Greening the Operating Room and Perioperative Arena: Environmental Sustainability for Anesthesia Practice
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Did you know?

- Operating rooms generate 20–30 percent of total hospital waste.
- Inhaled anesthetics are potent greenhouse gases.
- Many anesthesia equipment and facility design choices can have significant environmental impact.

According to a study from the University of Chicago, the health care sector accounts for 8 percent of the United States total greenhouse gas emissions. The investigators took into account the contribution generated by hospital activities, research and the production and distribution of pharmaceuticals. The analysis found that hospitals by far were the largest contributors of carbon emissions. Although the findings are worrisome, they suggest that greener health care delivery will have a large positive impact on our environment.

The Committee on Equipment and Facilities is advocating for increased environmental consciousness in our practices and the facilities in which we work. Physician anesthesiologists can lead by improving operating room design, anesthetic agent choice and management, and waste disposal and diversion, and can mitigate the negative environmental effect of anesthetic practice in all its forms. Like other industries, the environmental impact of our practice, if left unchecked, could trigger government regulation. Physician anesthesiologists, surgeons and health care administrators are best positioned to reduce the negative impact our practice has on the environment by proactively examining these issues. Physician anesthesiologists have an opportunity, through education and research, to lead the development of hospital initiatives that foster environmentally friendly policies and programs.²


2. This document has been developed by the ASA Committee on Equipment and Facilities but has not been reviewed or approved as a practice parameter or policy statement by the ASA House of Delegates. Variances from recommendations contained in this document may be acceptable based on the judgment of the responsible physician anesthesiologist. The recommendations are designed to encourage quality patient care and safety in the workplace but cannot guarantee a specific outcome. They are subject to revision from time to time as warranted by the availability of new information.

This document is intended to be informative on the subject matter covered and is not intended to provide specific legal or professional advice.

Please address questions or comments on this document to Susan Ryan at: ryans@anesthesia.ucsf.edu.
Sustainability issues can be addressed by looking closely at the following areas:

1. Anesthesia Equipment Choices
2. Inhaled Anesthetics
3. Fresh Gas Flow Management
4. Intravenous Pharmaceuticals
5. Waste Stream and Recycling
6. Donations
7. Green Meetings/Events
8. Perioperative and O.R. Design and Management

The Perioperative Greening Manual Appendix A provides a general method for implementation of sustainable changes (recycling in particular).

Additional Web Sources of Health Care Sustainability Information are also provided.

1. Anesthetic Equipment Choices

Introduction

Hospitals in the U.S. produce approximately 5.9 million tons of medical waste annually – with about one-third of this originating in operating rooms.1 Much of this is from surgical care; however, anesthesia contributes substantially as well.

Understandably, anesthesia is an equipment-intensive and waste-intensive specialty since all equipment must be clean to various standards, if not sterile. Partially for this reason, the trend has been toward an increase in disposable equipment – though other choices often exist, including reusable and reprocessed equipment. On the face of it, disposable equipment appears to be a very wasteful option, ecologically or “sustainably” speaking, since this practice leads to greater natural resource and manufacturing utilization, and landfill or incineration. However, assumption alone is not enough: sustainability must be examined as carefully as any other factor. To achieve the triple bottom line (cost, safety, sustainability) as often as possible, there must be a quantifiable analysis of sustainability as well as cost and safety.

Life Cycle Assessment: Cradle to Grave Analysis

Environmental impacts require quantification in order for physician anesthesiologists to begin to factor environmental impacts into clinical decision-making. Life cycle assessment (LCA) is an internationally accepted scientific method (ISO 14000) of such quantification.2 LCA applications range from basic materials (e.g., chemicals), to familiar products (e.g., Coca-Cola bottles), complex technological processes (e.g., automobiles), entire infrastructures and sectors of the economy that contribute significantly to impacts – enabling comparison of related products along environmental dimensions.

LCA begins with an inventory of all the inputs at each “life” stage including 1) raw material extraction; 2) refining and manufacturing; 3) packaging and transportation; 4) use, reuse and maintenance; 5) recycling; and 6) waste disposal. Several LCA impact categories exist, such as CO2 emissions, human health (e.g., carcinogenesis, respiratory disease) and ecosystem disruption (e.g., eutrophication or promotion of algae growth). Comparisons between items may indicate relative advantages for one outcome (e.g., CO2 emissions), which may be contrary to other outcomes (e.g., water use), and prioritization of risks and benefits must be considered. Importantly, LCA is specific to geographic regions – as energy sources and shipping requirements vary accordingly.

For example, whether electricity comes from coal or a cleaner source, such as wind power, it can tilt a life cycle assessment toward a different conclusion or option. Thus, care must be taken to extrapolate findings appropriately.

LCA applications to health care, thus far, have included areas as diverse as hemodialysis practices, nonsurgical management approaches to acute myocardial infarction management,4 and anesthetic drugs (see Inhaled Anesthetics section) and devices.5-9

Likely, LCAs will become more available for a variety of health care situations and can be utilized to guide procurement and processing decision-making. The United Kingdom’s National Health Service, in recognition of the critical importance of including environmental and greenhouse gas impacts into medical decision making, has just instituted a comprehensive medical sector guidance document for the evaluation of pharmaceutical and medical device products that incorporates LCA.10

Disposable Versus Reusable Equipment

Many types of anesthesia equipment may be purchased in a disposable or reusable form. Traditionally, the choice focused on cost, patient safety, efficacy and ease of use – however, has not included environmental consideration. Both disposable and reusable selections have potential to harm the environment, and both present tradeoffs. Disposable laryngoscope blades offer a good example of how complex the disposable/reusable decision can be. Disposable blades have become increasingly popular because they eliminate the risk of cross contamination between patients more easily. They eliminate the dollar and ecological costs of cleaning that involve labor and natural resources. Further, reusable items sometimes involve cleaning and disinfecting solutions that may be toxic to the environment. On the other hand, reusable blades may provide higher quality and reliability. Environmentally speaking, they avoid the ongoing carbon footprint of manufacturing and the substantial bulk waste that disposables contribute to landfill or incinerators (where toxins are released into the atmosphere). Importantly, the environmental impact and dollar cost of manufacturing, disposal and waste
management have not typically been considered in the purchase of disposable items – both because LCAs have not been available and because many purchasing departments do not figure future dollar savings in the total cost of reusable equipment. Full analyses may favor reusable items more often than is currently thought. A recent LCA study at Yale compared the environmental and dollar costs of various combinations of disposable and reusable laryngoscope handles and blades (cleaned to CDC specifications). They found that the environmental costs of the reusable handle/blade combination were approximately 1.5 to 7 times lower than those of the disposable handle/blade combination (with a wide spread of environmental cost savings due to various materials and cleaning methods used in multiple combinations, as well as disposable/reusable combinations and materials). Using a reusable (multiuse) handle reduced the environmental cost most significantly. Further, the annual direct cost savings totaled between $500,000 to well over $1 million (again, depending on disposable/reusable combinations and materials). Eckelman, et al., performed an LCA comparing reusable versus disposable LMAs at Yale-New Haven Hospital and demonstrated that reusables fared better on every impact category considered. Similarly, three LCAs of surgical equipment from Germany found lower CO2 equivalents and water use in reusable options. However, McGain, et al., found that although reusable and sterilized CVP kits were less expensive, they were environmentally much more costly – both in terms of CO2, emission equivalents and water use. Their article also compares electricity sources from Australia, Europe and the U.S. – showing great variability. They point out that the German surgical equipment LCAs included nuclear energy as opposed to coal (Australia) – accounting for some of the differences.

Life cycle assessments and environmental considerations within cost evaluation involve a relatively new and more inclusive perspective in the field of health care purchasing – particularly in the operating rooms. What are we able to conclude at this early point in this method’s use in health care and perioperative settings? LCAs definitely offer a method that can improve environmental purchasing. Further, they can point not only toward the most sustainable current product – they should provide an avenue to improve future choices. Though there are many variables involved, an LCA allows identification of the significant environmental costs – allowing a parsing out of possible manufacturing, cleaning, practice or disposal changes that could improve the environmental profile. Therefore, it seems reasonable not only to preferentially purchase reusable equipment where LCAs support this but also to investigate ways to improve the profiles of other reusable equipment (improved efficiency of autoclaving, for instance) – since disposable equipment will always have undesirable, ongoing manufacturing and disposal impacts.

Reusable and disposable equipment are not the only options available. Over the last 15 years, a new option has evolved: reprocessing.

Reprocessed Equipment

Reprocessing refers to a cleaning and resale process for single-use devices (SUDs) that are mechanically suitable for reuse. Quite often, SUDs are only designated “single-use” by the manufacturer. In many countries, SUDs are routinely considered reusable equipment. More recently, in the United States, reprocessing companies have begun to formalize and certify this strategy. They accept recently used equipment from hospitals, such as laparoscopic equipment, then proceed to 1) clean, 2) test and insure equipment is acceptable by FDA standards, 3) sterilize/clean, and 4) resell. Resale price can be as low as 50-60 percent of the original equipment price, offering substantial cost savings. Many individual hospitals and hospital systems have recorded dollar and environmental cost savings. For example, The University of Washington hospitals in Seattle saved $496,123 and diverted 5.8 tons of waste from landfill in one year by reprocessing over 100 types of SUDs. A larger corporation, Hospital Corporation of America (163 member hospitals), saved $17.6 million and diverted 298 tons of waste from landfill in 2010. Examples of items that are currently reprocessed include: pulse oximeter probes, laryngeal mask airways, blood pressure cuffs, hundreds of surgical instruments including laparoscopic surgical trocars, and sequential compression devices.

Government Oversight of Reprocessed Equipment

Reprocessing of equipment, especially invasive surgical devices, may raise concerns about performance and adequacy of sterilization. The Food and Drug Administration (FDA) currently requires that the reprocessing entity submit to a number of regulations and state in writing that the reprocessed medical device is “substantially equivalent” to the original equipment. Approximately 65-75 percent of reprocessed SUDs fall into Class II (medium risk), which requires submission to the FDA of a premarket notification report. The reprocessing entity must provide evidence of equivalence to the original device already on the market in terms of safety, effectiveness and intended use. Class II devices include pulse oximeter sensors, ultrasound catheters, drills, compression sleeves and most laparoscopic equipment. Because of safety concerns about the equivalency of SUDs, many physicians and other interested parties have lobbied for legislation requiring written patient consent, documentation of all reprocessed SUDs used during treatment and stricter systems of tracking SUD failures and injuries, while holding reprocessors fully liable for any adverse events.
The government has responded to these concerns by conducting several investigations and hearings about the reprocessing of SUDs and has introduced stricter regulations at all levels of production. Most notably, the Medical Device User Fee and Modernization Act (MDUFMA) of 2002 requires that all reprocessed SUDs be labeled and have the identification of the reprocessor company. All adverse events can be more easily tracked and reported to the FDA. MDUFMA also created more stringent FDA oversight of reprocessed SUDs. In January 2008, the U.S. Government Accountability Office (GAO) released a report indicating that reprocessed SUDs do not present an increased health risk to patients. Of the 434 adverse events reported to the FDA between 2003 and 2006 in which reprocessed SUDs were identified, only 65 actually involved a reprocessed device and all adverse events were similar to those reported for new devices.

Some of the companies offering reprocessed equipment are dedicated to this option alone. However, some major companies now offer both new/disposable and reprocessed equipment. Their argument is that contracting with an original equipment provider may ensure that the clinical performance is backed by the original source.

To date, independent studies have not addressed the sustainability of reprocessed anesthesia equipment in comparison with new or reusable equipment. Though this option seems sustainable because equipment is reused, there are clearly costs: Reprocessing equipment involves cleaning/autoclaving (environmental costs similar to reusable equipment), some repair and testing (environmental costs similar to new equipment) and additional transportation (a manufacturing type of environmental cost). Further, these costs are in addition to the original manufacturing environmental costs. Though dollar cost savings are clear, to consider this process clearly superior to other options in terms of sustainability is premature. It seems likely to be more sustainable when avoiding de novo manufacturing of complex surgical equipment; this is not so clear with more simple equipment. LCA confirmation for a number of products will be important.

**Reformulation**

Small equipment in operating rooms for both surgery and anesthesia often comes packaged as kits. This is extremely efficient for individual patients and surgeries, but kits may often contain equipment that is opened but not utilized. When single-use kits such as central venous line equipment from manufacturers are necessary, but include unnecessary plastic or other materials, a more sustainable option may be to work with vendors to reformulate or streamline the kit. When kits have been assembled by central supply, such as a surgical pack for a particular operation or an arterial line placement kit for physician anesthesiologists, the same reformulation option apply. Many hospitals have recorded environmental and dollar cost savings by reexamining their own equipment kits.13

**The Environmental Impact of Manufacturing and Disposing of Large Anesthesia Equipment**

The assembly of anesthesia machines and monitors continues to have a negative environmental impact. Machines and monitors are composed of metals, molded plastics and computer parts. Manufacturing and finishing of both metals and plastics often involves the release of environmental toxin. In 2008, the EPA amended the Clean Air Act adding National Emission Standards for Hazardous Air Pollutants (NESHAP). The legislation targets air pollution from nine metals, including cadmium, chromium, lead, manganese and nickel, which are often emitted into the air from various operations at metal and electronic fabrication and finishing plants. The computer industry uses over a thousand hazardous substances in the manufacturing of computer chips. Since these devices are manufactured in many locations around the world, there will need to be global cooperation from governments to reduce the resulting toxic wastes.

The disposal of monitoring equipment, computers and anesthesia machines also poses problems for the environment. Chip factories in Silicon Valley have left a legacy of pollution, creating 29 superfund sites in Santa Clara County alone. However, machines and monitors contain recyclable metals such as stainless steel, aluminum, brass, zinc, nickel and copper. The challenge is to separate the recyclable metals from the non-reusable materials. It is important to arrange environmentally preferable disposal with hospital waste management. An independent metal recycling facility may be more successful at recovering metal parts. Older anesthesia machines and monitors can also be refurbished and sold to a lab, another health care facility or veterinary clinic. There are also medical missions that will accept used equipment. Contracts can be negotiated that include taking back old equipment for refurbishing and donation, repurposing of parts, or recycling to a third-party verified green vendor.

**Batteries**

A variety of batteries used in many pieces of anesthesia and medical equipment are acceptable for current recycling programs. This is because of the passage of the Mercury-Containing and Rechargeable Battery Management Act (The Battery Act) by the federal government in 1996. This act required that all states comply and establish programs for the collection, transport and disposal of environmentally hazardous rechargeable batteries. In addition, all nickel-cadmium (Ni-Cd) batteries and lead acid batteries must be labeled with the universal recycling symbol of
three chasing arrows that form a triangle, a phrase stating the batteries must be recycled and a mandate that the rechargeable batteries be easily removable for purposes of proper disposal. The law led to the replacement of Ni-Cd batteries with lithium-ion (Li-ion) batteries. Although the toxic cadmium has been removed, these rechargeable batteries can be recycled through the Rechargeable Battery Management Act programs. Lead acid batteries that are used in anesthesia machines and other hospital equipment must be recycled. If machines are serviced under the manufacturers’ service contract, batteries will be properly recycled according to protocol. If machines are serviced in-house or by other companies, more effort may be required to insure proper handling of these toxic materials. Lead acid battery reuse leads the recycling effort with 98 percent of lead acid batteries being recycled in the United States.

The Battery Act also required that mercury be removed from disposable batteries making them safe for disposal in regular trash. Many businesses however recycle disposable alkaline batteries such AAA, AA, C, D and 9-volt batteries because they contain trace amounts of hazardous metals and because the metal part of the batteries are recyclable. Some states have adopted laws requiring disposable battery recycling. There are mail-in programs that can be used to recycle disposable batteries.

References:

2. The Environmental Impact of Inhaled Anesthetics

Inhaled Anesthetics are Greenhouse Gases

Potent inhaled anesthetics and nitrous oxide are greenhouse gases (GHG).1,2,3 Nitrous oxide, as well as being a greenhouse gas, is also destructive to the ozone layer.4 Since global warming potential (GWP) of airborne agents is currently under government scrutiny, many industries that emit GHG continue to search for low impact replacement compounds. Anesthetic gas emission into the greater atmosphere is not regulated partly because these agents are considered to be medically essential and because they were originally thought to make a negligible contribution to GHG and climate change. However, inhaled anesthetic use has expanded in the last 30 years and desflurane, in particular, has potentially greater environmental impact than older or alternative agents. Several recent studies have compared the relative environmental impact of various agents, and began to consider ways to minimize this aspect of our anesthesia environmental footprint.

The Global Warming Potential and Atmospheric Lifetime of Inhaled Anesthetics

The degree to which each anesthetic agent will act as a GHG depends on both its unique infrared absorption spectrum and its atmospheric lifetime. The gas warms the atmosphere when absorbed radiation is reemitted as heat, and a longer lifetime allows continued atmospheric warming. Because inhaled anesthetic agents undergo minimal in vivo metabolism (except the older agent halothane), the vast majority of exhaled gases remains intact and is routinely vented into the atmosphere through scavenger systems. The effect of the inhaled agent on the environment will remain until the gas undergoes degradation in the atmosphere.
The lifetime of newer potent inhaled agents is about one to 14 years. Nitrous oxide has a much longer atmospheric lifetime of 114 years.

GWP is a measure of how much a given mass of greenhouse gas contributes to global warming over a specified period of time. The Intergovernmental Panel on Climate Change uses 100 years; however, 20, 50, 500 years are common as well, depending on the gas in question. GWP is a relative scale that compares the contribution of the gas in question to that of the same mass of carbon dioxide. The GWP of carbon dioxide, by definition, is one. Desflurane has the highest GWP100 at 2,540 and is followed by isoflurane at 510 and sevoflurane at 130.

**Anesthetic Choice and Management Can Decrease Environmental Impact**

The impact of inhaled anesthetic agents on the environment will depend on the total annual consumption (the amount used and released to the atmosphere) and the relative rates of use of higher versus lower GWP agents. Annual consumption depends on the fresh gas flow rate, the use of nitrous oxide and the potency (MAC) of the agent being delivered in conjunction with the GWP. High fresh gas flows increase the effect of all volatile agents on the environment by releasing greater quantities of the agents to the atmosphere. Nitrous oxide will decrease the amount of volatile agent required, but this positive impact will be more than offset by the long atmospheric half-life of nitrous oxide allowing prolonged damage as a greenhouse gas and by its destruction of the ozone layer. Finally, a higher MAC (lower potency) means greater quantities of gas must be used relative to other gases at similar fresh gas flows. This is a key component that may be overlooked. For instance, nitrous oxide has a relatively low GWP, but it is usually used at 40-60 percent, thereby increasing the impact. Also, desflurane has a high GWP but also requires three to six times the quantity that sevoflurane or isoflurane would (assuming similar fresh gas flows) because a MAC requires 6 percent (desflurane) compared with 2 percent (sevoflurane) or 1.2 percent (isoflurane). See Table I following this section for GWP values and relative contribution of these gases.

Recently, a full comparative life cycle analysis was conducted for inhaled agents and propofol. This entails an assessment of environmental cost expressed as carbon dioxide footprint that examines all contributions from manufacturing through delivery and disposal. Scavenged anesthetic emissions (waste greenhouse gas emissions) constituted the overwhelming portion of the eco-footprint of inhaled anesthetics, with other aspects of manufacturing and delivery being very secondary. The full desflurane footprint was 15 times greater than isoflurane and 20 times greater than sevoflurane. This analysis uses 2L fresh gas flow for sevoflurane and 1L fresh gas flow for desflurane and isoflurane – and results would obviously be influenced by a change in flows. Nitrous oxide use increased each footprint significantly, both because of nitrous released into the atmosphere as a waste gas and because of nitrous manufacturing environmental costs. The authors, Dr. Sherman and colleagues, concluded that, in order to minimize environmental impact, desflurane and nitrous oxide should be reserved for cases where these agents are clearly preferred for clinical reasons, and other types of anesthetics such as intravenous agents and neuraxial blocks should be considered when appropriate. The propofol footprint, in their analysis, was four orders of magnitude lower than inhaled agents.

Dr. Sulbaek Andersen and colleagues agree that, all other considerations being equal, one might choose an inhaled agent with a lower environmental cost. However, they point out that this contribution to GHGs is minor compared to other sources, such as coal. They did, however, base their conclusions on the University of Michigan practice, which uses very little desflurane. This brings up two issues: First, the contribution to GHGs can be very low when desflurane is avoided. Second, the larger issue of which environmental practices are worth addressing is always controversial. There are many minor contributing gases or practices that alone are not considered significant but when added up may constitute a major contribution. This issue calls for individual practitioners to evaluate and balance their clinical practice patterns (not just inhaled anesthetic use) in the light of the available environmental, cost and safety information.

Another way to appreciate the eco-footprint of inhaled anesthetics is to examine individual daily practice. Table I following this section highlights: 1) differences between agents, 2) importance of avoiding wasteful higher fresh gas flows, and 3) comparison between anesthetic use and automobile emissions. This provides a yardstick from our daily lives and may assist physician anesthesiologists considering practice changes. The format is adapted from Ryan and Nielsen, utilizing the most recently calculated anesthetic lifetimes and GWPs from Sulbaek-Andersen et al. and a 2011 Environmental Protection Agency approximate calculation for U.S. automobile emissions. The use of desflurane for one hour results in the equivalent GHG effect of driving 200 to 400 miles (or 1,600 to 3,200 miles is equivalent to use of desflurane for one 8-hour-use day) compared with eight to 18 miles of driving per hour of use of sevoflurane or isoflurane (or 64–144 miles of driving per 8-hour-use day) (these computations all assume 1 MAC and compare similar fresh gas flows). This is calculated for the effect of one day’s use over the 100-year time frame; however, consider that quite a bit of additional inhaled anesthetic will be used over the hundred-year period.
Reduce Anesthetic Waste and Capture and Reuse Anesthetic Agents

A relatively simple way to reduce and reuse anesthetic agents is to utilize low fresh gas flows during the maintenance phase of the anesthetic (see section by Dr. Feldman on lower flow anesthesia). Preventing the scavenged agents from being released into the atmosphere can also reduce environmental impact. Development of systems to collect and reuse anesthetic gases is under way. One system currently available for commercial use in Canada uses a filter in a canister placed in the scavenging system of the anesthesia machine to adsorb the anesthetic. These canisters are later collected and the anesthetic retrieved and purified at a company facility. Another system in development cold-condenses the anesthetic from several anesthesia machines in special connected scavenging systems that lead to a common collection location. The goal of both enterprises is to produce generic anesthetics for reuse and resale. Full life cycle analyses of these retrieval and reuse processes have not yet been performed.

References:

3. Managing Fresh Gas Flow to Reduce Environmental Contamination

Introduction
When using a circle anesthesia system, any anesthetic gases and vapors that enter the scavenging system will flow through the hospital vacuum system and ultimately be vented outside the hospital to the atmosphere. The total fresh gas flow determines the amount of gas entering the scavenging system per minute. Whenever fresh gas flow exceeds the patient’s requirement, gases and vapors will enter the scavenging system and ultimately contaminate the atmosphere. By choosing the minimal total fresh gas flow, the environmental impact of anesthetic vapors and gases can be minimized. Although the environmental impact of a single case may be minimal, every practitioner can make a significant difference over the thousands of procedures during their career by practicing careful fresh gas flow management for each case. There are three strategies to minimize fresh gas flow and environmental contamination. To implement these strategies, it is important to understand how to utilize anesthetic agent and oxygen concentration monitors to safely deliver the minimum fresh gas flow.

<table>
<thead>
<tr>
<th>Table I. Greenhouse Gas Emissions of Common Inhaled Anesthetic Agents</th>
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<tr>
<td>1 MAC inhaled agent at various Fresh Gas Flows (FGF)</td>
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<td></td>
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<tr>
<td>Sevoflurane 2% 2L FGF</td>
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<td>Isoflurane 1.2% 2L FGF</td>
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<td>Desflurane 6% 2L FGF</td>
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<td>Desflurane 6% 1L FGF</td>
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<td>60 % nitrous oxide alone at 1L fresh gas flow</td>
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ENVIRONMENTAL SUSTAINABILITY FOR ANESTHESIA PRACTICE

Which Monitoring is Essential?
The ability to continuously measure inspired and expired oxygen and vapor concentrations is essential to safe and effective management of fresh gas flow. Minimizing environmental contamination requires fresh gas flows be reduced to match what the patient consumes as closely as possible. As fresh gas flow is reduced, increased time is required for the concentration of gases and vapors in the circuit to change when the vaporizer setting is adjusted or the fresh gas flows altered. There is, therefore, a risk of inadequate anesthetic concentration, especially during the early part of the anesthetic when there is significant uptake of anesthetic from the lungs. The exhaled concentration of vapor measured by the gas analyzer is the closest approximation to the alveolar concentration and should be used to estimate the current MAC value for a patient. Further, it is possible to reduce waste by using low fresh gas flows and setting the vaporizer to deliver a concentration greater than desired as long as the agent analyzer indicates an adequate anesthetic concentration in the circuit. Oxygen monitoring is critical to minimizing fresh gas flow since it is possible to set the total oxygen flow to be less than the patient’s oxygen consumption which will result in a progressive decrease in the oxygen concentration in the circuit and ultimately lead to hypoxemia.

What is the Minimum Safe Fresh Gas Flow?
It is only necessary to use a high fresh gas flow when a rapid change in the concentration of anesthetic vapor or gases is desired, most commonly during induction or emergence. Once the desired concentration of anesthetic vapor has been established in the circuit, it is possible to reduce the fresh gas flow. The maintenance phase of a procedure is often the longest part of the procedure and typically does not require rapid changes in gas concentrations. The maintenance phase, therefore, is the best opportunity to minimize fresh gas flow.

The minimum safe fresh gas flow supplies enough oxygen to satisfy the patient’s oxygen consumption, plus enough additional gas flow to replace gases lost due to leaks in the circuit and/or via a sidestream gas analyzer. Oxygen consumption during anesthesia varies between patients and even phases of the anesthetic. Using 5 mL/kg/minute as a rough estimate of oxygen consumption, an adult male (70 kg) will use 350 mL of oxygen per minute. If we assume there are no leaks from the circuit, a fresh gas flow of oxygen of 350 mL/minute is all that is required. Any greater fresh gas flow will spill the excess gas into the scavenging system and ultimately the environment. If the estimate of oxygen consumption is too low, the concentration of oxygen in the circuit will progressively diminish. Measuring the inspired oxygen concentration will be a guide to increasing oxygen flow so that the desired concentration in the circuit is maintained. From a practical perspective, if air or nitrous oxide is delivered along with oxygen, one cannot eliminate environmental contamination completely since the nitrogen in air, or the nitrous oxide flow that exceeds oxygen consumption, will ultimately displace an equivalent amount of gas out the scavenging system.

Leaks (or potential leaks) from the circuit need to be considered to determine the minimum safe fresh gas flow. True leaks from the circuit should be minimal when the anesthesia machine and breathing circuit have passed a leak test check during machine setup for the case. If one is using a sidestream gas analyzer that does not return gas to the circuit, add 200 mL/min to the calculated oxygen consumption. Another 100 mL/min should be added to determine the target fresh gas flow to accommodate any leaks from the circuit.

Strategy #1: Minimize Fresh Gas Flow During Maintenance

With this background, the first strategy to reduce the environmental impact of anesthetic vapors is to minimize the fresh gas flow during the maintenance phase of the case. As an example of a low, or minimal, flow anesthetic technique, consider a case of a 70 kg male requiring general anesthesia. Following intravenous induction, isoflurane was administered using oxygen and air at 2 L/min each for a total fresh gas flow of 4 L/min. Once the exhaled concentration of isoflurane is close to the inspired concentration, uptake from the lungs has slowed and the fresh gas flow can be reduced. Assuming oxygen consumption to be about 350 mL/min, the oxygen flow can be set to 350 mL/min. The air flowmeter can be set at 500 mL/min which would deliver an additional 105 mL/min of oxygen and the total fresh gas flow will be less than 1 L/min. If nitrous oxide is used, the oxygen flowmeter should be set to 500 mL/min at a minimum and nitrous oxide at 500 mL/min.

Managing this technique requires that the inspired oxygen concentration be monitored. If oxygen consumption exceeds the total oxygen delivered, the inspired oxygen concentration will diminish over time, which will be an indication that oxygen flow needs to be increased. There is still some environmental contamination with this technique, since the total fresh gas flow exceeds what is consumed, but it is easier to manage than a true “closed circuit” technique. Unless the patient has a large oxygen consumption (e.g., trauma, pregnancy) it should be possible during the maintenance phase of anesthesia to limit the fresh gas flow to a maximum of 1 L/minute. For smaller patients with even lower oxygen consumption requirements, the maintenance fresh gas flow can be reduced even further with the same caveat of monitoring inspired oxygen concentration.
Strategy #2: Turn Off the Fresh Gas Flow, Not the Vaporizer, During Intubation

One of the common practices during the induction phase of anesthesia is to use a high fresh gas flow while mask ventilating the patient and turn off the vaporizer while intubating the patient. The goal of this practice is to avoid contaminating the operating room with anesthetic vapor. In reality however, the anesthetic vapor that has accumulated in the circuit during mask ventilation, is washed into the room by the fresh gas flow. Room contamination is not avoided and the vapor in the circuit is wasted. Alternatively, one can turn off the fresh gas flow during intubation and leave the vaporizer on. In the absence of fresh gas flow, none of the anesthetic vapor is washed into the room and the reservoir of vapor that has built up in the circuit is preserved. The primary advantage of this strategy is the possibility to adjust fresh gas flow to a minimum setting soon after intubation since the anesthetic vapor concentration in the circuit is preserved. Again, when the anesthetic agent monitor indicates an adequate exhaled vapor concentration and a small difference between inspired and expired agent concentrations, it is reasonable to use a minimum fresh gas flow setting.

This process of turning off the fresh gas flow and not the vaporizer may not be appropriate for all cases since the extra step of turning on the fresh gas flow is required in the event of a difficult airway and the need to continue mask ventilation. Each practitioner should make a decision about their own comfort level with airway management and fresh gas flow changes. In any event, turning off the vaporizer during intubation while leaving fresh gas flow high does not achieve the goal of avoiding room contamination.

Strategy #3: Set the Vaporizer to Deliver a Concentration Greater than Intended

The concentration of anesthetic vapor in the breathing circuit is determined by the vaporizer setting and the total fresh gas flow. Unless a high fresh gas flow is used, the inspired concentration of anesthetic vapor measured by the agent monitor may be less than the vaporizer setting depending upon the concentration of anesthetic agent in the exhaled gas and the amount of rebreathing. As fresh gas flow is reduced, the same inspired anesthetic concentration can be achieved by increasing the vaporizer setting. Keeping in mind that the exhaled concentration of anesthetic vapor is the best indication of the level of anesthesia, one can increase the vaporizer setting at lower fresh gas flows to deliver sufficient anesthetic vapor to achieve the desired exhaled concentration. An important caveat to this strategy is that over time, the uptake of anesthetic from the lungs will diminish and the inspired concentration will approach the vaporizer setting. If the vaporizer is set to deliver a high concentration of anesthetic agent, there is a risk of anesthetic overdose. Setting the inspired anesthetic concentration alarm can help to alert the clinician to the accumulation of anesthetic vapor beyond a desired level.

Additional Thoughts

In addition to strategies based on fresh gas flow, techniques to reduce the anesthetic vapor concentration required for adequate anesthetic depth will also minimize environmental contamination. Using adjuncts like narcotics, regional analgesia or even infiltration of local anesthetic in the surgical field at the start of the procedure can reduce the required anesthetic vapor concentration. If less vapor is used, there will inevitably be less environmental contamination. Finding the minimum anesthetic concentration necessary may increase the risk of awareness, an unacceptable patient outcome. Use of monitors of anesthetic depth and monitoring the exhaled agent concentration will help to assure that the patient is receiving agent at a sufficient level.

These strategies for minimizing environmental contamination by anesthetic vapors are necessary due to the interaction between fresh gas flow and anesthetic vapor delivery inherent to most anesthesia machine designs. Future designs will eliminate the interaction between fresh gas flow and vapor delivery making it easier to practice in an environmentally conscious manner.

Protocol for Calculating a Safe Minimum Fresh Gas Flow

- Estimate patient oxygen consumption to be 5 mL/kg/min
- Add 100 mL/min to account for any leaks from the circuit
- Set total oxygen flow (oxygen + 21 percent of air flow) to be 20 percent greater than estimated oxygen consumption
- Add 200 mL/min if using a sidestream gas analyzer that does not return sampled gas to the circuit
- Add 100 mL/min to account for any leaks from the circuit
- Monitor inspired oxygen concentration to insure adequate oxygen flow
- Monitor exhaled anesthetic vapor concentration to insure adequate MAC

NOTE: It may be possible to reduce the total fresh gas flow further if the circuit leak is less than 100 mL/min or oxygen consumption is less than the estimated value. Fresh gas flow can safely be reduced further but the inspired oxygen concentration must be monitored to insure that it is adequate.

A more complete discussion of this topic can be found in a recent review article.

References
4. Environmentally Conscious Use of Intravenous Anesthetics and Other Pharmaceuticals

Physician anesthesiologists have long focused on patient safety. One neglected aspect of patient safety is the effect of possible toxins (anesthetic agents and other drugs we use) on the environment and therefore indirectly on the long-term health and safety of the population. How can we provide a safe anesthetic that minimizes environmental impact? A recent publication by Ryan and Nielsen1 demonstrated that vapor anesthetics and nitrous oxide are significant greenhouse gases. Is the logical response to these data to simply switch to Total Intravenous Anesthesia (TIVA) and immediately stop polluting the atmosphere? Unfortunately, it is not that simple. And the answer is important, since we face changing demographics (an aging population) that will lead to increasing numbers of anesthetics.

There are at least two routes by which the intravenous pharmaceuticals we routinely use during administration of anesthesia can end up in our drinking water: 1) directly via the disposal of unused drugs, and 2) indirectly via human excretion.2 Although pharmaceutical contaminants are often measured below acutely toxic levels in the water supply, it is the well-described combination of high rates of pharmaceutical production/use with modifications leading to "environmental persistence"2 that is a growing source of concern. The effects of these trace pharmaceuticals are unknown but concerning, especially for pregnant women and children because of increased susceptibility during growth and development.3

Generations of physician anesthesiologists have been trained to draw up emergency drugs for every case. Preparation for adverse outcomes is a basic tenet of anesthesia education, and obviously patient safety is paramount. However, this automatic practice may lead to a stunning amount of waste.

A second issue with emergency drugs is the way they are prepared. It is routine (although becoming less so) for anesthesia providers to draw up their own emergency drugs at the beginning of each day. These commonly include phenylephrine, ephedrine, epinephrine, atropine and succinylcholine. Often phenylephrine and epinephrine require double dilution, with each vial representing 100 mL of diluted drug.

The practice of physician anesthesiologists drawing up and diluting their own drugs poses two risks to patient safety: 1) increased drug waste and subsequent environmental impact, and 2) a risk of drug contamination when appropriate procedures are not followed. The U.S. Pharmacopeia (USP)4 sets guidelines for storage and handling of all drugs. Assuming compliance with the USP – or at any rate at the end of the day – unused drugs must then be disposed of, thereby starting the journey into our nation’s water supply.

There are at least two effective ways to reduce waste for these drugs that seem unlikely to diminish patient safety. First, reduce the number of drugs routinely drawn up. For example, atropine is rarely used and can be rapidly accessed in a code situation. Ephedrine, though commonly used, is not truly an emergency drug. The time taken to dilute it to treat hypotension is unlikely to affect patient outcome (especially when blood pressure is only obtained every two to five minutes). The issues here are complex and have not been studied. Does having numerous drugs drawn up make it more likely to grab the wrong drug in an emergency? Or does the need to draw up a drug in an emergency make it more likely to grab the wrong vial and draw up the wrong drug? Barcoded, prefilled syringes may be an answer to both reducing drug errors and reducing drug wastage, although the system would have to be simple to use and not introduce more steps and thus more opportunities for error.
Secondly, for some institutions, it may be possible to have double diluted emergency drugs such as phenylephrine and epinephrine drawn up by the pharmacy under a laminar flow hood (premixed syringes are also available but are a very expensive option). These syringes are good for 24 hours at room temperature and much longer (nine days) in the refrigerator. One vial provides drug for 10–20 rooms (depending on syringe size).

Striving to reduce our drug waste is clearly a good idea. What about drug choice? Increasingly, we have data that support considering the specific impact of each drug we elect to use. In 2003, the Stockholm County Council started an environmental risk-classification database of pharmaceuticals with the goal of diminishing pharmaceutical residue in the water, air and ground. Drugs are classified based on: 1) environmental risk (essentially the ratio of the predicted concentration to the safe environmental drug concentration), and 2) environmental hazard (a nine-point index based on Persistence, Bioaccumulation and Toxicity, or PBT index). While not all commonly used anesthesia drugs are included or fully evaluated, the table below compiles some of interest. While TIVA decreases vapor use, the table suggests that propofol may not be an environmentally sound choice since it has the highest PBT index value of 9. Could isoflurane with ultra-low flows be less harmful to the environment than propofol? Would that margin be offset if it increases ondansetron use? What would be the environmental, as well as the cost, impact of not using ondansetron routinely for postoperative nausea and vomiting prophylaxis (PBT index=6)? These are all questions that could have a major impact on our anesthetic practice, although currently we do not have the data to answer them.

In summary, as we mix our emergency drugs and choose our approach to anesthetic management, it behooves us to remain cognizant of the impact of the remnants of this process, and certainly for how long our environment will be subject to their effects. Reduce waste where you can and choose your drugs wisely.

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<table>
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References:
5. Waste Stream Management and Recycling Opportunities

Types of Operating Room Waste

Current estimates suggest that operating rooms are responsible for 20–30 percent of total hospital waste. Packaging material used to protect and maintain the sterility of supplies and equipment accounts for a large part of the waste. Also, increased use of disposable supplies and equipment contributes to the problem. Infectious material, sharps and certain medications, which are hazardous to the environment, must be discarded into special containers and fall under the category of regulated medical waste (RMW).

Solid Waste Recycling Opportunities

Most of the material generated in the operating room is solid waste, which can be recycled if it has not been contaminated by bodily fluids. A report from the Department of Anesthesia at Western Hospital in Australia notes that anesthesia waste stream represented 25 percent of the total operating room waste and 60 percent of anesthesia waste is recyclable. This report also found that one of the barriers to recycling is failure to separate infectious waste from clean waste.

Successful operating room recycling programs have procedures to recycle material such as plastics, glass, paper and blue wrap in recycle bins before the patient enters the room. Much of the recyclable waste is generated when materials are opened and prepared before the case begins. Closing the bags or bins before the patient enters the room eliminates infectious contamination. Hospitals regulations often require that all waste remain in the operating room suite until the conclusion of the case to ensure that the trash can be inspect if the sponges, needles or equipment counts are incorrect. Recycle bins will often need to remain in the room until the wound is closed.

Recycled materials have monetary value and can be sold to recycling facilities. This decreases the expense of solid waste disposal. Operating room recycling also increases awareness of waste segregation. It can often be tied in with RMW reduction, which is far more expensive than solid waste disposal. Many U.S. hospitals report substantial cost savings when recycling is utilized effectively in the operating room.

Please see Appendix A: The Perioperative Greening Manual by Dr. T. Kate Huncke for further discussion of establishing an operating room recycling program.

Regulated Medical Waste Reduction

The Centers for Disease Control and Prevention (CDC) suggests that only 2-3 percent of hospital waste needs to be disposed of as infectious waste. This is much lower than the 50-70 percent of waste that is generally put in the biohazard waste stream. A more realistic goal would be to reduce RMW to 6-15 percent of the total waste from the operating room. Waste reduction can be accomplished with ongoing staff education. Posters with pictures of what truly qualifies as RMW has led to reductions in the volume of red bag, or RMW, refuse. RMW must be treated before it is sent to landfill. Limiting the volume of RMW for disposal leads to substantial dollar and environmental savings for the hospital since the cost can be as much as 500 percent higher.

Donation of unused items to medical missions can be an excellent way to reduce waste under many circumstances. Please see Donations section.

References:


6. Donations

Donations to Developing Countries

The most significant change in the last few years regarding donations of health care related materials to developing countries is the concept of responsible donation. Receiving countries do not want items that are expired or that, in general, you would not want to use on your patients. Put another way, they do not want our trash. The goal of any donation should be of primary benefit to the recipient and using such a method to “green” an operating room a distant second. Surplus equipment that is in good working condition is of great value to developing countries. With approximately 80 percent of their equipment donated, the dependence on donor aid is significant. The World Health Organization (WHO) guidelines on donating equipment to developing countries seek to improve donation utilization through donation action planning. Summarized, the four principles are:

- Donations should have maximal recipient benefit.
- Donations should be given with due respect for the wishes and authority of the recipient and conform to local government policies.
- Donations should have no quality double standard.
- Donors and recipients should engage in effective communication.
In the following paragraphs, a few of the many significant topics surrounding developing country donations will be discussed.

**Responsible Donating**

Responsible donating involves providing the right equipment to the right facilities and caregivers. Matching equipment supply and demand is not simply about need – an understanding of the available resources necessary to use donated materials can be crucial. The World Federation of Societies of Anesthesiologists (WFSA) maintains an extensive list of considerations but examples include:

- Consider inconsistent or absent electricity that may limit the use of certain technologies if devices do not use backup batteries or a supply of batteries is not available.
- Consider sterile processing and clean water availability for reusable equipment.
- Consider biomedical support for failed devices.

**What to Donate – Consumables or Reusables?**

The ethics surrounding single-use material donations are troublesome since reuse will likely occur but may vary depending on the equipment reused. For example, needle and syringe reuse increases HIV and hepatitis transmission, but other equipment decontaminated in dilute bleach (if available) may be relatively safe. Effective communication to establish an intended recipient’s ability to use and possibly reuse equipment safely may be of value.

**Auctions**

Auctions may be a source of inexpensive medical equipment. However, the equipment is sold “as is” and it is up to the donator to ensure that the equipment is in proper working order. In the U.K., up to 50 percent of auctioned equipment may be sent overseas.

**Wasted Resources**

Although well intentioned, failure to donate responsibly consumes precious resources (even if only transportation and shipping) without delivering benefit to the intended recipients. Donors are responsible for some, and perhaps all, of the packaging, shipping, customs clearance, local transportation, and installation expenses. It is recommended that equipment be shipped in bulk. At last estimate, about 50 percent of donated equipment is unused due to requiring repair, recipient sophistication, lack of education, etc., resulting in equipment graveyards in the recipient’s backyards. A donation action plan that includes providing operating manuals, disposable accessories, spare parts and using effective communication to ensure that the recipient not only needs the equipment to be donated but that the recipient can operate and maintain it can mitigate the risk.

**Resources**

A Google search using the keywords “medical,” “equipment,” “donation,” “organizations” yielded 25,900,000 hits. Please be diligent in researching the experiences of those who have donated and those who have received goods through an organization. Good donation experiences, including donation efficacy, reported by both sides of the donation may suggest future successes, but poor experiences or outcomes should make one wary. If the reader has ample resources, another route would be direct donation. While we will leave it to the reader to determine the best donation route, REMEDY (Recovered Medical Equipment for the Developing World) is an example of a nonprofit organization that provides institutions with a “how-to” training kit for setting up your own donation service in your institution.

**References:**


**7. Green Meetings/Events**

As anesthesia providers, our professional lives include more than the operating rooms and perioperative areas. Many of us are also involved in private practice or department administration and educational event planning. At the very least, we all attend continuing medical education (CME) events, workshops and conventions. These events afford many opportunities to decrease our eco-footprint and to provide awareness of sustainability issues.

Some organizations have the ability to evaluate the eco-footprint of their meetings. The University of California at San Francisco offers this, along with an evaluation form and point system. Their website and form may be used as a template along with the following list of suggestions for more sustainable meetings. Keep in mind that the following list encompasses opportunities for all sizes of events from small group meetings to large conventions – thus, many, but not all, may apply to a particular event.
Food
Worldwide, agriculture is as big a concern for climate change as fossil fuel-related transportation. Food production methods, storage and transport are all significant climate and health issues. In the developed world, our food may be transported long distances and we tend to eat very high on the food chain (meat). Additionally, 30 percent of the food produced worldwide is lost or wasted. In Europe and North America, most of this is post-production waste at multiple points between the market (often, blemished produce is not even sold) and disposal in the home (not eaten efficiently, thrown away). Consumers on these continents waste 95-115 kg/person/year. Further contributing to the eco-footprint, disposable plates, utensils and food end up in landfill. The following suggestions can increase sustainability of food at our meetings:

1. **Decrease red meat options**
   This action likely provides the greatest single reduction in the dining eco-footprint. Beef and lamb have at least three times the eco-footprint of poultry and fish due to feed, land and transportation issues. In addition to poultry and fish, vegetarian options should be provided and constitute an even lower footprint. Reducing meat in the diet is one of the highest priorities of global food sustainability planning groups.

2. **Do not over purchase**
   Work closely with event planners to calculate food quantities needed. Verify arrangements for donation or use of remaining edible food.

3. **Prefer local or regional producers**
   Reducing transportation of food can reduce the eco-footprint by another 5 percent. This is a contributor but pales in comparison to type of food consumed, which constitutes most of the eco-footprint.

4. **Prefer sustainably grown food**
   In many cases, recognizing and choosing sustainable food is still taking your best guess. However, in general, pesticides and antibiotic use constitute health and environmental pollutants. These are most easily avoided in the United States by purchasing organics (USDA Organic Certified) since this label bans antibiotic and pesticide use.

5. **Prefer more sustainable dinnerware**
   Choice of utensils, plates and cups makes a difference. Good quality compostables made from plant materials are available when disposables are preferred. At the very least, avoid Styrofoam-type products.

6. **Reuse, recycle and compost**
   Many facilities can now compost dinnerware materials and food. Recycling should be provided for cans and bottles.

**Alternative Methods of Meeting Attendance**
Many meetings or educational events require in-person attendance. However, the value of face-to-face interaction varies greatly depending on the event. Physical attendance has often become optional due to technological advances; the environmental value of virtual attendance or listening to recorded CME talks is very large. Air travel, in particular, has a huge eco-footprint. Some options for real-time, virtual event participation include:

1. Webinars
2. Teleconferencing: audio/visual on personal computer
3. Conference call
4. Meeting projection by LCD screen to larger audiences at specified location/time

When real-time is not possible or essential:
1. Webinars are often available in archives.
2. Recorded talks can often be purchased after a meeting.

**Advertising**
In the past, most advertising for larger events such as continuing medical education (CME) has been by printed flier through the mail. Obviously, the eco-footprint of email advertising is much smaller than printed advertising. However, when printed advertising is necessary, consider the following:

1. Use lower environmental-impact materials, including recycled paper content and more eco-friendly inks.
2. State these sustainability measures in your flier somewhere.
3. Continue to consider where email advertising can be substituted effectively.

**Syllabus/Meeting Agenda**
Materials for meetings can often be distributed by email for tablet or computer download. Many meetings now place slide presentations on the web with a password for attendees. Should hard copy materials be necessary, consider the following:

1. Print papers double-sided.
2. Utilize recycled paper (higher/lower percent recycled content papers are available).
3. Avoid plastic protective sleeves or covers.
4. Recycle plastic protective sleeves.
5. Continue to consider where virtual materials can be effectively substituted.
Venue for Larger Events

When you are planning larger group/department/CME events, begin by discussing possible sustainability measures with event coordinators from your institution and from the proposed venue. In addition, many hospitals now have sustainability coordinators that may have suggestions for “greening events.” Some issues to consider when booking/utilizing a venue:

1. Inquire whether the venue is LEED-certified or has any commitment to sustainability – particularly in areas of energy and water conservation, recycling, and sustainable purchasing (some hotels are LEED-certified – either because of new construction or remodeling and sustainable management).
2. Newer or remodeled venues are more likely to be energy efficient.
3. Consider Internet availability to allow virtual materials to be used during presentations rather than hard-copy syllabi.
4. Avoid excessive air conditioning (high energy cost).
5. Choose a venue that is centrally located, with public transportation options.

Hotel and Restaurant Recommendations

A list of hotels and restaurants are often provided for very large events. Consider the following:

1. Try to contract preferentially with hotels with sustainability commitment.
2. Note hotels and restaurants with sustainability commitments within recommendation lists provided to participants.
3. Try to contract with or recommend hotels and restaurants within walking distance or convenient by public transportation.

Transportation

Transportation is an issue for all sized meetings. Consider all of the following that apply:

1. Encourage active transportation (walking, bicycling) and public transportation by scheduling meetings that are amenable to these options by both time and place.
2. If necessary, provide chartered public transportation on an efficient schedule.
3. Publicize your chartered transportation schedule in order to avoid confusion and unnecessary taxi transport.
4. If publicizing taxi options, note greener companies with hybrid/electric technology.
5. Contract with hybrid technology taxi companies if they are needed.
6. Provide a “ride board” and consider publicizing this by email to local participants.

Advocate for Sustainability

When you attend a meeting, you can be a powerful advocate for sustainability in general or for some particular issue about which you feel strongly (recycling, for instance). Consider communicating your praise and/or concerns via the following:

1. Written meeting evaluations.
2. Direct, personal communication with administrative personnel at the meeting check-in desk at CME events. Quite often, these are members of the event coordinating team.
3. Personal or email communication with physician organizers of the event. They are often in the most influential position to affect future change.

References:


8. Environmental Sustainability in Perioperative Settings and Operating Room Design

Green Guidance for Remodeling and Construction of Operating Room Facilities

It is important that operating room design and health care facilities strive to limit their environmental impact. The Leadership in Energy and Environmental Design (LEED) and Green Guide for Health Care offer green design guidance for remodeling or new construction. LEED certification specifically for health care is in development. In order for a new project or renovation to be LEED certified, it must accumulate a required number of points in the following six areas of green design and operation: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation and design. A total of 100 points is available and based on the degree of compliance, projects will receive LEED certificate rating of “certified” with 40-49 points, “silver” with 50-59 points, “gold” with 60-79 points or
“platinum” with 80 or more points. LEED certification is voluntary, but state and local governments may offer tax incentives when a facility meets the required level of achievement. While there are other programs of sustainable certification in use, LEED certification offers a clear example of how goals common to these programs can be achieved.

1. **Features of a Sustainable Site**
   LEED certification points in this area depend upon evaluation of factors such as site selection, site development (protecting habitat, maximizing open space), alternative transportation (accessibility to public transportation, bicycle storage, parking capacity, and low-emission vehicles), storm water design, and light pollution. A maximum of 26 points can be earned in this category, and as a prerequisite, the site must prevent pollution during construction.

2. **Water Conservation**
   A reduction in water use is important for certification. Low-flow fixtures should be utilized in urinals, toilets and showers; and sensing “turn off” devices should be used at sinks. Reclaiming water that does not interfere with patient safety, infection control and operative sterility needs should be considered in the design. The building will be rated for efficient use of water in landscaping, continued water use reduction, and wastewater technology.

3. **Energy Conservation**
   Energy and atmosphere evaluation examines energy performance. Points are based on several benchmarks including optimal energy efficiency, the use of onsite renewable energy, monitoring and tracking usage, and “green” power usage such as wind or solar power. The use of natural lighting is encouraged and when artificial lighting must be used, motion sensors can help conserve energy. Light emitting diode (LED) bulbs are now available for use in O.R. surgical lighting. Substantial cost savings can be generated through energy conservation.

4. **Use of Low-Impact Materials for Construction**
   Materials and resources should encourage the use of eco-friendly material. It requires, at a minimum, the storage/collection of recyclable materials. Additional points are given for building reuse (maintaining existing walls, roof, etc.), construction waste control, materials reuse, and for using recycled, regional, or quickly renewable materials. Health care waste and diversion is a special area of concern. Activities in surgical suites and perioperative areas produce voluminous waste with more biohazardous waste than other areas of a health care facility. Recycling opportunities will be improved by thoughtful O.R. design that allows for sufficient space and separation of uncontaminated material prior to the patient entering the O.R. or patient contamination.

5. **Air Quality**
   LEED certification requires the building to meet two prerequisites for indoor environmental quality: minimum indoor air quality and the control of tobacco smoke. It is then evaluated for monitoring outside air delivery, enhanced ventilation and low-fume materials (glues, paints, flooring systems, wood products). In addition, factors such as temperature comfort, daylight and views are also rated.

6. **Creativity and Innovation in Green Design Scores Points**
   Finally, innovation in design awards credit is granted to projects that demonstrate quantifiable environmental benefit through new strategies and techniques not specifically addressed in the LEED rating system. Also, additional points are earned if the designer or architect is LEED accredited. Several examples of design that can promote more environmentally sustainable anesthesia include inhaled anesthesia systems design and space considerations to avoid contamination. Anesthetic gas waste discharged into the atmosphere is currently not regulated. However, this may be a future area worthy of design innovation since volatile agents act as greenhouse gases and nitrous oxide both depletes the ozone layer and acts as a greenhouse gas. Inhaled anesthetic reclamation systems under development will be helpful for reducing or neutralizing waste gases. Providing space that prevents contamination of recyclable materials and unopened equipment will also decrease unnecessary waste.

**References:**

APPENDIX A
Perioperative Greening Manual
Toni Torriollo, M.D., and T. Kate Huncke, M.D.

Overview
Renewable energy and reusable products have gained significant global interest with their ability to cut costs and reduce the earth's burden. Opportunities to reduce the ecological footprint of perioperative areas have never been more abundant and there has never been an easier time to affect change. A range of devices and processes are currently available:
- Single-use device (SUD) reprocessing
- Reusables versus disposables: gowns, surgical drapes, basins, pulse oximeter probes
- Operating room (O.R.) kit formulation
- Waste Anesthetic Gas Scavenging Systems
- Energy efficient lighting and thermal comfort
- Regulated medical waste (RMW) minimization/segregation
- Recycling blue sterile wrap or substituting wrap with reusable hard tray cases
- Recycling of medical plastics
- Green cleaning/proper disinfection in a surgical setting
- Medical equipment and supplies donation
- Battery recycling

Raising Awareness
Raising awareness is the most crucial phase of a successful operating room (O.R.) greening program. Ask to speak at physician, nursing and staff meetings. Begin initial presentations by pointing out what is already being done at your institution. Perhaps energy efficient light bulbs have been installed throughout the hospital. Maybe the institution already recycles paper and plastic outside of the O.R.s, but for various reasons the perioperative areas have not started recycling. Continue by providing some statistics regarding waste production per capita, the size of landfills, the nature-sparing effect and economic advantages of using recycled materials.

Once O.R. personnel have been reminded of the importance and benefits of eco-friendly behavior, introduce the topic of greening the O.R. Stress the significance of following established guidelines to maximize benefits and minimize risks concerning infection control. Keep in mind that O.R. staff have many responsibilities and may forget or feel there is no time to "go green." They will need frequent reminders and encouragement.

Education will be an ongoing process, especially as new employees are hired. During initial presentations, try to recruit personnel to help with the educational campaign. Encourage feedback to stimulate cultural change and interest and to gain insight for improvement. Do not forget that the information you assemble can be distributed in formal presentations or via automated email reminders and colorful posters in the O.R.s and perioperative areas.

Assembling a Green Team
Most hospitals do not have a sustainability coordinator. However, many people within the hospital have an interest in saving the environment. Initiation of green programs will need leaders in a variety of different departments to become the "go-to" person for development of sustainability projects. These individuals can designate themselves as "green champions." The green champion will commit to do the following:
1. Identify opportunities
2. Educate staff
3. Monitor progress
4. Report or collect statistics
5. Re-educate personnel

The following areas of the hospital will need to participate:
1. All phases of perioperative nursing leadership
2. Anesthesiology department
3. Building services
4. Hospital administration
5. Housekeeping
6. Purchasing
7. Scrub technicians
8. Surgery department

Important green champions within the Department of Anesthesiology should include the following:
1. Physician anesthesiologists
2. Residents and trainees
3. Anesthesiologist assistants
4. Nurse anesthetists
5. Anesthesia technicians

A good way to begin a greening program is to have green champions in the Department of Anesthesiology select one of the initiatives outlined above in the overview. Depending on the project, green champions from other departments may be contacted to help coordinate the effort. For example, minimization of regulated medical waste (red bag waste) would require coordination of "green champions" from anesthesiology, nursing, building services and purchasing.
Nurse anesthetists and physician anesthesiologists would produce a teaching document or slideshow to outline the benefits of reducing RMW and to detail what does and does not belong in red bag waste. The document could then be presented or emailed to all hospital personnel that come in contact with RMW. O.R. nursing leadership could audit the red bag waste and provide examples of violations. Building services would record the reduction in red bag waste after initiation of the education program. Red bag waste reduction could be converted to dollar savings and the overall results would be reported back to the staff.

**Operating Room Recycling Programs**

Many pieces of surgical equipment and anesthesia supplies are made of recyclable material such as plastics, paper, glass and metal. It is estimated that approximately 60 percent of anesthesia general waste can be recycled.¹ So why are the O.R.s not already recycling? Concern regarding infectious contamination has been one of the biggest barriers to fully capturing recyclable material from the O.R. Workers in recycling facilities manually sort material and are concerned about exposure to bodily fluids. Recycling facilities will not accept material that has been in contact with a patient. Similarly, there is concern that recyclable materials contain residual medications and materials that must be handled as hazardous waste. Current recycling technology cannot separate hazardous material from recyclable products.

Increasingly, medical centers are attempting to establish medical plastic recycling programs in the operating rooms and medical procedure units. Most of the packaging material for anesthesia and surgical equipment contains plastics that can be recycled. Generated almost exclusively by the O.R., “blue wrap” is made of a plastic resin called polypropylene and is fully recyclable. Almost every piece of anesthesia equipment is wrapped in opaque or clear soft plastic material that can be collected and combined with blue wrap for recycling. Equipment is often packaged in Tyvek®, which is made of a fully recyclable plastic fiber material. Tyvek® is used to package medical equipment because it acts as an effective bacterial and moisture barrier. Tyvek® looks like paper but cannot be punctured or torn and can be distinguished from paper packaging material by manually testing its tensile strength. If it cannot be torn, it is Tyvek® and can be recycled with other plastics such as surgical basins, saline bottles and plastic equipment trays.

Paper packaging is present in much smaller quantities in the operating room, but cardboard packaging is abundant and should be recycled (glove boxes, local anesthetic boxes, equipment boxes, etc.). Remember paper and cardboard cannot be recycled if wet, so these boxes should be kept separate from wet saline bottles or trays. Recycling bins in anesthesia workrooms and other stock rooms create an easy way to collect small boxes and sheets of paper.

Glass can be recycled, but the low yield and expense involved with collection and transport may not be worth the intraoperative collection.

There are practical and regulatory considerations that must be factored into the processes established for intraoperative recycling. Clean disposable medical equipment that was intended for use on patients but was not used (clean laryngeal mask airways, clean suction tubing, oral airways, gloves, etc.) should not be recycled. The recycling facility cannot ensure the equipment lacks bodily fluid, and fear of contamination may cause the entire recycling load to be rejected. Closing the recycling bags or bins before the patient enters the room decreases the risk of infectious contamination. Hospital regulations and operating room nursing societies often require that all waste remain in the operating room suite until the conclusion of the case to ensure that the trash can be inspected if sponge, needle or equipment counts are incorrect. Recycle bins will need to remain in the room until the wound is closed.

**Step-by-Step Guide: How to Start an Intraoperative Recycling Program for Plastics and/or Paper**

Establishing recycling programs in the operating room or procedure suite requires careful planning and motivation. Execution of the program should not compromise patient or personnel safety, which is our first priority. The following is a list of steps utilized by institutions that practice intraoperative recycling of clean soft plastics and paper goods.

1. Contact your institution’s environmental or waste management services. Ask them to contact the hospital’s recycling facility to find out if they will accept clean soft plastics or paper from the operating room. Emphasize the process for collection will ensure that the collected items are free of hazardous materials and bodily fluids. The recycler may want to meet with operating room personnel to take inventory of potentially recyclable items and observe the steps involved in collection.

2. Once you know O.R. recyclables will be accepted, ask environmental services what materials are already being recycled at your institution and how this process could be safely extended to the operating room. Determine which plastics (numbers 1-7) can be recycled and whether or not plastic and paper can be collected in the same bag to be sorted later at the recycling facility. Ask about color-coding and how to obtain the proper colored bins or bags for recycling in the O.R. The selected color should easily distinguish O.R. recyclables from hospital wide recycling, linen and general solid waste. The color-coding must be integrated across this institution so that the loading dock personnel can quickly identify where the waste should be sent. Bags used in O.R. recycling should
be appropriately colored but also transparent to facilitate visual auditing of the material. Determine who will deliver the recycling bags, who will accept them and where they will be stored. Where do used bags of recycled materials get sent? Can they go down the garbage chute with the other trash? Do they need special pickup? In most institutions, housekeeping should be able to send out sealed recycling bags in the same manner they do the regular trash, and waste management services will ensure bags get delivered to the appropriate facilities.

3. Contact your director of perioperative services to determine what, if any, green initiatives already exist in the O.R.s. Based on existing practices, determine the best way to implement the recycling of paper and plastic. Specifically, ask about recycling bags versus recycling bins. Many O.R.s are already crowded and the addition of more garbage bins may be difficult and expensive. It may be better to supply the O.R. with recycling bags only. Bins may be better served in anesthesia or housekeeping workrooms, areas that generate significant cardboard and paper waste but do not encounter patients and therefore do not have to be emptied after every case. If you are at a large institution, ask the perioperative director if there is a small cluster of O.R.s where you can begin recycling, get feedback, then spread out to other areas.

4. With the Director of Perioperative Services, determine an actual plan for recycling in the O.R. that will not overwhelm the staff. Intraoperative collection should be as simple as possible. Asking personnel to sort paper and plastics into separate bags in the O.R. may be a nuisance, especially during busy case preparation. Under these circumstances it may be easier to collect only plastics in the O.R. and paper/cardboard from stock rooms. If the recycling facility is willing to sort plastic and paper at their site, then O.R. paper and plastic can be collected into one common bag at the beginning of the case. An easy system is to use a regular garbage bin lined with a regular garbage bag. Place a “green” bag over the regular bag during case opening to collect packaging and blue wrap. Just prior to the patient entering, remove the green bags from the bin to reveal the regular garbage bag underneath. Seal the green bags to prevent contamination but keep them in the O.R. until the final instrument count is deemed correct.

5. Prepare small posters for each O.R. demonstrating which plastics are recyclable and which are not. Pictures, rather than words, work best. Prepare a short slideshow talk describing the importance of recycling, the information you learned from talking to waste management, and the plan you have developed with the perioperative director for instituting a recycling program.

6. Put your recycling posters in each of the O.R.s. Give your short talk at the anesthesia physicians’ conference, nursing meetings and anesthesia technician meetings.

7. Contact the directors of housekeeping, materials management, environmental or building services, and perioperative nursing. If applicable, also contact the head anesthesia technician, chief nurse anesthetist and chief anesthesia resident. Now that you have put up your posters and given your brief presentations, you have stirred up interest and enthusiasm. Ask the directors to help recruit personnel who will serve as “green champions.” Green champions must be willing to develop, train and audit the recycling program.

8. Set up a meeting with green team members to discuss the logistics of an intraoperative recycling program. Reiterate the benefits of recycling. It decreases waste and saves money. Recyclable materials also have value, they can be sold to the recycling facility to defray transportation and labor costs of other trash materials. Enlist green champions to encourage and assist recycling in the O.R., give them specific areas to focus on. For example, nurses and O.R. technicians are responsible for filling the recycling bags with clean paper, blue wrap and plastic as they open for a case. Nurses then seal up the recycling bags prior to patient entry to prevent contamination by drugs and bodily fluids. The green champion nurse would encourage and oversee correct recycling in the O.R. as well as give periodic reminders at nursing meetings. The green champion anesthesia technician can similarly remind the other technicians to recycle paper and cardboard boxes from the workroom. The green champion from housekeeping can ensure a steady supply of green O.R. bags, remind assistants to line bins with green bags prior to each case, and educate personnel not to line garbage bins outside the O.R. or linen bins with the green bags. In a large institution, the green champions may want to set up small meetings with O.R. clusters, technicians, nurse anesthetists, physicians, etc., to review the program and get feedback.

9. Develop training materials. The green champions should create training materials that clearly describe each department’s role and areas to contribute. Materials should also emphasize that soft plastics and paper must be free of bodily fluid contamination. This can be accomplished by strictly limiting the collection of materials to the time prior to patient entry into the operating room. Perceived contamination must also be avoided. Do not collect materials that are intended for contact with bodily fluids such as unused IV tubing, gloves, endotracheal tubes, oral airways, etc. The recycling facility has no way of verifying the material is clean and may reject...
the load. Once the patient enters the room, the recycling bag should be tied closed and stored in the suite until the conclusion of the procedure. Housekeeping must transport the bags to the loading dock and maintain a system that separates recyclables from solid waste. Environmental services should collect statistics. The amount of recyclable materials diverted out of the solid waste stream should be reported back to the staff.

10. Distribute training materials. This may include but is not limited to periodic live presentations, O.R. posters, written documents or reminders distributed automatically via email.

**Disposable Stainless Steel Laryngoscope Blade Recycling:**

1. Ask the “green champions” of housekeeping, materials management, and environmental and building services whether or not the recycling facility will accept disinfected disposable stainless laryngoscope blades.

2. If the recycling facility will purchase the disinfected blades, meet with central sterile to discuss the process for disinfection. Several dozen blades can be disinfected at once by placing them in a tunnel washer.

3. Purchase small bins for collecting the used laryngoscope blades in the operating room or procedure suites. Place the bins on the anesthesia machine or cart for easy access.

4. Ask the anesthesia technicians to collect the used blades each day and store them in a large brute. When the brute is full, the blades can be transported to central sterile for disinfection.

5. Central sterile personnel should disinfect the blades in a tunnel washer, place them into a large collecting bin, and transport them to the loading dock for pickup and delivery to the recycling facility. The large collection bins must be clearly distinguishable from paper, plastic and solid waste collection containers on the loading dock. Bin color-coding allows the hauler to quickly determine the appropriate destination for the collected materials.

6. Collect data on the amount of stainless steel diverted to the recycling facility and report the finding back to all clinicians and personnel involved.

**Sharps Containers**

As a brief reminder about sharps containers, it is imperative that needles, syringes, blades, razors, broken glass, etc., be discarded in sharps containers. Unfortunately, during busy times (such as intubation or extubation) it is tempting to throw gloves, endotracheal tubes, paper and other regular waste in the sharps container. This may be due to crowded operating rooms where the sharps container is large and the nearest receptacle. The collection of sharps container waste is very expensive and everything in the sharps container must be treated with harsh chemicals that are not environmentally friendly. Green champions should encourage proper use of the sharps containers and may want to include this topic with educational materials.

**References:**


Please address comments regarding Perioperative Greening Manual to Dr. Kate Huncke at: tessa.huncke@nyumc.org.
Greening the Operating Room and Perioperative Arena: Environmental Sustainability for Anesthesia Practice

Guidance document produced by the ASA Environmental Task Force
Task Force Co-Chairs: Tessa K. Hunke, M.D., and Jodi Sherman, M.D.

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www.asahq.org/resources/resources-from-asa-committees/greening-the-operating-room

APPENDIX B
Anesthesiology Sustainability Checklist

Jodi Sherman, M.D., Tessa Hunke, M.D., and Susan Ryan, M.D., Ph.D.

1. Reduce Inhaled Anesthetic Atmospheric Waste
   a. Utilize low fresh gas flows
   b. Avoid high impact inhaled anesthetics: Desflurane, Nitrous Oxide
   c. Consider intravenous and regional techniques
   d. Invest in WAG trapping (for volatiles only) or WAG destroying (all inhaled anesthetics, including Nitrous Oxide) technology for the Anesthesia Machine

2. Reduce I.V. Pharmaceutical Waste
   a. Use prefilled syringes
   b. Use appropriate sized vials for an individual patient
   c. Dispose of unused medications and vials according to regulations (and not exceeding)

3. Reduce Anesthesia Equipment Waste
   a. Only open equipment intended for immediate use
   b. Consider purchase of reusable or reprocessed equipment over disposable
   c. Reprocess or recycle suitable disposable equipment
   d. Adjust stock levels to minimize discarding expired items
   e. Reformulate prefabricated kits to eliminate unnecessary items
   f. Reformulate anesthesia supply carts to eliminate unnecessary items
   g. Donate expired or unused open equipment

4. Solid Waste Segregation
   a. Segregate waste according to type (pharmaceutical, solid, biohazard, etc.)
   b. Avoid default of placing all waste into a biohazard or sharps bins
   c. Recycle batteries
   d. Consider intraoperative recycling program for clean plastics, paper and cardboard
   e. Use reusable sharps containers

5. Linens
   a. Consider reusable linens
   b. Minimize excessive use of reusable and disposable towels and blankets

6. Electronics
   a. Avoid excess electronics without proven benefit to patient care
   b. Use a certified sustainable electronics recycling vendor to dispose of old equipment
   c. When negotiating equipment upgrades, request vendors take back old equipment and refurbish and donate or use a certified sustainable electronics recycling vendor

7. Leadership
   a. Develop/join a Sustainability Committee at a department, hospital, or society level and advocate for a sustainability officer
   b. Collaborate with hospital leadership to embed pollution prevention as part of the core business mission, to improve the health of our patients, employees and the surrounding community
   c. Become involved in environmental preferable purchasing
   d. Educate staff regarding the health, safety, and cost benefits of environmental projects
   e. Evaluate new equipment, facility, and behavior options for improved sustainability
   f. Consider strategic sustainability research projects that will lead to financial and environmental savings for the hospital.
**Additional Web Sources of Health Care Sustainability Information**

*(all last accessed October 2, 2014)*

**Greening the O.R., Practice Greenhealth:**
An initiative by Practice Greenhealth to tackle the problem of environmental impact by identifying key interventions that can reduce waste, energy, worker exposure to hazardous chemicals and save money. This initiative is an attempt to collect data on these interventions and share them as a means to encourage widespread adoption across the sector. See website for ways to become involved.

www.practicegreenhealth.org/educate/greening/greening-the-or/.

**Health Care Without Harm:** Global organization working to implement ecologically sound and healthy alternatives to health care practices that pollute the environment and contribute to disease. www.noharm.org/

**Practice Greenhealth:** A networking organization that offers information, best practices and solutions for greening health care practices and facilities. Members include hospitals, health care systems, businesses and other stakeholders engaged in the greening of health care to improve the health of patients, staff and the environment. www.practicegreenhealth.org/

**CleanMed:** Annual environmental conference to catalyze environmental improvements in the health care sector.
www.cleanmed.org/

**Greenseal:** An independent nonprofit organization that provides a guide to green cleaning products.
www.greenseal.org/

**REMEDY – Recovered Medical Equipment for the Developing World:** Describes rationale and methods for donation of medical equipment. http://www.remedyinc.org/

**Medshare – Medical Equipment Recovery Service:**
Provides efficient recovery and redistribution of surplus medical supplies and equipment to underserved health care facilities in developing countries. www.medshare.org/

**Healthier Hospitals Initiative:** A coalition of major health systems and organizations committed to improving sustainability and safety across the health care sector.
www.healthierhospitals.org

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**Greening the Operating Room and Perioperative Arena:**

*Environmental Sustainability for Anesthesia Practice*

Produced by the Task Force on Environmental Sustainability Committee on Equipment and Facilities

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