The objective of this study was to identify leading practices to promote environmentally friendly and efficient efforts in the provision of surgical health care. Health care is the second leading contributor to waste in the United States. Despite widespread enthusiasm for "going green" in the US economy, little substantive information is available to the medical community, to our knowledge. We explore safe and efficient strategies for hospitals and providers to protect the environment while delivering high-quality care. We performed a systematic review of the literature using relevant PubMed search terms and surveyed a panel of hospital managers and chief executive officers of health care organizations pursuing green initiatives. Recommendations were itemized and reviewed by a 7-member panel to generate a consensus agreement. We identified 43 published articles and used interview data from the panel. The following 5 green recommendations for surgical practices were identified: operating room waste reduction and segregation, reprocessing of single-use medical devices, environmentally preferable purchasing, energy consumption management, and pharmaceutical waste management. The medical community has a large opportunity to implement green practices in surgical units. These practices can provide significant benefits to the health care community and to the environment. Additional research and advocacy are needed to further explore green practices in health care.

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Health care facilities are the second leading contributor of waste in the United States, producing more than 6600 tons of waste per day and more than 4 billion pounds of waste annually.1,2 Operating room and labor-delivery waste alone account for approximately 70% of hospital waste.3 In the current era, hospitals routinely dispose of waste using costly autoclaves, microwave sterilization systems, and chemical disinfection. In addition, many hospitals use incineration and dumping of waste into landfills.4 These disposal methods can be associated with several environmental and public health concerns.

Certain sectors of US industries, including some hospitals, have demonstrated leadership in creating eco-friendly sustainable development strategies. These include recycling, serving sustainable foods, reprocessing of devices, increasing energy efficiency, eliminating mercury products, managing pharmaceutical waste, and creating green buildings. When applied appropriately, these green (environmentally friendly) strategies can be associated with significant cost savings. The challenge in the health care setting is how to creatively find ways to support sustainability amidst handling large amounts of hazardous or infectious medical waste while ensuring patient safety.

The primary objective of this study was to review the published literature regarding green initiatives in health care. A secondary objective was to draw on the wisdom of leaders engaged in green efforts within and outside the medical commu-
We conducted a literature search of PubMed and bibliographies of other relevant journals from January 1, 1980, through December 31, 2008. We used Medical Subject Headings search terms classified into the following 3 main categories: (1) problems (waste management, medical waste disposal, public health concerns, environmental, incineration, and landfill), (2) interventions (surgery green initiatives, green in surgery, operating room green practices, recycling in operating room, recycling in surgery, reducing waste in surgery, surgical waste disposal, and hospital waste management), and (3) results (cost savings, staff response, environmental impact, public impact, and protests). Combinations of these terms from each category were performed to select relevant articles and abstracts.

A panel of subject matter experts was selected from leaders in the field of medical green practices. Panelists were interviewed between June 1 and December 31, 2008. Interviews were conducted and recorded in person or via telephone for at least 30 minutes each. Ten questions were asked of each expert (Table 1), and extra time was reserved for additional comments. Panelists were queried about current medical waste production, options for reducing or eliminating waste, and potential benefits to public and medical organizations from going green. At the end of each interview, they were also asked to identify an area of greatest concern to them and to list 5 action items for hospitals and providers. Hospital and participant data were de-identified. Consensus among panelists on surgical green initiatives was determined by ranking common responses, identifying the top 5 priorities from the resultant list, and discussing the pooled results to achieve unanimous agreement. Results from the literature review were used to support or closely examine information obtained from the panel. The panel approved the consensus recommendations without changes.

### METHODS

**LITERATURE REVIEW**

We identified 113 peer-reviewed US-based articles regarding the environment and regarding environmentally friendly practices. There were 98 full-text articles, of which 43 fulfilled inclusion criteria for the study. These articles were used to validate and expand on consensus recommendations by the panel.

**PANEL OF EXPERTS**

The panel was composed of 7 leaders in the field of medical green practices. Panelists included the clinical products specialist and the director of environmental sciences of a tertiary medical institution in the Northeast, the research director of the medical organization Health Care Without Harm, the chief executive officer of Ascend Healthcare Solutions, 2 board-certified general surgeons from hospitals with more than 500 beds, and a public health expert with 15 years’ experience in the field.

All 7 panelists independently identified operating room waste reduction and segregation as the most effective and practical method for initiating green practices in surgical units. Three of 7 recommended the same 5 green initiatives, with varying order of preference. Only one panelist listed 3 items that varied significantly from the others obtained.

After tallying the results obtained from the survey and reviewing the data against the published literature, the following 5 strategies were agreed on by the group to be the highest-priority solutions for the surgical community: (1) operating room waste reduction and segregation, (2) reprocessing of single-use medical devices, (3) environmentally preferable purchasing, (4) energy consumption management, and (5) pharmaceutical waste management. We explore each of these strategies in light of the systematic literature review performed.

### COMMENT

**OPERATING ROOM WASTE REDUCTION AND SEGREGATION**

Medical waste can be separated into the following 5 main categories that require different treatment and disposal...
reduction in medical waste volume over 7 years.\(^3\) An-
in addition to several others, have amounted to a 50%-
of the blue wrap used to store instruments by switching-
cal gowns. A different hospital reduced by 70% its use-
saved $60 000 annually by switching to reusable surgi-
other hospital reduced its waste by 50 000 pounds and-
listed in-
stance, although usually disposed of in red bags, items-
believed to occur because of a misunderstanding of what-
level into red bags. In fact, as much as 90% of red-bag-
trated medical waste could be decreased by more than-
quantities of these 2 items were reduced, the volume of-
procedure based on federal guidelines: infectious and-
pathologic (eg, tissues and body fluids), sharps, phar-
maceuticals, radioactive, and general waste (eg, paper and-
unsoiled linens).\(^3\) Two kinds of disposal bags are used-
to separate waste, red bags for specific infectious and-
pathologic waste and clear bags for all noninfectious waste.-
Radioactive and sharp wastes are disposed of in preas-
signed containers depending on their level of contami-
nation with infectious waste. The problem is that most-
waist in surgical units is misallocated at an individual-
level into red bags. In fact, as much as 90% of red-bag-
trate the period when most waste requiring red bags is gen-
tient is wheeled into the operating room, which marks-
then replacing them with red bags just before the pa-
more readily available during surgical preparation and-
To render waste segregation easier for staff, a medi-
cal center initiated a simple system of making clear bags-
more readily available during surgical preparation and-
then replacing them with red bags just before the pa-
tient is wheeled into the operating room, which marks-
the period when most waste requiring red bags is gen-
erated.\(^3\) The medical center also began washing and re-
using all surgical scrubs and jackets.\(^3\) These 2 changes, in-
addition to several others, have amounted to a 50%-
reduction in medical waste volume over 7 years.\(^3\) An-
other hospital reduced its waste by 50 000 pounds and-
saved $60 000 annually by switching to reusable surgi-
cal gowns. A different hospital reduced by 70% its use of-
the blue wrap used to store instruments by switching-
to hard cases, with estimated yearly savings of $26 000.\(^6\)

Table 2. Common Materials Used in Surgical Practices 
That Should Not Be Placed in Red-Bag Waste

<table>
<thead>
<tr>
<th>Material</th>
<th>Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper towels</td>
<td>Casts and splints</td>
</tr>
<tr>
<td>Vent tubing</td>
<td>Packaging materials</td>
</tr>
<tr>
<td>Suction tubes</td>
<td>Alcohol preps and wipes</td>
</tr>
<tr>
<td>Intravenous bags</td>
<td>Dressings and gauze</td>
</tr>
<tr>
<td>Foley bags</td>
<td>Cotton</td>
</tr>
<tr>
<td>Foley catheters</td>
<td>Tapes</td>
</tr>
<tr>
<td>Batteries</td>
<td>Diapers and incontinence pads</td>
</tr>
<tr>
<td>Masks</td>
<td>Bedpans</td>
</tr>
<tr>
<td>Gowns</td>
<td>Urinals</td>
</tr>
<tr>
<td>Drapes</td>
<td>Emesis basins</td>
</tr>
</tbody>
</table>

The importance of careful diligent waste segregation-
becomes clear when the cost associated with disposal of-
each type is considered. Figure 1 compares the rela-
tive cost of waste per volume of each category of waste-
with its cost. Although hazardous and regulated med-
cal waste (equivalent to infectious waste) make up only-
24% of medical waste, they account for 86% of costs.\(^6\) 
Unfortunately, an estimated 40% of regulated medical-
waist from operating rooms is packaging material and-
another 40% is suction canister waste.\(^3\) Therefore, if the-
quantities of these 2 items were reduced, the volume of-
regulated medical waste could be decreased by more than-
30%.

To reprocess single-use devices. Under the Medical Device User Fee and Modernization Act 
of 2002, a reprocessed single-use device is any “original de-
vice that has previously been used on a patient and has been-
subjected to additional processing and manufacturing for-
the purpose of an additional single use on a patient.”\(^9\) Twenty-five percent of more than 6000 US hospitals and-
2700 ambulatory surgery centers report using at least 1 type-
of reprocessed single-use device.\(^10\) The cost savings and the 
appeal of an environmentally friendly alternative offered 
by the reprocessing industry make it an attractive invest-
ment for hospitals. For instance, Ascent Healthcare Solu-
tions in 2008 alone reported a supply cost savings of-
$138 142 000 [1 950 447.2 kg] and 4 300 000 pounds (2150 
tons [1950.5 metric tons]) of medical waste diverted from-
US landfills.\(^11\) Given that more than 60% of medical de-

cides on the US Food and Drug Administration’s list of-
single-use devices known to be reprocessed or considered 
for reprocessing are used in surgical treatment, surgical prac-
tices stand to benefit significantly and should take greater 
interest in reprocessing efforts.\(^12\) Figure 2 shows cost sav-
ings across various surgical specialties from the reprocess-
ing of commonly used devices.\(^13\) Despite these data, con-

cerns exist about the safety of these devices.\(^14\) To date, the 
US Government Accountability Office has found no ev-
eidence indicating that the use of reprocessed devices in-
creases health risk.\(^15\)\(^16\)

ENVIRONMENTALLY PREFERABLE PURCHASING 

Hospitals for a Healthy Environment, a collaboration be-
tween the US Environmental Protection Agency and the 
American Hospital Association, advocates for the use of 
environmentally preferable purchasing in all depart-
ments of hospitals. They define environmentally preferable 
purchasing as the “act of purchasing products/services 
whose environmental impacts have been considered and 
found to be less damaging to the envi-
ronment and human health when compared to compet-
ing products/services.”\(^17\) Apart from cost savings, envi-
ronmentally preferable purchasing creates a healthier 
hospital environment for patients and staff, which fur-

Figure 1. Comparison of waste volume and cost. Courtesy of Colleen Cusick, RN, The Johns Hopkins Go Green Initiative.

Figure 2. Environmentally preferable purchasing.

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Percentage of Cost</th>
<th>Percentage of Waste Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulated Medical Waste</td>
<td>34%</td>
<td>25%</td>
</tr>
<tr>
<td>Hazardous Waste</td>
<td>52%</td>
<td>5%</td>
</tr>
<tr>
<td>Recycled Waste</td>
<td>17%</td>
<td>1%</td>
</tr>
<tr>
<td>Solid Waste</td>
<td>59%</td>
<td>13%</td>
</tr>
</tbody>
</table>
ther reduces long-term expenditure. Material managers of surgical units can support environmentally preferable purchasing by obtaining supplies from vendors who use environmentally friendly raw materials or products. Hospitals should aim to eliminate all mercury products and to replace these with approved alternatives that are easily recycled or require no specialized disposal.

Other general practices that have been shown to improve the overall effect on the environment could be adopted by surgical units. For instance, surgical facilities can commit to using only unbleached recycled paper instead of chlorine-bleached white paper given that manufacturing of the latter releases dioxins into our waterways as a by-product. By using 100% recycled paper, hospitals can reduce manufacturing energy use by 44%, decrease greenhouse gas emissions by 37%, and cut solid waste emissions and water use by 50%. Other suggestions include reducing product packaging, switching to safer cleaning products, and purchasing products that are free of latex, polyvinyl chloride, and diethylhexylphthalate. This could reduce the incidence of allergic reactions, asthma, eye damage, burns, and indirect contamination of hospital food and the water supply.

Although significant, cost savings vary depending on types and amount of environmentally preferable purchasing used by various hospitals. However, it is estimated that a 1000-bed hospital could save, for example, $175,000 per year and reduce waste by 34,000 pounds if they use reusable sharps containers instead of disposable ones. In addition, the direct environmental and public health impact of environmentally preferable purchasing is important, given studies that have highlighted the effects of current waste disposal strategies.

ENERGY CONSUMPTION MANAGEMENT

The health care industry accounts for 9% of America’s commercial energy use, driven by its dependence on energy-intensive medical equipment, special lighting, and a 24-hour operating schedule. It is estimated that 25% of a hospital’s operating cost goes toward meeting its energy needs, with distribution varying among departments. Understandably, surgical units consume a large proportion of this energy not only in the operating rooms and postanesthesia care units but also in the clinics, waiting rooms, and nursing and physician stations, where energy is used to power monitors, computers, and coffee machines. By managing energy use, surgical practices could save between 25% and 45% in energy costs. Monthly savings could be increased further by implementing energy efficiency programs (Table 3). Given the high rate of energy waste, instituting simple energy efficiency program changes can result in significant savings, as experienced by New York–Presbyterian Hospital in New York City; by replacing older lighting, air conditioning, water chilling, and pumping systems with newer, more efficient models, the hospital expects annual savings of $1.77 million.

As an additional incentive, hospitals can qualify for federal tax deductions under the Energy Policy Act of 2005 for new or renovated buildings that save 50% or more of their projected annual energy costs for heating, cooling, and lighting. An investment tax credit can also be claimed if practices use combined heat and power systems or specific solar lighting and photovoltaic systems.

**Table 3. Energy Efficiency Programs**

<table>
<thead>
<tr>
<th>Program</th>
<th>Mean Savings, $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy-efficient heating, venting, and air-conditioning system designs</td>
<td></td>
</tr>
<tr>
<td>Energy-efficient lighting system designs</td>
<td></td>
</tr>
<tr>
<td>Energy-efficient sterilization, gas, and water plants</td>
<td></td>
</tr>
<tr>
<td>Energy-efficient waste disposal systems</td>
<td></td>
</tr>
<tr>
<td>Energy-efficient housekeeping methods</td>
<td></td>
</tr>
<tr>
<td>Energy-efficient medical and nonmedical equipment</td>
<td></td>
</tr>
<tr>
<td>Thermal storage analysis systems and cooling analysis systems</td>
<td></td>
</tr>
<tr>
<td>Energy-efficient building infrastructure designs</td>
<td></td>
</tr>
<tr>
<td>Effective cogeneration feasibility analysis and design</td>
<td></td>
</tr>
<tr>
<td>Highly motivated and trained staff, including senior management, for initiating and implementing energy-saving protocols</td>
<td></td>
</tr>
</tbody>
</table>

*From data by Ruparel.*

![Figure 2. Comparison of mean savings associated with reprocessing of specific devices in various surgical specialties. A, Operating room reprocessing savings by surgical specialty. B, Mean distribution of $100 000 in device reprocessing savings across 20 facilities. Adapted from Flynn and Knishinsky.*](image)
In conclusion, information obtained from the literature review and from the panel reveals a strong need for better and more widespread environmentally friendly initiatives in the medical community. The field of surgery represents a high-yield area for which green practices can be implemented, often with associated cost savings. These findings are consistent with those in other industries, in which sustainable practices are achievable, meaningful, and popular among consumers. As physicians, we share a common desire to deliver the highest possible quality care to our patients directly and indirectly. This goal should guide our efforts as we seek ways to improve public health and sustainability through green initiatives. While the proposed practices are based on the observations and experiences of leaders in the field, additional research is needed to further explore the effect of surgical care on the environment.

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Additional Contributions: Colleen Cusick, RN, and Hugh Waters, PhD, contributed to the study.

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Table 4. Resource Conservation and Recovery Act List of Hazardous and Toxic Pharmaceutical Agents

<table>
<thead>
<tr>
<th>P-Listed Acutely Hazardous Waste</th>
<th>U-Listed Toxic Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic trioxide</td>
<td>Chloral hydrate&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Epinephrine&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Chloramphenicol</td>
</tr>
<tr>
<td>Nicotine</td>
<td>Cyclophosphamide</td>
</tr>
<tr>
<td>Nitroglycerin</td>
<td>Daunomycin</td>
</tr>
<tr>
<td>Phentermine&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Dichlorodifluoromethane</td>
</tr>
<tr>
<td>Physostigmine</td>
<td>Diethyldithiosteryl</td>
</tr>
<tr>
<td>Physostigmine salicylate</td>
<td>Hexachlorophene</td>
</tr>
<tr>
<td>Warfarin sodium ≥0.3%</td>
<td>Lindane</td>
</tr>
<tr>
<td></td>
<td>Melphalan</td>
</tr>
<tr>
<td></td>
<td>Mercury</td>
</tr>
<tr>
<td></td>
<td>Mitomycin</td>
</tr>
<tr>
<td></td>
<td>Paraldehyde&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Phenol</td>
</tr>
<tr>
<td></td>
<td>Reserpine</td>
</tr>
<tr>
<td></td>
<td>Resorcinol</td>
</tr>
<tr>
<td></td>
<td>Saccharin</td>
</tr>
<tr>
<td></td>
<td>Selenium sulfide</td>
</tr>
<tr>
<td></td>
<td>Streptozotin</td>
</tr>
<tr>
<td></td>
<td>Trichloromonofluoromethane</td>
</tr>
<tr>
<td></td>
<td>Uracil mustard</td>
</tr>
<tr>
<td></td>
<td>Warfarin sodium &lt;0.3%</td>
</tr>
</tbody>
</table>

<sup>a</sup>Continuous intravenous infusion.
<sup>b</sup>Most common hazardous waste.

PHARMACEUTICAL WASTE MANAGEMENT

The environmental effect of pharmaceutical agents is a new and controversial issue. The US Geological Services confirmed evidence of contamination of surface, ground, and drinking water by pharmaceutical compounds, including antibiotics, corticosteroids, hormones, and other drugs. The agency sampled 139 streams across the country and reported at least 1 pharmaceutical contaminant in 80% of samples. The impact of these drugs on humans is not yet known, although effects of endocrine disruptors on reproduction have been shown in aquatic organisms.

While much is yet to be discovered, many within the public health community have advocated for the use of the precautionary principle that “parties should take measures to protect public health and the environment, even in the absence of clear, scientific evidence of harm.” It is a subject worth the attention of the surgical community, given that we use and prescribe several of the more common drugs that end up as pharmaceutical waste contaminants in public waterways.

The federal Resource Conservation and Recovery Act classifies these drugs (listed in Table 4) as P-listed waste (acutely hazardous) or as U-listed waste (toxic). This Act and the Clean Water Act’s general pretreatment regulations contain specific statements regarding disposal of P-listed and U-listed waste, which are summarized in a document by Hospitals for a Healthy Environment titled Managing Pharmaceutical Waste: A 10-Step Blueprint for Health Care Facilities in the United States. Pharmacies and waste management services in hospitals can be good resources for guidelines regarding correct disposal of pharmaceutical waste and can provide needed education to surgical staff.
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