Volatile Anesthetics and Climate Change: How You Can Make a Difference

David Abts, MD
Assistant Professor, University of Colorado School of Medicine
Department of Anesthesiology
Denver Health Medical Center
March 1st, 2019

Goals
- Gain an understanding of the environmental impact of aspects of our anesthesia practice
- Address some clinical concerns of sevoflurane use
- Cost: does it play a role?
- Future directions in anesthesiology and healthcare at large

Global Climate Change
- Prominent in recent news cycles
- Will most likely only to continue to grow in profile and importance

The New York Times
Major Climate Report Describes a Strong Risk of Crisis as Early as 2040

- Intergovernmental Panel on Climate Change (IPCC)
- Group of UN-commissioned scientists to advise world leaders
- Report findings
  - Many climate change catastrophes are likely to be realized at 1.5 degree C rise
  - Likely to happen by 2040
  - To prevent, global greenhouse gas emissions must be reduced by 45% from 2010 levels by 2030
Global Warming Potentials

- GWP_{CO2} = measure of gas’ ability to trap heat compared with CO2 over 100 year time horizon
- Sevoflurane 130
- Isoflurane 510
- Desflurane 2540
- N2O 298
- CO2 1

Background

- Montreal Protocol 1987
  - Commitment to reduce ozone-depleting gases
  - After 1985 discovery of hole in ozone layer
- Kyoto Protocol 1997
  - Commitment to reduce greenhouse gases
  - Volatile anesthetics and N2O deemed medically necessary
  - No regulation regarding their use and disposal
  - OSHA standards for occupational exposure
  - Vented directly to atmosphere once they leave hospital

Definitions

- ODP = Ozone depleting potential
- GWP = Global warming potential
- GWP_{t} = Warming potential relative to CO2 for specified time period

BJA 2010

- Experimentally measured the IR spectra of the volatile anesthetics
- Further refined the calculated GWPs for the common volatile anesthetics

Calculated halogenated anesthetic contribution to radiative forcing of climate change

- Atmospheric window = Spectra of IR radiation leaving earth’s surface
- Radiative forcing = absorption spectra of a gas in earth’s atmospheric window → imbalance between IR radiation entering and leaving earth’s atmosphere
- Radiative forcing is dependent on the wavelength of gases’ absorption features

Set the stage for further atmospheric studies to follow
2011 A&A, Massachusetts General Hospital
Escalated concern for ecotoxicological consequences of our common anesthetic gases
Although erroneous on the subject of halogenated anesthetics (claimed all depleted ozone), brought attention to the dual ozone-depleting and global warming potential of N₂O
Also brought attention to scale at which N₂O is used → 20 tons at MGH in 2006, 35,000 tons nationally in healthcare sector

Assessing the Impact on Global Climate from General Anesthetic Gases
Mads P. Sulbaek Andersen, PhD, Ole J. Nielson, PhD, Timothy J. Wellington, PhD, Boris Kojochor, PhD, and Stanley P. Sanders, PhD

2012 A&A in response to 2011 Ichizawa article
Most up to date science on the GWP, radiative forcing and ODP of our volatile anesthetics, including N₂O
Reintroduced graph of absorption spectra of volatile anesthetics in context of "atmospheric window"

Life Cycle Greenhouse Gas Emissions of Anesthetic Drugs
Jodi Sherman, MD, Cathy Le, Vanessa Lamers, and Matthew Eckelmann, PhD

2012 A&A Study to examine the life cycle climate change impacts of 5 anesthetics drugs: Isoflurane, Desflurane, Sevoflurane, Nitrous oxide, Propofol
Cradle to grave approach used, examining resource extraction, drug manufacturing, transport to healthcare facilities, drug delivery to the patient, and disposal/emission to the environment
At each stage energy, material inputs and emissions were considered.
Emissions are calculated in CO₂ equivalents
Fresh gas flows are assumed to be 1L/min for desflurane and isoflurane, 2L/min for sevoflurane
N₂O is assumed to be administered in a 60% concentration

Life cycle GHG emissions for desflurane are 15x those of isoflurane and 20x those of sevoflurane
Isoflurane and sevoflurane have similar GHG emission profiles in O₂/air mixture – largely due to higher FGF rates in this analysis.
When co-administered with N₂O emissions for isoflurane increase by 65% and those for sevoflurane increase by 900%

2015 study examining the atmospheric content of halogenated volatile anesthetics
First study to estimate global warming contribution from each agent using “top down” analysis
Air samples drawn from 4 locations: icebreaker research vessel in the north Pacific, South Korea Antarctic station, Jungfraujoch Observatory (Switzerland), Dubendorf (suburban Zurich) from 2000-2014
Collectively, volatile anesthetics can have an appreciable impact on radiative forcing. In 2014, by this measurement, approximately 3.1 million tons of CO₂ equivalents were released into the atmosphere. Of which, approximately 80% was due to desflurane.

Healthcare Sector

- How significant are greenhouse gas emissions in context of the healthcare sector?
- How significant is the healthcare sector in terms of total national emissions?

### Table: One hour of anesthetic is like driving a car (how many?) miles

<table>
<thead>
<tr>
<th>Concentration (MAC-hr)</th>
<th>Sevoflurane (%),0.2</th>
<th>Desflurane (%),0.2</th>
<th>Enflurane (%),0.2</th>
<th>Isoflurane (%),0.2</th>
<th>N₂O (%),0.8 MAC-hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3 L/min</td>
<td>4</td>
<td>7</td>
<td>25</td>
<td>29</td>
<td>77</td>
</tr>
<tr>
<td>0.5 L/min</td>
<td>13</td>
<td>27</td>
<td>91</td>
<td>97</td>
<td>112</td>
</tr>
<tr>
<td>0.7 L/min</td>
<td>19</td>
<td>46</td>
<td>152</td>
<td>182</td>
<td>206</td>
</tr>
<tr>
<td>1.0 L/min</td>
<td>26</td>
<td>74</td>
<td>1,076</td>
<td>564</td>
<td>1,035</td>
</tr>
</tbody>
</table>

- Assumed EPR 2012 full-throttle speed of 25–30 miles per gallon
- Because N₂O cannot be burned at 100%, the near typical percentage of 80% is used. In combination, 0.8 MAC hour of N₂O produces deplete 3.95 MMT of CO₂.
- EPA: Environmental Protection Agency; MAC, Minimum Anesthetic Concentration; N₂O nitrous oxide

As of 2013, the US healthcare sector responsible for 10% of US GHG emissions

US healthcare emissions responsible for 400,000+ DALY's lost

Comparable impact to scope of preventable in-hospital deaths

### Research Letter

Estimate of the Carbon Footprint of the US Health Care Sector

- 2009 JAMA
- First attempt to estimate the carbon footprint of the US healthcare sector
- GHG emissions estimated using 2007 data on health expenditures published by the National Health Accounts Team
- In 2007 US healthcare sector accounted for 16% of GDP and 8% of GHG emissions
- For comparison, in 2004 NHS accounted for 3% of total UK CO₂ emissions

### Environmental Impacts of the U.S. Health Care System and Effects on Public Health

Matthew J. Eckelman, MD, PhD, and Jodi Sherman, MD

- As of 2013, the US healthcare sector responsible for 10% of US GHG emissions
- US healthcare emissions responsible for 400,000+ DALY's lost
- Comparable impact to scope of preventable in-hospital deaths
2017 study published in The Lancet
Examine the carbon footprint of the OR for three different hospitals in different healthcare systems for the year 2011
- Vancouver, Canada
- Minneapolis, USA
- Oxford, England

Study included three scopes
Scope 1: GHG emissions attributable to volatile anesthetics
Scope 2: GHG emissions attributable to energy consumption of the ORs
Scope 3: GHG emissions attributable to supply chain and waste

Table 1: Annual greenhouse gas emissions from volatile anesthetics

<table>
<thead>
<tr>
<th>Volume purchased (1/week)</th>
<th>CO2 (lb/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCM</td>
<td>UMMHC</td>
</tr>
<tr>
<td>Sevoflurane</td>
<td>591.7</td>
</tr>
<tr>
<td>Isoflurane</td>
<td>342</td>
</tr>
<tr>
<td>Enflurane</td>
<td>122</td>
</tr>
<tr>
<td>Total</td>
<td>2,936.72</td>
</tr>
</tbody>
</table>

CO2 calculated using 2015 Global Warming Potential (GWP) values of 250 for sevoflurane, 36 for isoflurane, and 1 for enflurane. *VCM (Vancouver General Hospital, UMMHC (University of Minnesota Medical Center), JHU (Johns Hopkins Hospital).

Table 2: Annual operating theatre energy expenditures and greenhouse gas emissions

<table>
<thead>
<tr>
<th>Energy (kWh/year)</th>
<th>CO2 (lb/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCM</td>
<td>UMMHC</td>
</tr>
<tr>
<td>Heating</td>
<td>215.8</td>
</tr>
<tr>
<td>Cooling</td>
<td>66</td>
</tr>
<tr>
<td>Ventilation</td>
<td>44.9</td>
</tr>
<tr>
<td>Lighting</td>
<td>2.96</td>
</tr>
<tr>
<td>Plug loads</td>
<td>113</td>
</tr>
<tr>
<td>Total</td>
<td>33.82</td>
</tr>
</tbody>
</table>

CO2 equivalents: VCM (Vancouver General Hospital, UMMHC (University of Minnesota Medical Center), JHU (Johns Hopkins Hospital). AV/SA and UMMHC, theatre lighting included plug loads and surgical spotlights, but non-operating lights, non-surgical lighting is reported separately based on lighting activity. All lighting was computed in Theatre submeters, hence only operational reported for both lighting only plug loads.
Study highlights importance of energy grid composition

For North American hospitals, volatile anesthetics were largest contributors to GHG emissions by far

- 10x that of JRH in England
- With 1/3 fewer cases performed
- ~20k cases at UMMC and VGH, ~30k cases at JRH
- Disparity can be accounted for by preferential use of desflurane at North American sites

Volatile Anesthetic Lifespans

- Sevoflurane 1.1 years
- Isoflurane 3.2 years
- Desflurane 14 years
- N₂O 114 years

Global Warming Potentials

- GWP₁₀₀ = measure of gas’ ability to trap heat compared with CO₂ over 100 year time horizon

- Sevoflurane 130
- Isoflurane 510
- Desflurane 2540
- N₂O 298
Sevoflurane

- **Advantages**
  - Smallest environmental burden defined by GWP and atmospheric lifetime
  - Instances of clinical advantage
    - Mask induction, pulmonary disease, etc

- **Disadvantages**
  - 2L/min minimum flow requirement, right?
  - Compound A – induced nephrotoxicity, right?

- **Cost?**

- **Sevoflurane approved for use by FDA in 1995**
- **Product insert/FDA website**

**WARNINGS**

Although data from controlled clinical studies at low flow rates are limited, findings taken from patient and animal studies suggest that there is a potential for renal injury which is presumed due to Compound A. Animal and human studies demonstrate that sevoflurane administered for more than 2 MAC hours and at fresh gas flow rates of < 2 L/min may be associated with proteinuria and glycosuria.

Sevoflurane may be associated with glycosuria and proteinuria when used for long procedures at low flow rates. The safety of low flow sevoflurane on renal function was evaluated in patients with normal preoperative renal function. One study compared sevoflurane (N = 98) to an active control (N = 90) administered for ≥ 2 hours at a fresh gas flow rate of ≤ 1 L/minute. Per study defined criteria, one patient in the sevoflurane group developed elevations of creatinine, in addition to glycosuria and proteinuria. This patient received sevoflurane at fresh gas flow rates of ≤ 800 mL/minute. Using these same criteria, there were no patients in the active control group who developed treatment emergent elevations in serum creatinine.


This is the evidence for their recommendation.
1997 A&A

Study of 12 healthy volunteers
½ to receive 8hr desflurane anesthetic, ½ to receive 8hr sevoflurane anesthetic, then switch (1.25 MAC)
7 volunteers completed study
Variety of laboratory tests run day of experiment and several days after to assess renal integrity


Some sevoflurane volunteers demonstrated renal microinjury
- Elevations in urine albumin, glucose, alpha-GST, pi-GST
- Neither anesthetic affected serum Cr or BUN
- Neither anesthetic affected volunteers’ ability to concentrate urine in response to vasopressin

In General
- Studies demonstrating compound A-mediated renal injury
  - Animal studies evaluated compound A directly, not sevoflurane
  - Human studies have all been small with a variety of confounding variables

Effect of total flow rate on the concentration of degradation products generated by reaction between sevoflurane and soda lime
H. Bito and K. Ikeda
- 1995 BJA
- 24 ASA 1-2 patients undergoing tympanoplasty
- Sevoflurane/N₂O anesthesia administered
- Compound A measured in circuit at different time points
- Patients randomized to 1L/min, 3L/min, 6L/min flows

Anesthesiology 1997
48 ASA 1-2 patients undergoing gastrectomy for gastric CA enrolled
- Randomized to either low-flow sevo (1L/min), high-flow sevo (6-10L/min), low-flow iso (1L/min)
- Baralyme CO₂ absorbant used (glass balls in high-flow sevo group), compound A concentrations measured throughout the case
- Blood samples obtained pre-op and on POD 1-3 to measure BUN/Cr
- 24hr Urine samples obtained pre-op and on POD 1-3 to measure Cr, N-acetyl-B-D-glucosaminidase (NAG), alanine aminopeptidase (AAP)

Effects of Low-flow Sevoflurane Anesthesia on Renal Function
Comparison with High-flow Sevoflurane Anesthesia and Low-flow Isoflurane Anesthesia
H. Bito et al. M.D., Yukako Kasumi, M.D., Kazuyuki Ikeda, M.D., F.R.C.A.1
- Anesthesiology 1997
- 48 ASA 1-2 patients undergoing gastrectomy for gastric CA enrolled
- Randomized to either low-flow sevo (1L/min), high-flow sevo (6-10L/min), low-flow iso (1L/min)
- Baralyme CO₂ absorbant used (glass balls in high-flow sevo group), compound A concentrations measured throughout the case
- Blood samples obtained pre-op and on POD 1-3 to measure BUN/Cr
- 24hr Urine samples obtained pre-op and on POD 1-3 to measure Cr, N-acetyl-B-D-glucosaminidase (NAG), alanine aminopeptidase (AAP)

Effects of Low-flow Sevoflurane Anesthesia on Renal Function
Comparison with High-flow Sevoflurane Anesthesia and Low-flow Isoflurane Anesthesia
Anesthesiology 1997; 86: 1231-7.
- Average concentration of compound A in low-flow sevo group 20ppm, which trended down over time
- Average case duration ~ 6hrs
- No differences amongst groups postoperatively
  - BUN decreased in all groups
  - Cr decreased POD 3 in sevo groups, not in iso group
  - CrCl increased in all groups
  - 24hr urinary NAG and AAP excretion increased in all groups

---


30 ASA 1-2 patients with head & neck CA scheduled to undergo surgery > 10hrs
Randomized to low-flow sevo (1L/min), high-flow sevo (6-10L/min), low-flow iso (1L/min)
Baralyme CO2 absorbant used (glass balls in high-flow sevo group), compound A concentrations measured throughout the case
Blood samples obtained pre-op and on POD 1-3, 5 to measure BUN/Cr, LFTs
24hr Urine samples obtained pre-op and on POD 1-3, 5 to measure Cr, N-acetyl-B-D-glucosaminidase (NAG), albumin, protein, glucose

---


- Average case duration 18 hrs (10-24hrs)
- Average compound A concentration in low-flow sevo group was 26ppm at 2hr
- Average AUC for compound A in low-flow sevo group 277ppm-hr (renal injury surmised to occur at 150-342ppm-h based on rat model)
- No increases in Cr, no decreases in CrCl,
- No differences amongst groups
- Increases in urinary excretion of protein, albumin, glucose, NAG, in all groups,
- No differences amongst groups

---


- 7 different modern CO2 absorbants tested in a patient model under dessicated and normally hydrated conditions
- Sevoflurane administered at FGF 0.5L/min for 3 hrs

---


- 40 patients ASA 1-3 randomized to either sevoflurane or desflurane anesthesia
- Cases lasted at least 90 minutes
- FGF maintained at 0.5L/min – 1L/min
- Compound A measured in circuit throughout case

2017 meta-analysis Medical Gas Research
• 6 RCTs included, 873 patients
• Sevoflurane compared to isoflurane
• Serum Cr/BUN, urinary protein and glucose evaluated
• No statistical differences identified between the two
• Conclusion: sevoflurane does not produce elevations in Cr and BUN


One last thing...
• Important to remember that much of the research was performed by entities with significant personal and corporate stake in the success of their product


• Significant body of evidence supports the safe use of sevoflurane in low-flow anesthesia
• Even in presence of strong bases (Baralyme – KOH), human compound-A mediated nephrotoxicity has not been demonstrated
• Studies that have demonstrated compound-A mediated nephrotoxicity have not had results repeated
• Newer CO2 absorbents contain only small fractions of strong bases → minimal compound-A production at low flows
• Strong argument can be made that 2L/min FGF FDA recommendation does not incorporate all relevant evidence

Cost
• Sevoflurane is expensive, right?
• Desflurane may be environmentally bad, but can we save $$$ with ultra low-flow anesthesia?
• There may be cost savings for many anesthesia departments
Cost of anaesthesia

- 1992 Dion published an equation in the CJA for calculating the costs of volatile anesthetics in clinical use.
- 1993, Loke and Shearer published an equation in CJA for calculating cost per MAC hour and a method for establishing cost equivalency.

Assuming everyone still uses 2L/min FGF sevoflurane, is there cost savings to using low-flow desflurane?
Where is the break even point for the two gases?

\[ \text{\$MAC hour}_{\text{des}} = \text{\$MAC hour}_{\text{sevo}} \]

**Desflurane**
- MAC = 6%
- MW = 168
- T = 312 K (39 C)
- Density (liquid) = 1.44 g/ml

**Sevoflurane**
- MAC = 2%
- MW = 200
- T = 294 K (21 C)
- Density (liquid) = 1.51 g/ml

Denver Health
- Sevoflurane = $X/ml
- Desflurane = $2.25X/ml
- FGF_d = 0.36 L/min

UCH
- Sevoflurane = $X/ml
- Desflurane = $1.86X/ml
- FGF_u = 0.43 L/min
VA
- Sevoflurane = $X/ml
- Desflurane = $1.73X/ml
- $FGF_d = 0.47 \text{ L/min}$

Childrens Hospital Colorado
- Sevoflurane = $X/ml$
- Desflurane = $2.1X/ml$
- $FGF_d = 0.38 \text{ L/min}$

Denver Health’s annual volatile anesthetic budget is approximately $300k
- January – September 2017
  - $230,097
- January – September 2018
  - $110,685
- This represents 53% savings 2018 over 2017 and 51% under projected annual budget
- Only intervention was majority of providers switching to sevoflurane as “default” volatile about 1/1/2018 (with 2L/min $FGF$ as practice habit)

Economic and Environmental Considerations During Low Fresh Gas Flow Volatile Agent Administration After Change to a Nonreactive Carbon Dioxide Absorbent
Richard H. Epstein, MD, CPRP, MD,* Franklin Decker, MD, PhD;† David F. Maguire, MD,* Yung K. Agarwala, DO, and David M. Gessle, DO
- 2016 Anesthesia & Analgesia
- Thomas Jefferson University
- Department of Anesthesia changed from Sodalime (NaOH containing) CO$_2$ absorbers to Litholyme (non-compound A forming) CO$_2$ absorbers
- All department providers instructed to reduce their FGFs during sevoflurane anesthetics to 1.25L/min, or less

- Savings on sevo administration ended up cost neutral with extra cost of litholyme absorbent
  - Attributed to practice inertia (providers not reducing their flows to goal)
  - Imprecision in sevoflurane ordering (lag time, extra storage)
  - Did prove to be at least cost neutral

Hypothesis tested
- The cost savings from reduced sevo consumption would modestly exceed the incremental cost of premium CO$_2$ absorbent
While multiple factors determine overall cost, it is likely that for many institutions, transitioning away from preferential desflurane use represents potentially significant cost savings.

It can be fairly simple to calculate cost savings, or cost neutrality should an institution decide to optimize its OR carbon footprint.

**Counter Argument**

- “Drop in the bucket”
- Patient safety
- I’ll practice how I want to

**A Different Perspective on Anesthetics and Climate Change**

- A&A Editorial 2013
  - “The overall contribution of inhalational anesthetics to greenhouse gas emissions is miniscule…” approximately 0.01% of that of the CO₂ released by global fossil fuel combustion.”
  - This comes from a study which extrapolated the emissions from University of Michigan to global emissions
  - Little des used at UM (6L), did not account for N₂O, did not account for life cycle assessments
  - “We believe the notion that miniscule impact on the environment compares with clinical issues such as cardioprotection, airway irritability, rapidity of recovery, and cost is inappropriate.”

**Table**

- **Sensitivity Analysis of Cost Savings**

<table>
<thead>
<tr>
<th>Estimated annual increase in absorbent cost (US$)</th>
<th>Estimated annual increase in absorbent cost (US$)</th>
<th>Estimated annual increase in absorbent cost (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5000</td>
<td>10000</td>
</tr>
<tr>
<td>5000</td>
<td>0</td>
<td>5000</td>
</tr>
<tr>
<td>10000</td>
<td>5000</td>
<td>0</td>
</tr>
</tbody>
</table>

- **Chart**

  - Sensitivity Analysis of Cost Savings

- **Figure**

  - An image showing the sensitivity analysis of cost savings.
Future Directions

- N₂O destruction
- Waste anesthetic gas reclamation
- Novel volatile anesthetics
- Common sense strategies for personal practice

Decreased emission of nitrous oxide from delivery wards—case study in Sweden

- N₂O
- N₂O can be catalytically split \( \rightarrow \) N₂ + O₂
- Commercial system for this exists (Anesclean®)
- System employed on L&D ward at Karolinska University Hospital, Stockholm Sweden
- 95% of collected N₂O catalytically destroyed
- LCA showed GHG benefit to system

Waste anesthetic gas (WAG) reclamation

- Blue-Zone Technologies (Toronto, ON) produces a system \( \rightarrow \) Deltasorb®, Centralsorb® to capture VAs at the level of the machine, or central HVAC system
- Allow for desorption of halogenated agents as liquids for potential processing and reuse.
- System in place in some Canadian hospitals
- Not yet FDA approved

Novel Volatile Anesthetics

- Xenon
- Noble gas with profound analgesic effects, neuroprotection, hemodynamic stability, low blood-gas partition coefficient
- No known detrimental ecotoxocoligical effects
- Limited by high cost and energy consumption of fractional distillation of liquid air
- Use would only be possible in closed circuit system with reclamation of gas

Managing fresh gas flows

- Aim for 1L/min FGF if using sevoflurane for maintenance of anesthesia
- If using isoflurane or desflurane, aim for closed-circuit maintenance of anesthesia
  - Calculate O₂ consumption \( \sim \) 5ml O₂/kg/min
  - Minimum FGF = O₂ consumption (O₂ flow + 21% air flow) + leaks
- During intubation, reduce FGF to zero
- Turn vaporizer off before increasing FGF for emergence

Managing fresh gas flows

- Aim for 1L/min FGF if using sevoflurane for maintenance of anesthesia
- If using isoflurane or desflurane, aim for closed-circuit maintenance of anesthesia
  - Calculate O₂ consumption \( \sim \) 5ml O₂/kg/min
  - Minimum FGF = O₂ consumption (O₂ flow + 21% air flow) + leaks
- During intubation, reduce FGF to zero
- Turn vaporizer off before increasing FGF for emergence
According to US Energy Information Administration, healthcare sector is second largest energy consumer

- Inpatient facility, notably perioperative care, consuming the most
- As physicians we have been called to a life of stewardship
- As anesthesiologists, we have the ability to expand our advances in patient safety and individual outcomes to include the world we live in
- We are uniquely positioned for leadership in the area of sustainability

Some Good News

- In 2018, Denver Health reduced its volatile anesthetic associated GHG emissions by ~80%
- Overall perioperative GHG emissions were reduced by approximately 40%
- We have almost reached our 45% reduction in carbon emissions!

Summary

- Differences exist amongst anesthetics regarding environmental impact
  - Sevoflurane > Isoflurane > N2O > Desflurane
- Safety concerns about sevoflurane haven’t been supported by research
- Significant cost savings are likely with reduction in desflurane use
- Anesthesia is uniquely positioned to impact health from patient to global level through our decision making

Thank You

- Special thanks
  - Lisa Chirico
  - Clark Lyda
  - Mario Villasenor
  - April Ort
  - Paul Scott

Resources


14) Anesthesiology News. April, 2017


30) Berkow, L., Sherman J. The Value of Environmental Sustainability in Anesthesia. JAA Monitor. 2018; 82,4:8-10.
