend carelessly, extravagantly, or to no purpose.

- OED Online

Reduce, Reuse, Recycle, Redesign

- ASA Task Force
  https://www.asahq.org/For-Members/Clinical-Information/Greening-the-Operating-Room.aspx
  - ASA Committee on Equipment and Facilities – Charlotte Bell, MD
  - T. Kate Huncke, Susan Ryan, Jodi Sherman

- Scope of Activities
  - **Environmental sustainability in anesthesia equipment choices**
  - **Environmental impact of inhaled anesthetics in clinical use**
  - **Management of fresh gas flow (FGF) to reduce environmental contamination**
  - **Intravenous pharmaceutical environmental issues**
  - **Waste stream management and recycling opportunities**
  - **Environment sustainability in perioperative settings and operating room design**

Green Anesthetic Delivery

Emotional or Rational?

Greenhouse Gases

- Greenhouse Gases – Contribute to Reducing Heat Loss from the Earth
  - Temperature of the Earth depends upon balance of energy entering and leaving the atmosphere
  - Absorption and re-emission of radiant energy by gases in the atmosphere increases global temperature
- Types of Gases
  - Carbon Dioxide, Methane, N_2O
  - Flourocarbons: eg. Isoflurane, Sevoflurane, Desflurane
- Relative impact of a Greenhouse gas
  - Radiative warming
  - Atmospheric lifetime

Global Warming Potential

- Absolute Global Warming Potential: watts/m^2/ppb/yr

$$\mathrm{AGWP}_x(t') = \int_0^{t'} F_x[x(t)]\,dt$$

where F_x is radiative forcing per unit mass of species x
x(t) is decay function for species x

- Global Warming Potential over a given time period relative to CO2

$$\mathrm{GWP}_x(100) = \frac{\int_0^{t'} F_x \exp(-t/\tau_x)\,dt}{\int_0^{t'} F_{CO_2} R(t)\,dt}$$

Ref: Sulbaek-Anderson et. al. BJA 2010;105:760.

1 MAC-Hour Impact

1 MAC Inhaled Agent	Atmospheric Lifetime (Years)	100-Year GWP (per kg)*	Ratio of CO_2 Equivalents Produced	Equivalent Auto Miles Driven (Miles)†
2% Sevoflurane at 2 L FGF	1.1	130	1.0	8
Isoflurane				
1.2% at 2 L FGF	3.2	510	2.2	18
1.2% at 1 L FGF			1.1	9
Desflurane				
6% at 2 L FGF	14	2540	49.2	400
6% at 1 L FGF			24.6	200
60% Nitrous Oxide Alone at 1 L FGF	114	298		61

Ryan, S.2012 Greening the Operating Room. ASA White Paper.

Inhalation Anesthetics

- Potent Anesthetic Vapors and Nitrous Oxide

Table 1. Summary of Radiative Properties, Atmospheric Lifetimes, and Global Warming Potentials for Nitrous Oxide and the Halogenated Anesthetic Gases

			GWP			
Compound	Atmospheric lifetime (y)	Radiative efficiency (W m^{-2} ppb^{-1})	20-y time horizon	100-y time horizon	500-y time horizon	Ozone depletion potential
Nitrous oxide, N_2O	114[8]	0.00303[8]	289[8]	298[8]	153[8]	0.017[17]
Halothane, $CF_3CHClBr$	1.0[8]	0.165[a]	190[a]	50[a,b]	20[a]	0.4[a,c]
Enflurane, $CHFClCF_2OCF_2H$	4.3[8]	0.447[a]	2370[a]	680[a,d]	210[a]	0.01[a,c]
Isoflurane, $CF_3CHClOCHF_2$	3.2[13]	0.453[13]	1800[13]	510[13]	160[13]	0.01[a,c]
Desflurane, $CF_3CHFOCHF_2$	14[3]	0.469[13]	6810[3]	2540[3]	130[3]	0[a,c]
Sevoflurane, $(CF_3)_2CHOCH_2F$	1.1[3]	0.351[13]	440[3]	130[3]	40[3]	0[a,c]

- Impact due to atmospheric lifetime and degree of IR absorption
- Estimate: Global anesthetic use is similar to impact of:
  - One coal fired power generating facility
  - 1 million passenger cars
- Not Environmentally benign: Rational use based upon clinical advantage

Ref: Sulbaek-Anderson et. al. A&A 2012;114:1081.

Global Impact

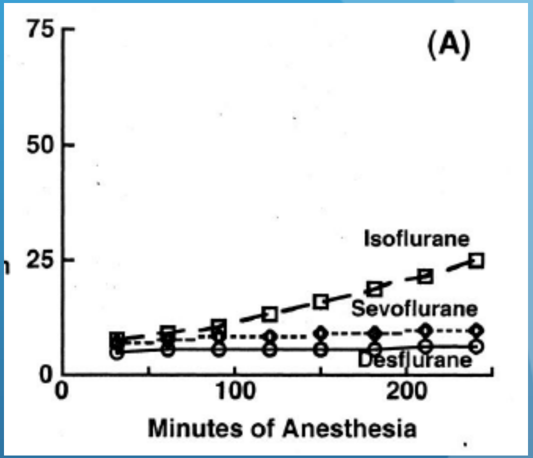
- GHG Contribution of Anesthetics relative to CO2
  (Sulbaek-Anderson et al. Br J Anaesth 2010;105:760)
  - 0.01% of annual CO2 emissions OR "One Coal-Fired Power Plant or 1 million cars"
  - Assumptions
    - Data modeled on Univ of Michigan experience – Desflurane?
    - No life cycle analysis
    - No Nitrous Oxide
    - Does not include veterinary and laboratory uses
- Patient needs more important than "green" considerations
- Economic Factors
  - Reduces waste and cost at the same time
  - Cost of Green practice becomes a factor – What is the ROI?

“Green” Management of Anesthetic Vapors

- Choice of Agent
- Technique – “Art” of induction, maintenance and emergence
- Adjuncts to reduce inhaled concentration
  - Regional anesthesia
  - Analgesics – Opioids, Ketamine
- Recovering or Eliminating Anesthetics from the Waste Stream
- Technology Advances to enhance delivery

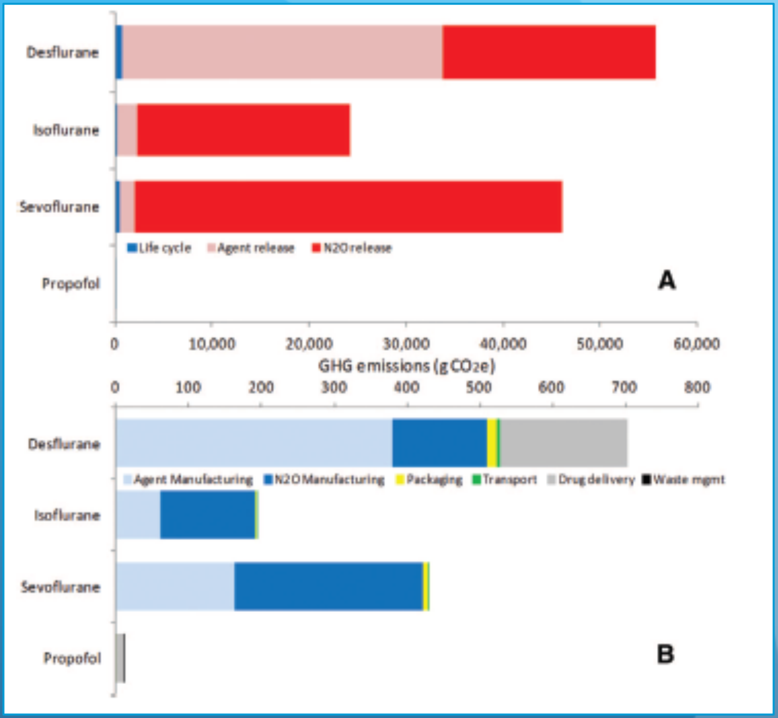
"Green" Anesthetic Choice

- Sevoflurane or Isoflurane preferred
    - Lower GWP than Desflurane
    - Lower MAC value reduces amount delivered
- Desflurane when there is clinical advantage
  (Eger & Shafer, A&A 2005;101:688)
    - Longer procedures?
    - Obese patients
- Nitrous Oxide – Do we need it?
    - Long atmospheric lifetime – 114 years!
    - Low potency requires high concentrations



Is TIVA Better?

- Is TIVA Better?
  - Propofol lower footprint in life cycle analysis
    - 50% wastage
    - Disposables for administration
    - Energy for pumps
- Other Considerations
  - Environmental persistence of waste
  - Propofol shortages already occur



Sherman et. al. A&A 2012;114:1086

Recovery and Destruction

- Methods
  - Anesthesia Gas Reclamation – cryogenic vapor condensing system
  - Anesclean – N2O catalytic breakdown, vapor collection
  - Blue Zone – Canister based Vapor recovery system
  - Gas Phase Photochemical Destruction – Johnson/Rauchenwald
- DIsadvantages
  - Complex
  - Overhead of recapturing and processing for return to use
  - Potential value but better delivery erodes the ROI of the recovery systems
- Better Delivery
  - Some waste is inevitable – closed circuit not realistic
  - How much waste will justify the recovery process?

N2O Breakdown

- Nitrous Oxide release can be managed
- Breakdown into N_2 and O_2 by catalytic splitting
- N2O for Delivery Analgesia

Life time years	Interest rate	Electricity price €/kWh (2011)	**Specific cost €/kg CO_2-eq.**	Capital cost	Electricity cost
10	4 %	0.115	**0.073**	84 %	2.6 %
10	4 %	0.23	**0.074**	81 %	5.1 %
10	6 %	0.115	**0.079**	85 %	2.4 %
10	6 %	0.23	**0.081**	83 %	4.7 %
15	4 %	0.115	**0.057**	78 %	3.6 %
15	4 %	0.23	**0.059**	75 %	6.9 %
15	6 %	0.115	**0.063**	80 %	3.2 %
15	6 %	0.23	**0.065**	78 %	6.2 %

Ek M, Tjus K Swedish Env Research Institute

Closed Circuit Anesthesia is not New

"A simple technique is described for such reuse of anesthetic gases and vapors, wherein oxygen only, is added during the anesthetic, and that, in amounts approximating metabolic requirements."

Ralph Waters, Advantages and Technique of Carbon Dioxid Filtration with Inhalation Anesthesia. A&A 1926;160.

“Green” Technique

- Induction
  - Don’t turn off the vaporizer
  - Limit Maximum flow to Open Circuit Condition
  - Overpressure vaporizer setting and reduce fresh gas flow
  - Circuits with lower internal volume are preferred
- Maintenance
  - Minimal flow anesthesia based upon oxygen consumption
  - Advantageous to return sampled gas to the breathing circuit
- Emergence
  - Coasting: Maintain minimal fresh gas flow until ready to turn off the vaporizer
  - Avoid increasing flows and gradually reducing vapor concentration
- Oxygen and Agent Concentration Monitoring is Essential

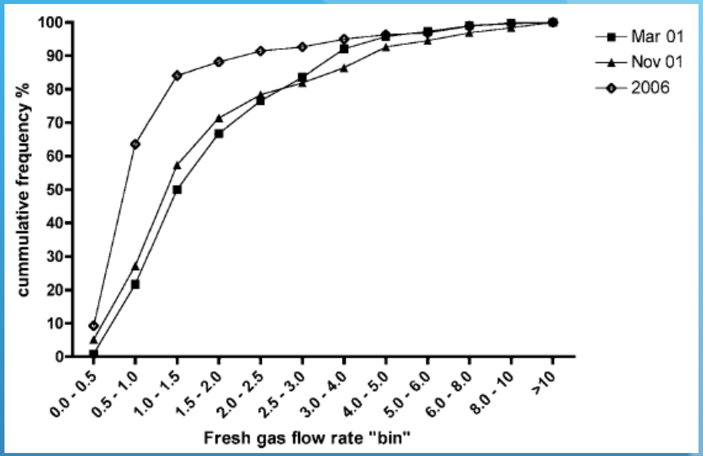
Feldman JM. A&A 2012;114:1093

Simple Guidelines

- Practice Guidelines for all expensive drugs
  (Lubarsky et al Anesth. 1997;86:1145)
  - Inh Agents:
    - Isoflurane preferred
    - Flow > 1 L/min should not be required
  - Reduced overall cost from $66+/case to $32+/case
  - Sustainable?
- Individual Feedback
  (Body et. al. Anesth 1999;90:1171)
  - Feedback to each provider on FGF relative to peers before intervention
  - Educational program
    - Iso @ 1 L/min; Des @ 1 L/min; Sevo @ 2 L/min
  - Follow up at two time points post-intervention
  - Reduced mid-anesthetic FGF by 26%: 2.4±1.1, 1.8±1.0, 1.9±1.1 L/min
  - Expensive Agent use Increased

Education and Guidance

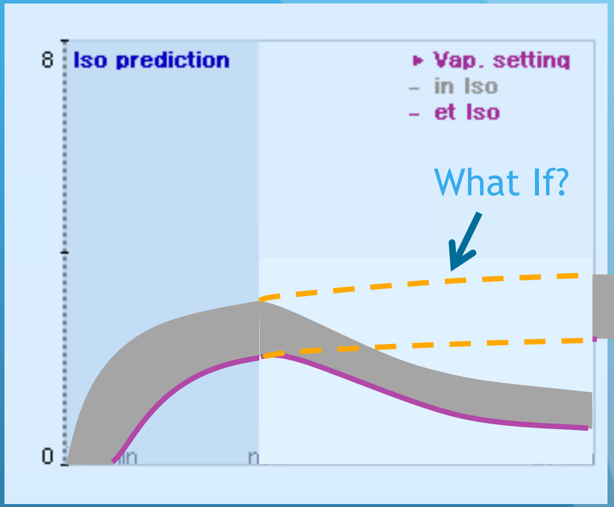
- Multiple year documentation
  - Audit (2001)
    Kennedy et al. NZ J Med 2003;116:U438.
    - FGF average 2 L/min
    - Likely reflects low flow during maintenance



  - Audit (2006) – The "Predictor"
    Kennedy et al. A&A 2008;106:1487
    - Guide to future (10 minutes) ET gas concentration
    - FGF average of 1.3 L/min (35% decrease or $US130,000)

Guidance – Vapor View (Draeger)

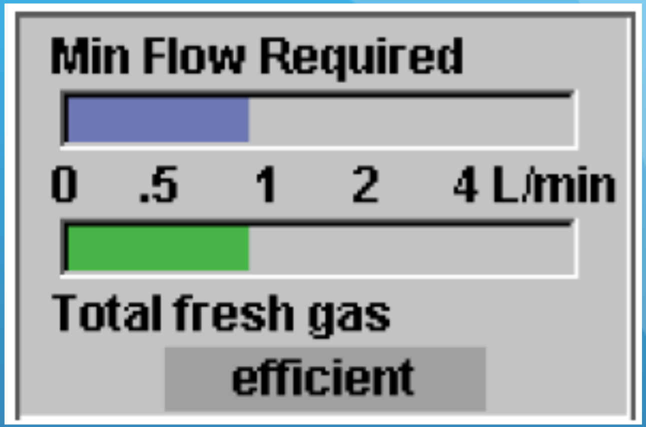
- Predictive display of Oxygen and Vapor concentrations
  - 10 minute history
  - 20 minute prediction
- What-if feature indicates outcome of settings before confirmed
- Models of machine properties and patient uptake



- Encourages reducing flow since outcome is predicted
- Low flow Target is not provided
- Combined with Econometer

"Target" Approach (Manual)

- Low Flow Wizard (Draeger Med)
  - Determines minimum flow based upon uptake
  - Guides user to more efficient setting
  - Fresh gas flow reduced by 46% in a simulator study (Luria et. al. A&A 2013;117:1135)



- Not useful during induction, emergence or when gas concentrations must change rapidly
- No information about when it is OK to follow the wizard recommendation for min flow
- No connection with vaporizer setting or vapor concentration

"Target" Approach (Automated)

- Basic Functions
  - Set expired target for Oxygen and Vapor
  - Set minimum fresh gas flow
- ET Control (GE)
  - 40-55% Reduction in Vapor Usage
    (Singaravelu & Barclay, BJA 2013:110:561)
  - 44% Reduction in CO_2 Equivalent Emissions
    (Tay et. al. Anaesth Intensiv Care 2013:41;95)
- Zeus (Draeger)
  (Lortat-Jacob Anaesthesia 2009:64;1229)
  - Desflurane and O_2 65% reduction; N_2O 80% reduction
  - No difference in hemodynamic stability or BIS level

“Target” Approach (Automated)

- ET Control (GE Aisys)
- Function
  - Set: Target ETO2 and ETAA concentrations & Minimum FGF
  - Automated delivery at minimum FGF unless greater flows needed to meet ET targets then FGF increases
- Evaluation
  - 40-55% Reduction in Vapor Usage
    (Singaravelu & Barclay, BJA 2013:110:561)
  - 44% Reduction in CO_2 Equivalent Emissions
    (Tay et. al. Anaesth Intensiv Care 2013:41;95)
- Insures adequate desired oxygen and vapor concentration
- Reduces burden on the provider
- Default low flow values help with gaps in provider knowledge
- Perceived Barriers: Short case, leaks, safety in pediatric patients re: circuit resistance, dead space.

“Target” Approach (Automated)

- Zeus (Draeger)
- Auto control mode available
- Closed circuit delivery of Anesthetic Agent and Oxygen
  - Attempts to achieve absolute minimum flow
- User selects target concentrations of Vapor and O2
- Closed loop control of gas delivery based upon utilization
- Evaluation
  (Lortat-Jacob Anaesthesia 2009:64;1229)
  - Desflurane and O2 65% reduction; N2O 80% reduction
  - No difference in hemodynamic stability or BIS level

The Future

- Smart Pilot (Draeger)
- Navigator (GE Healthcare)

Obstacles to Green Practice

- Data supporting indications for anesthetic agents
- Managing FGF remains an "art" and depends upon skill and commitment of provider
- Technology aids make us less reliant on "Art" BUT
  - Regulatory barrier
  - Financial barrier
- Auditing and reporting FGF requires a champion

Change Strategies

- Switch – Chip and Dan Heath (http://heathbrothers.com/download/switch-framework.pdf)
  - Direct the Rider – rational side
  - Motivate the Elephant – emotional side
  - Shape the Path –
- Fixing Malnutrition in Vietnam
  - Direction: Found the success stories – Bright Spots
  - Motivation: child health and use of local people
  - Path: Provided simple solutions

Motivating Change

- Direct the Rider (rational)
  - Education on the environmental impact of practice
  - Requires a champion
  - Find the bright spots – who does it well?
- Motivate the elephant (emotional)
  - Track individual and group performance – App?
    - Report time at variance from "optimal"
  - Report utilization in CO2 equivalents eg. miles driven or mpg
- Shape the Path
  - Technology is making it easier – 1st world solution
  - Need low cost solutions – simple formulas and technology

Summary

- “Green” management of anesthetic delivery
  - Reduces waste and cost
  - Confers environmental advantage
- Individuals can make a difference
  - Impact is multiplied by a lifetime of anesthetics (20,000+ for a busy career)
- Agent Selection
  - Isoflurane and Sevoflurane are preferred agents based upon GWP
  - Desflurane and N2O selected based upon clinical advantage

Summary

- Technology
  - Can make it easier to manage fresh gas flow and reduce waste
  - Expensive
- Additional Work
  - Simplify reporting systems
  - Document life cycle impact of anesthetics including GWP
  - ROI for delivery technology and waste management
  - Address the Regulatory hurdle in the US

Thank You