Greening the Operating Room: Reduce, Reuse, Recycle, and Redesign

Authors: T. Kate Huncke, MD; Susan Ryan, PhD, MD; Harriet W. Hopf, MD; Deborah Axelrod, MD; Jeffrey M. Feldman, MD, MSE; Toni Torrillo, MD; William Paulsen, PhD; Caitlin Stanton, MPH; Spencer Yost, MD; Adam B. Striker, MD

Produced by the Committee on Equipment and Facilities
Charlotte Bell, MD, Chair

Did you know?

- *Operating rooms (ORs) generate 20%-30% of total hospital waste*
- *Inhaled anesthetics are potent greenhouse gases (GHGs)*
- *Many anesthesia equipment and facility design choices can have significant environmental impact*

According to a study from the University of Chicago, the healthcare sector accounts for 8% of the United States total green house gas emissions (1). 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.

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 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.

The Committee on Equipment and Facilities is advocating for increased environmental consciousness in our practices and the facilities in which we work. 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. Anesthesiologists, surgeons, and healthcare administrators are best positioned to reduce the negative impact our practice has on the environment by proactively examining these issues. Anesthesiologists have an opportunity, through education and research, to lead the development of hospital initiatives that foster environmentally friendly policies and programs.

These issues can be addressed by clicking on the topics below:

1. Environmental sustainability in anesthesia equipment choices
2. Environmental impact of inhaled anesthetics in clinical use
3. Management of fresh gas flow (FGF) to reduce environmental contamination
4. Intravenous pharmaceutical environmental issues
5. Waste stream management and recycling opportunities
6. Environment sustainability in perioperative settings and operating room design

A general method for implementation of sustainable changes (recycling in particular) is illustrated in: The Perioperative Greening Manual - Appendix A

1. Anesthesia Equipment Choices

Authors: Adam B. Striker, MD; Caitlin Stanton, MPH; T. Kate Huncke, MD

Disposable Versus Reusable Equipment

Many types of anesthesia equipment may be purchased in a disposable or reusable form. Both selections have potential to harm the environment. Traditionally, the choice focused on cost, patient safety, and ease of disposal and care of equipment. For example disposable equipment, such as disposable laryngoscope blades, has become increasingly popular because it eliminates the risk of cross contamination between patients. Eliminating the costs of cleaning that involve labor, specialized equipment and quality control saves money. Further, reusable items sometimes involve cleaning and disinfecting solutions that may be toxic to the environment. On the other hand, disposable items may be of lower quality and contribute substantially to the bulk waste of landfill or incinerators—where toxins are released into the atmosphere. The environmental impact of manufacturing, disposal, and waste management has not typically been considered in the cost of purchasing disposable items. A full 'life cycle' analysis may actually favor reusable items more often than is currently thought. Very few life-cycle analyses have been performed on anesthesia equipment. By interfacing with purchasing and sustainability coordinators, anesthesia and surgical practices can determine which items have the lowest cost and environmental impact.

Reprocessed Equipment

Some single use devices (SUDs) or disposable items are suitable for reprocessing. Examples of items that are labeled as one time use but can be cleaned, reprocessed and resold at substantially reduced costs to the hospital are pulse oximeter probes, blood pressure cuffs, hundreds of surgical instruments including laparoscopic surgical trocars, and sequential compression devices. Several companies currently provide this service. Environmentally friendly pasteurization for sterilization may be used for equipment items that do not penetrate the skin; however, some companies use ethylene oxide for sterilization, which is more toxic but ensures invasive surgical equipment is adequately sterilized.

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 state in writing that the reprocessed medical device is "substantially equivalent" to the original equipment. Approximately 65% to 75% 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, manufacturers, and politicians 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. 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 (2). 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 major pulse oximetry companies currently offer reprocessed sensors at prices comparable to third party reprocessors. Contracting with an original equipment provider may ensure that the clinical performance is backed by the original source.

Environmental Impact of Manufacturing and Disposing of 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.

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 which 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% 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.

Back to list of topics

2. The Environmental Impact of Inhaled Anesthetics

Author: Susan Ryan, PhD, MD

Inhaled Anesthetics are Greenhouse Gases

Potent inhaled anesthetics and nitrous oxide are GHGs.[3-5] Nitrous oxide, as well as being a GHG, is also destructive to the ozone layer.[6] Because global warming potential (GWP) of airborne agents is currently under government scrutiny, many industries that emit GHGs 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 they were originally thought to make a negligible contribution to GHGs and climate change. However, inhaled anesthetic use has expanded in the past 30 years, and desflurane, in particular, has potentially greater environmental impact than do older or alternative agents. Several recent studies have compared the relative environmental impact of various agents and begun 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 (except the older agent halothane) undergo minimal in vivo metabolism, 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 1 to 14 years. Nitrous oxide has a much longer atmospheric lifetime of 114 years.

The GWP is a measure of how much a given mass of GHG contributes to global warming over a specified period of time. The Intergovernmental Panel on Climate Change uses 100 years; however, 20, 50, and 500 years are common as well, depending on the gas in question. The 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 1. Desflurane has the highest GWP_{100} at 2540, followed by isoflurane at 510 and sevoflurane at 130.[5]

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 FGF rate, the use of nitrous oxide, and the potency (MAC) of the agent being delivered in conjunction with the GWP. High FGFs 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 nitrous oxide's long atmospheric half-life, allowing prolonged damage as a GHG, and 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 FGFs. 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%, thereby increasing the impact. Also, desflurane has a high GWP but also requires 3 to 6 times the quantity than would sevoflurane or isoflurane (assuming similar FGFs) because a MAC requires 6% desflurane compared with 2% sevoflurane or 1.2% isoflurane. **Table 1** lists GWP values and relative contribution of these gases.

Table 1. Greenhouse Gas Emissions of Common Inhaled Anesthetic Agents[5,8]

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

***In comparison with CO_2, where CO_2 = 1**
†Per 1 hour use of anesthetic
Abbreviations: CO_2 = carbon dioxide; FGF = fresh gas flow; GWP = global warming potential
Note: For details of computations, please see references 5 and 8.

Recently, a full comparative life-cycle analysis was conducted for inhaled agents and propofol.[7] 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 GHG 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 that of isoflurane and 20 times greater than that of sevoflurane. This analysis uses 2 L FGF for sevoflurane and 1 L FGF for desflurane and isoflurane—and results would obviously be influenced by a change in flows. Nitrous oxide use significantly increased each footprint because of both nitrous released into the atmosphere as a waste gas and 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 in which these agents are clearly preferred for clinical reasons and that other types of anesthetics, such as intravenous agents and neuraxial blocks, should be considered when appropriate. The propofol footprint, in their analysis, was 4 orders of magnitude lower than that of 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.[5] 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 1** highlights: 1) differences between agents; 2) the importance of avoiding wasteful higher FGFs; and 3) the comparison between anesthetic use and automobile emissions. This provides a yardstick from our daily lives and may assist anesthesiologists considering practice changes. The format is adapted from Ryan and Nielsen,[8] utilizing the most recently calculated anesthetic lifetimes and GWPs from Sulbaek Andersen et al.[5] and a 2011 EPA approximate calculation for US automobile emissions.[9] The use of desflurane for 1 hour results in the equivalent GHG effect of driving 200 to 400 miles compared with 8 to 18 miles of driving per 1 hour of use of sevoflurane or isoflurane; or, driving 1600 to 3200 miles is equivalent to the use of desflurane for one 8 hour–use day, and driving 64 to 144 miles is equivalent to the use of sevoflurane or isoflurane for one 8 hour–use day (these computations all assume 1 MAC and compare similar FGFs). This is calculated for the effect of 1 day's use over the 100-year time frame; however, consider that quite a bit of additional inhaled anesthetic will be used over the 100-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 FGFs during the maintenance phase of the anesthetic (see **"Managing Fresh Gas Flow to Reduce Environmental Contamination"** by Dr. Feldman). 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 underway. 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.

Back to list of topics

3. Managing Fresh Gas Flow to Reduce Environmental Contamination

Author: Jeffrey M. Feldman, MD, MSE

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 FGF determines the amount of gas entering the scavenging system per minute.** Whenever FGF exceeds the patient's requirement, gases and vapors will enter the scavenging system and, ultimately, contaminate the atmosphere. By choosing the minimal total FGF, 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 his/her career by practicing careful FGF management for each case. There are three strategies to minimize FGF 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 FGF**.

Which Monitoring is Essential?

The continuous measurement of inspired and expired oxygen and vapor concentrations is essential to safe and effective management of FGF. Minimizing environmental contamination requires that FGFs be reduced to match what the patient consumes as closely as possible. As FGF 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 FGFs are 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.

Furthermore, it is possible to reduce waste by using low FGFs 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 FGF because 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 FGF 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 FGF. The maintenance phase 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 FGF.

The minimum safe FGF 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/min as a rough estimate of oxygen consumption, an adult male (weighing 70 kg) will use 350 mL/min of oxygen. If we assume that there are no leaks from the circuit, an FGF of oxygen of 350 mL/min is all that is required. Any greater FGF 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 completely eliminate environmental contamination because 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 FGF. 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 FGF 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 FGF 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 FGF of 4 liters/min. Once the exhaled concentration of isoflurane is close to the inspired concentration, uptake from the lungs has slowed and the FGF can be reduced. Assuming oxygen consumption to be about 350 mL/min, the oxygen flow can be set to 350 mL/min. The air flow meter can be set at 500 mL/min, which would deliver an additional 105 mL/min of oxygen, and the total FGF will be less than 1 L/min. If nitrous oxide is used, the oxygen flow meter 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 because the total FGF 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., due to trauma, pregnancy, etc.), it should be possible to limit the FGF to a maximum of 1 L/min during the maintenance phase of anesthesia.

For smaller patients with even lower oxygen consumption requirements, the maintenance FGF can be reduced even further, with the same caveat of monitoring the 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 FGF while mask ventilating the patient and to turn off the vaporizer while intubating the patient. The goal of this practice is to avoid contaminating the OR 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 FGF. Room contamination is not avoided, and the vapor in the circuit is wasted. Alternatively, one can turn off the FGF during intubation and leave the vaporizer on. In the absence of FGF, 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 FGF to a minimum setting soon after intubation because the anesthetic vapor concentration in the circuit is preserved.[10] 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 FGF setting.

This process of turning off the FGF and not the vaporizer may not be appropriate for all cases because the extra step of turning on the FGF is required in the event of a difficult airway and the need to continue mask ventilation. Each practitioner should make a decision about his/her own comfort level with airway management and FGF changes. In any event, turning off the vaporizer during intubation while leaving the FGF 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 FGF. Unless a high FGF 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 FGF 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 FGFs 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 alert the clinician to the accumulation of anesthetic vapor beyond a desired level.

Additional Thoughts

In addition to strategies based on FGF, 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. Using monitors of anesthetic depth and monitoring the exhaled agent concentration will help assure that the patient is receiving the agent at a sufficient level.

These strategies for minimizing environmental contamination by anesthetic vapors are necessary due to the interaction between FGF and anesthetic vapor delivery inherent to most anesthesia machine designs. Future designs will eliminate the interaction between FGF 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
- Set total oxygen flow (oxygen + 21% of air flow) to be 20% 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 ensure adequate oxygen flow
- Monitor exhaled anesthetic vapor concentration to insure adequate MAC

Note: It may be possible to reduce the total FGF further if the circuit leak is less than 100 mL/min or oxygen consumption is less than the estimated value. The FGF can safely be further reduced, but the inspired oxygen concentration must be monitored to ensure that it is adequate.

A more complete discussion of this topic can be found in a recent review article.[11]

Back to list of topics

4. Environmentally Conscious Use of Intravenous Anesthetics and Other Pharmaceuticals

Authors: Deborah Axelrod, MD; Harriet W. Hopf, MD

Introduction

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 Nielsen demonstrated that vapor anesthetics and nitrous oxide are significant GHGs.[8]

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, because we face changing demographics (i.e., an aging population) that will lead to increasing numbers of anesthetics.

Environmental Impact of Intravenous Pharmaceuticals

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.[12] 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" that is a growing source of concern.[12] The effects of these trace pharmaceuticals are unknown but concerning, especially for pregnant women and children because of increased susceptibility during growth and development.[13]

Generations of 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 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 US Pharmacopeia (USP) sets guidelines for storage and handling of all drugs.[14] 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.

Reducing Drug Waste

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 2-5 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? Bar-coded, 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.

This:

Could be this:

Second, 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 (9 days) in the refrigerator. One vial provides drug for 10-20 rooms (depending on syringe size).

Drug Choice

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.[15]

Drugs are classified based on: 1) **environmental risk,** which is, essentially, the ratio of the predicted concentration to the safe environmental drug concentration); and 2) **environmental hazard,** a 9-point index based on persistence, bioaccumulation, and toxicity (PBT index). While not all commonly used anesthesia drugs are included or fully evaluated, **Table 2** compiles some of interest. While TIVA decreases vapor use, the table suggests that propofol may not be an environmentally sound choice because 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 (PBT index of 6) use? What would be the environmental, as well as the cost, impact of not routinely using ondansetron for postoperative nausea and vomiting prophylaxis? 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.

Table 2. Environmental Risk and Hazard of Some Commonly Used Drugs

Drug	Environmental Risk	Environmental Hazard			
		P	B	T	PBT Index
Propofol	Unknown	3	3	3	9
Succinylcholine	Maybe	Unknown	Unknown	Unknown	Unknown
Atracurium	Maybe	2	0	0	2
Fentanyl	Maybe	3	3	2	8
Morphine	Unknown	Unknown	Unknown	Unknown	Unknown
Metoprolol	Insignificant	3	0	1	4
Labetalol	Unknown	3	0	3	6
Lidocaine	Insignificant	3	0	0	3
Ketorolac	Insignificant	3	0	1	4
Midazolam	Insignificant	3	0	2	5
Ondansetron	Insignificant	3	0	3	6

Abbreviation: PBT = persistence, bioaccumulation, and toxicity

Conclusion

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 when you can, and wisely choose your drugs!

Back to list of topics

5. Waste Stream Management and Recycling Opportunities

Authors: T. Kate Huncke, MD; Spencer Yost, MD

Types of Operating Room Waste

Current estimates suggest that ORs are responsible for 20%-30% of total hospital waste.[1] 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 materials, sharps, and certain medications that 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 OR 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% of the total OR waste and that 60% of anesthesia waste is recyclable.[16] This report also found that one of the barriers to recycling is failure to separate infectious waste from clean waste.

Successful OR 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 OR suite until the conclusion of the case to ensure that the trash can be inspected 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. Also, OR recycling increases awareness of waste segregation. It can often be tied in with RMW reduction, which is far more expensive than is solid waste disposal. Many US hospitals report substantial cost savings when recycling is effectively utilized in the OR.

Regulated Medical Waste Reduction

The Centers for Disease Control and Prevention suggests that only 2%-3% of hospital waste needs to be disposed of as infectious waste. This is much lower than the 50%-70% of waste that is generally put in the biohazard waste stream. A more realistic goal would be to reduce RMW to 6%-15% of the total waste from the OR. 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. The RMW must be treated before it is sent to a landfill. Limiting the volume of RMW for disposal leads to substantial dollar and environmental savings for the hospital because the cost can be as much as 500% higher.

Donations

Donation of unused items to medical missions is an excellent way to reduce waste. Many clean or opened/unused items that would be placed in a landfill can be collected and sent to developing countries. MedShare International is a nonprofit organization that provides staff training, receptacle bins, and pick-up services to collect medical equipment that cannot be used in the United States due to FDA regulations, expiration, or break in sterility. REMEDY (Recovered Medical Equipment for the Developing World) is another nonprofit organization that provides institutions with a "how to" training kit for setting up your own donation service in your institution.

Both organizations accept dozens of pieces of equipment that are used every day in our practices. This may, in fact, shift some disposal issues to other countries that may not have the means or environmental awareness to provide proper disposal; this issue should be addressed as part of equipment use education when the items are donated.

Back to list of topics

6. Environmental Sustainability in Perioperative Settings and Operating Room Design

Author: Susan Ryan, PhD, MD

Green Guidance for Remodeling and Constructing Operating Room Facilities

It is important that OR designs and health care facilities strive to limit their environmental impact. The Leadership in Energy and Environmental Design (LEED) (www.usgbc.org) and Green Guide for Health Care (www.gghc.org) offer green design guidance for remodeling or new construction. A LEED certification that is 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 a 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. Obtaining a 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.

Features of a Sustainable Site

The LEED certification points in the area of sustainable sites depends upon evaluation of factors such as site selection, site development (e.g., protecting habitat, maximizing open space, etc.), alternative transportation (e.g., 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.

Water Conservation

A reduction in water use is important for certification. Low-flow fixtures should be utilized in urinals, toilets, and showers; motion-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.

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 bulbs are now available for use in OR surgical lighting. Substantial cost savings can be generated through energy conservation.

Use of Low-Impact Materials for Construction

Certification points for materials and resources encourage the use of eco-friendly material. Certification requires, at a minimum, the storage/collection of recyclable materials. Additional points are given for building reuse (e.g., maintaining existing walls, roof, etc.), construction waste control, materials reuse, and using recycled, regional, 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 produced by other areas of a health care facility. Recycling opportunities will be improved by thoughtful OR design that allows for sufficient space and separation of uncontaminated material prior to the patient entering the OR or patient contamination.

Air Quality

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 (e.g., glues, paints, flooring systems, wood products, etc.). In addition, factors such as temperature comfort, daylight, and views are also rated.

Creativity and Innovation in Green Design

Finally, innovation in design LEED 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. Examples of design that can promote more environmentally sustainable anesthesia include inhaled anesthesia system design and space considerations that avoid contamination. Anesthetic gas waste discharged into the atmosphere is currently not regulated. However, this may be an area worthy of design innovation because volatile agents act as GHGs and nitrous oxide both depletes the ozone layer and acts as a GHG. 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.

Additional Sources of Information

CleanMed [Web site]. Available at: http://www.cleanmed.org/. Annual environmental conference to catalyze environmental improvements in the health care sector.

Greening the Operating Room. Practice Greenhealth [Web site]. Available at: http://practicegreenhealth.org/initiatives/greening-operating-room. An initiative to tackle the problem of environmental impact by identifying key interventions to reduce waste, energy, and worker exposure to hazardous chemicals and save money, with an attempt to collect and share data on these interventions to encourage widespread adoption across the sector.

Green Seal [Web site]. Available at: http://www.greenseal.org/. An independent nonprofit organization that provides a guide to green cleaning products.

Health Care Without Harm [Web site]. Available at: http://www.noharm.org/. Global organization working to implement ecologically sound and healthy alternatives to health care practices that pollute the environment and contribute to disease.

Healthier Hospitals Initiative [Web site]. Available at: www.healthierhospitals.org. Coalition of major health systems and organizations committed to improving sustainability and safety across the health care sector.

How to recycle batteries. Battery University [Web site]. Available at: http://www.batteryuniversity.com/partone-20.htm. Information about various types of batteries and recycling.

MedShare [Web site]. Available at: http://www.medshare.org/. Medical equipment recovery service that provides efficient recovery and redistribution of surplus medical supplies and equipment to underserved health care facilities in developing countries.

Practice Greenhealth [Web site]. Available at: http://www.practicegreenhealth.org/. 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.

Recycled Anesthetic Technology Saves Dollars, Environment. Vanderbilt Magazine [Web site]. Available at: http://www.vanderbilt.edu/magazines/vanderbilt-magazine/2009/03/recycled-anesthetic-technology-saves-dollars-environment/. Information about anesthesia gas recycling technology.

REMEDY, Recovered Medical Equipment for the Developing World [Web site]. Available at: http://www.remedyinc.org/. Describes rationale and methods for donation of medical equipment.

Sustainable Hospitals [Web site]. Available at: http://www.sustainablehospitals.org/cgi-bin/DB_Index.cgi. Technical support for health care industry looking to select products and work practices that reduce environmental and occupational hazards.

The Simple Solution: Deltasorb® Anesthetic Collection Service. Blue-Zone [Web site]. Available at: http://www.bluezone.ca/. Information about anesthesia gas recycling technology.

References

1. Chung JW, Meltzer DO. Estimate of the carbon footprint of the US health care sector. *JAMA.* 2009; 302(18):1970-1972.
2. United States Government Accountability Office. *Report to the Committee on Oversight and Government Reform, House of Representatives. Reprocessed Single-Use Medical Devices: FDA Oversight Has Increased, and Available Information Does Not Indicate That Use Presents an Elevated Health Risk.* Washington, DC: United States Government Accountability Office; 2008.
3. Brown AC, Canosa-Mas CE, Parr AD, Pierce JM, Wayne RP. Tropospheric lifetimes of halogenated anaesthetics. *Nature.* 1989;341(6243):635-637.
4. Oyaro N, Sellevåg SR, Nielsen CJ. Atmospheric chemistry of hydrofluoroethers: reaction of a series of hydrofluoroethers with OH radicals and Cl atoms, atmospheric lifetimes, and global warming potentials. *J Phys Chem A.* 2005;109(2):337-346.
5. Sulbaek Andersen MP, Nielsen OJ, Wallington TJ, Karpichev B, Sander SP. Medical intelligence article: assessing the impact on global climate from general anesthetic gases. *Anesth Analg.* 2012;114(5):1081-1085.
6. Ravishankara AR, Daniel JS, Portmann RW. Nitrous oxide (N_2O): the dominant ozone-depleting substance emitted in the 21st century. *Science.* 2009;326(5949):123-125.
7. Sherman J, Le C, Lamers V, Eckelman M. Life cycle greenhouse gas emissions of anesthetic drugs. *Anesth Analg.* 2012;114(5):1086-1090.
8. Ryan SM, Nielsen CJ. Global warming potential of inhaled anesthetics: application to clinical use. *Anesth Analg.* 2010;111(1):92-98.
9. Green Power Equivalency Calculator Methodologies. Environmental Protection Agency [Web site]. Available at: www.epa.gov/greenpower/pubs/calcmeth.htm#vehicles. Accessed: April 20, 2012.
10. Feldman JM. A simple strategy for faster induction and more cost-effective use of anesthetic vapor. *J Clin Monit Comput.* 1999;15(1):17-21.
11. Feldman JM. Managing fresh gas flow to reduce environmental contamination. *Anesth Analg.* 2012;114(5):1093-1101.
12. Fent K, Weston AA, Caminada D. Ecotoxicology of human pharmaceuticals. *Aquat Toxicol.* 2006;76(2):122-159.
13. Vandenberg LN, Colborn T, Heindel JJ, et al. Hormones and endocrine-disrupting chemicals: low-dose effects and nonmonotonic dose responses. *Endocr Rev.* 2012;33(3):378-455.
14. United States Pharmacopeial Convention. *USP–NF 2010.* Rockville, MD: United States Pharmacopeia and the National Formulary; 2009. Available at: http://www.usp.org/usp-nf.
15. Stockholm County Council: Environmentally Classified Pharmaceuticals. Janusinfo [Web site]. Stockholm; 2010. Available at: http://www.janusinfo.se/v/About-the-environment-and-pharmaceuticals/Environmentially-classified-pharmaceuticals/V-Various/. Accessed: May 11, 2011.
16. McGain E, Hendel SA, Story DA. An audit of potentially recyclable waste from anesthetic practice. *Anaesth Intensive Care.* 2009;37(5):820-823.

Please e-mail comments regarding **Greening the Operating Room: Reduce, Reuse, Recycle, and Redesign** to Dr. Susan Ryan: **ryans@anesthesia.ucsf.edu**

Appendix A—The Perioperative Greening Manual

Authors: Toni Torrillo, MD; T. Kate Huncke, MD

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, including:

- Reprocessing single-use devices
- Evaluating reusables versus disposables (e.g., gowns, surgical drapes, basins, pulse oximeter probes , etc.)
- Formulating operating room (OR) kits
- Utilizing waste anesthetic gas scavenging systems
- Using energy-efficient lighting and thermal comfort
- Minimizing/segregating regulated medical waste (RMW)
- Recycling blue sterile wrap or substituting wrap with reusable hard tray cases
- Recycling medical plastics
- Green cleaning/proper disinfecting in a surgical setting
- Donating medical equipment and supplies
- Recycling batteries

Raising Awareness

Raising awareness is the most crucial phase of a successful OR 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 ORs 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, and the nature-sparing effect and economic advantages of using recycled materials.

Once OR personnel have been reminded of the importance and benefits of eco-friendly behavior, introduce the topic of greening the OR. Stress the significance of following established guidelines to maximize benefits and minimize risks concerning infection control. Keep in mind that OR 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 e-mail reminders and colorful posters in the ORs 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. Reeducate personnel

The following areas of the hospital will need to participate:

1. Nursing (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. Anesthesiologists
2. Residents and trainees
3. Anesthesiologist assistants
4. Certified registered nurse anesthetists (CRNAs)
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 RMW (i.e., red bag waste) would require coordination of "green champions" from anesthesiology, nursing, building services, and purchasing.

Nurses and anesthesiologists would produce a teaching document or slide show 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 e-mailed to all hospital personnel who come in contact with RMW. The OR nursing leadership could audit the red bag waste and provide examples of violations. Building services would record the reduction in red bag waste after the 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 plastic, paper, glass, and metal. It is estimated that approximately 60% of anesthesia general waste can be recycled.[1] So, why are the ORs not already recycling? Concern regarding infectious contamination has been one of the biggest barriers to fully capturing recyclable material from the OR. 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 ORs 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 OR, "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. It 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 OR, but cardboard packaging (e.g., glove boxes, local anesthetic boxes, equipment boxes, etc.) is abundant and should be recycled. 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 (e.g., clean laryngeal mask airways, clean suction tubing, oral airways, gloves, etc.) should not be recycled.
The recycling facility cannot ensure that 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 OR nursing societies often require that all waste remain in the OR 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 OR 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 and ask them to contact the hospital's recycling facility to find out if it will accept clean soft plastics or paper from the OR. Emphasize that 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 OR personnel to take inventory of potentially recyclable items and observe the steps involved in collection.

2. Once you know OR 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 OR. 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 OR. The selected color should easily distinguish OR recyclables from hospital-wide recycling, linen, and general solid waste.

The color coding must be integrated across the institution so that the loading dock personnel can quickly identify where the waste should be sent. Bags used in OR 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 that they do the regular trash, and waste management services will ensure that the 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 ORs. 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 ORs are already crowded, and the addition of more garbage bins may be difficult and expensive. It may be better to supply the OR 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 ORs where you can begin recycling and get feedback before spreading to other areas.

4. With the Director of Perioperative Services, determine an actual plan for recycling in the OR 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 OR may be a nuisance, especially during busy case preparation. Under these circumstances, it may be easier to collect only plastics in the OR and paper/cardboard from stock rooms. If the recycling facility is willing to sort plastic and paper at their site, then OR 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 OR until the final instrument count is deemed correct.

5. Prepare small posters for each OR that demonstrate which plastics are recyclable and which are not. Pictures, rather than words, work best. Prepare a short slide show and 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 ORs. Give your short talk at the anesthesia physicians' conference, nurses' meetings, and anesthesia technicians' 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 CRNA, 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 a 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 OR, giving them specific areas on which to focus. For example, nurses and OR 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 OR 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 OR bags, remind assistants to line bins with green bags prior to each case, and educate personnel not to line garbage bins outside the OR or linen bins with the green bags. In a large institution, the green champions may want to set up small meetings with OR clusters, technicians, CRNAs, 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 OR. Perceived contamination must also be avoided. Do not collect materials that are intended for contact with bodily fluids, such as unused intravenous tubing, gloves, endotracheal tubes, oral airways, etc. The recycling facility has no way of verifying that 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, OR posters, and written documents or reminders automatically distributed via e-mail.

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 the central sterile department 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 OR 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 the central sterile department 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 (e.g., 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 ORs 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.

Reference

1. McGain E, Hendel SA, Story DA. An audit of potentially recyclable waste from anesthetic practice. *Anaesth Intensive Care.* 2009;37(5):820-823.

Please e-mail comments regarding **Appendix A—The Perioperative Greening Manual** to Dr. Kate Huncke: tessa.huncke@nyumc.org