One-fourth of all operating room (OR) waste is attributed to anesthesia-related material. The goal of this project was to reduce the waste and increase cost savings of opened and unused endotracheal (ET) tubes and disposable laryngoscope handles and blades in 2 separate OR environments. The production of these unused anesthesia supplies was assessed weekly in each of 2 OR environments for 8 weeks before an educational intervention, and for 8 weeks following the intervention. The average weekly waste production was summarized for each study period, compared between periods (preintervention vs postintervention), and analyzed per 100 surgeries using the 2-sample t test. The overall average weekly waste for ET tubes was significantly reduced from 26.7 ± 10.7 to 10.0 ± 6.1 from pre to post intervention (P = < .001), representing a 62.6% reduction. A similar significant reduction in waste was observed for laryngoscope handles (15.9 ± 8.1 vs 7.2 ± 3.1; P = .004; a 54.7% reduction) and laryngoscope blades (21.5 ± 11.0 vs 9.9 ± 4.4; P = .004; a 54.0% reduction). These results highlight the significance and feasibility of an educational intervention in reducing the environmental and economic waste produced by anesthetic practices in the OR.

Keywords: Anesthesia, cost savings, education, operating room, waste reduction.

The concern about financial and environmental sustainability in the US healthcare system is not new. The United States spent $3.5 trillion on healthcare in 2016, and of this, $320 billion was spent on goods and services.1,2 Virtually everyone agrees that these costs are unsustainable.3 Similar to rising economic expenditures, there has also been a substantial rise in the amount of waste that the healthcare industry generates.4,5 Since 1992, there has been a 15% annual increase in the waste produced by US hospitals.6 Major contributing factors include a rapidly increasing population, increasing number and size of healthcare facilities, and a trend of using disposable medical products.7 An estimated 13.5 to 14.9 kg (30-33 lb) of waste is produced per patient each day, or 5.4 billion kg (12 billion lb) of waste annually.7 Furthermore, for every pound of product made in the United States, 14.4 kg (32 lb) of waste are generated in the manufacturing process alone.8

Operating rooms (ORs) are responsible for a considerable amount of a hospital’s supply costs and waste production. Approximately 20% to 30% of all hospital supplies and 70% of its total waste volume originate from ORs.9,10 Of this, 25% of all OR waste has been attributed to anesthesia-related materials.11 The recent proliferation of disposable and single-use products, in particular, has exacerbated waste production.10,12 The surge in the use of disposable products was originally driven by several factors: reasonable upfront cost and value, convenience, and ease and cost of maintenance in a climate of strict infection control.2,12 Much of the anesthesia equipment we use comes as a single-use item, including breathing circuits, carbon dioxide absorbent containers, pulse oximeter probes, laryngoscope handles and blades (LHBs), endotracheal (ET) tubes, laryngeal mask airways, warming blankets, and numerous other sources.12 It is with good intentions that healthcare facilities increasingly opt for these disposable products. However, current evidence demonstrates that the use of disposables over their reusable counterparts has substantial economic and environmental drawbacks. They impose recurring monetary investments, are remarkably detrimental to the environment, and have not been proved superior to reusable products in bolstering infection control.2,6,9,10,12-17 Despite the proliferation of single-use instruments, their theoretical advantages in terms of cost, sterility, and patient outcomes have not been proved.13

Certain disposable products, such as LHBs, may cost less to purchase and maintain; however, this cost is misleading.12 This cost assumes a life cycle or ecofootprint that extends from purchase to disposal in a waste container.12,14 In reality, the footprint of each product should include costs associated with material procurement, manufacturing, labor, and energy and water use before purchase as well as disposal labor, energy, landfill costs, and environmental impact after placement in the waste container.12,14 Moreover, many of the “single-use” products used in healthcare are labeled as such by the manufacturer, not the Food and Drug Administration.12 This arrangement allows manufacturers to capitalize on a system in which more products are manufactured and
sold.12 Furthermore, many of these companies are now recovering these “single-use” products after patient use, reprocessing the items at their facility, and then selling them back to the hospital at a discount.12 In essence, hospitals are paying for the same “single-use” product twice, or more, further incentivizing manufacturers to push their products on hospitals and patients.

At the authors’ large academic medical center, the disposable LHBs are recycled, although this process does not recover all the raw materials used in their manufacture. These products are composed of stainless steel, aluminum, plastic, and a 3V lithium-ion battery. The metals are melted down and repurposed, and the battery is sent to a facility that specializes in battery recycling. However, the process of recycling lithium-ion batteries is energy intensive and achieves an average recycling efficiency of only 40% to 50%.18,19 During this recycling process, only certain valuable elements are scavenged, including cobalt, nickel, and copper, but the rest is discarded.18,19 This waste can cause substantial damage to the environment.18 Moreover, costs associated with fossil fuel use from mining and for transport, and the recycling process itself, further increase the environmental footprint.18

Given the tremendous cumulative amount of waste and costs associated with the disposal of healthcare waste, there is substantial environmental and economic potential in waste management initiatives. Common corporate strategies to contain healthcare costs have traditionally employed expenditure reductions, such as cuts to programs and employee benefits.3 However, rather than cutting expenditures, strategies aimed at reducing waste are particularly appealing. The literature on the topic of waste reduction and resultant cost savings, particularly after an educational intervention, consistently demonstrates the value in driving down healthcare costs.2,3,5,9,12,16,17,21-24

This research study employed a similar strategy. In the ORs at the study institution, ET tubes and LHBs were observed being repeatedly opened by anesthesia providers but not used for the planned case and ultimately being discarded because of potential cross-contamination between patients. In large part, this waste was caused by anesthesia providers setting up for a surgical case, including opening and preparing ET tubes and LHBs, before having finalized an anesthetic plan. Recognizing that these plans can change multiple times before the procedure start, it was hypothesized that an educational intervention might result in reduced waste production and increased cost savings.

Materials and Methods
This waste reduction study was conducted at Mayo Clinic Hospital, Saint Marys Campus, in Rochester, Minnesota, over two 8-week periods. Phase 1 of the study represented the preeducation control and was implemented from April to May 2017. The data were collected from ORs in 2 different surgical areas, termed area 1 and area 2. Area 1 is composed of 26 ORs, and area 2 has 11 ORs. Anesthesia Department support technicians were instructed to collect opened and unused ET tubes and LHBs if they were left out on any surface between cases or if they were anywhere in the OR, including in a drawer, at the end of the day. Standards for removal of opened and unused supplies from ORs are set by the Joint Commission. These standards state: “[ET tubes] should be kept free from contamination until the time of use. Once opened, there is potential for microorganisms to settle on the device the longer it remains open and unused.”25 Standards for LHBs are virtually identical.25 Consistent with other facilities, this institution set guidelines to remove and discard opened and unused supplies in accordance with Joint Commission guidelines.

After the supplies were collected, recorded, and categorized, photos were taken of the items to provide a visual emphasis on the waste being produced (Figures 1 and 2). An educational intervention was then conducted separately for all core anesthesia staff of area 1 and area 2 in January 2018. The educational digital slide...
(PowerPoint, Microsoft Corp) presentations included the identified problem, phase 1 results, goals of the study, and new practice guidelines. With approval from departmental leadership, a flyer containing practice guidelines and photos of the waste was developed and posted in key locations throughout both surgical units.

The practice guidelines included the following strategies:

- Do not prepare ET tubes or laryngoscopy equipment for the next patient until after the current case has finished.
- Keep laryngoscopy equipment in its packaging until the anesthetic plan has been discussed with the anesthesia team and the surgical staff has left to bring the patient to the OR.
- If the anesthetic plan includes the use of video laryngoscopy, the disposable LHB should remain unopened on the anesthesia cart.
- If the anesthetic plan is monitored anesthesia care and/or spinal anesthesia, the ET tube and LHB should remain unopened on the anesthesia cart.

Phase 2 of the study represented the postintervention experimental collection period and was carried out from February 2018 to April 2018. In addition to the digital slide (PowerPoint) presentations, weekly emails were sent to anesthesia providers in both surgical units as a reminder of the initiative and to relay progress updates. The opened, unused supplies were again collected, recorded, and categorized.

- **Calculation of Costs.** Costs were calculated from the average weekly waste production from both surgical units using the following averaged market prices. The average market cost of 1 conventional disposable laryngoscope handle (LH) in a medium standard size (IntuBrite) and 1 laryngoscope blade (LB, Miller 2) was calculated by averaging the online prices from the websites of 3 major medical equipment distributors: LifeAssist, OHM Medical, and Emergency Medical Products Inc. At the time of analysis, the average price of 1 LH and 1 LB was $12.13 and $9.17, respectively. The ET tubes are made of polyvinyl chloride (PVC) and ultimately sent to an incinerator and burned. The type and size of ET tubes collected during the study varied and included ET tubes with a considerably higher cost, for instance, wire spiral and oral/nasal RAE ET tubes (named after their inventors Ring, Adair, and Elwin in 1975). However, most were a Shiley Endotracheal Tube with TaperGuard Cuff, Murphy Eye with Preloaded Stylet. The average market cost of 1 basic 8.0-mm ET tube of this make was again calculated by averaging the online prices from 3 medical equipment distributors: Tri-anim, Medsav Solutions, and MedEquip Depot. At the time of analysis, the average price of a single ET tube, not including the cost of disposal ($0.14/lb on average), was $19.16 apiece.

- **Statistical Analysis.** Descriptive statistics were used to describe OR characteristics, including waste production and volume of cases, during the baseline and intervention periods. The average weekly waste production was summarized for each 8-week period and compared between periods (phase 1 vs phase 2) and per 100 surgeries using the 2-sample t test. A P value of less than .05 was required for statistical significance. A formal sample-size/statistical power analysis was not performed. The decision to study 8 weeks for both phases was determined based on resource requirements and time constraints.

**Results**

During the study period, a substantial reduction in the average weekly waste in both surgical units (areas 1 and 2) was observed (Figure 3). In area 1, the larger surgical unit (26 ORs), the average weekly number of ET tubes collected during phase 1 was 30.6. In phase 2 an average of 11.6 ET tubes were collected per week in area 1. This represents a 62.1% reduction in ET tube waste.
Table 1. Average Weekly Number of Opened and Unused Anesthesia Supplies Before and After Educational Intervention per 100 Surgeries

<table>
<thead>
<tr>
<th>Supplies</th>
<th>Preintervention Waste, No./wk (SD)</th>
<th>Postintervention Waste, No./wk (SD)</th>
<th>P value&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endotracheal tubes</td>
<td>11.5 (4.5)</td>
<td>5.2 (3.4)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Laryngoscope handles</td>
<td>6.2 (2.0)</td>
<td>4.0 (2.0)</td>
<td>.006</td>
</tr>
<tr>
<td>Laryngoscope blades</td>
<td>8.4 (2.9)</td>
<td>5.4 (2.5)</td>
<td>.006</td>
</tr>
</tbody>
</table>

<sup>a</sup>A P < .05 is significant.

Table 2. Total Cost Savings of Opened, Unused Supplies Before and After Educational Intervention (US Dollars)

<table>
<thead>
<tr>
<th>Supplies</th>
<th>Preintervention Cost</th>
<th>Postintervention Cost</th>
<th>Cost savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endotracheal tubes</td>
<td>4,092.58</td>
<td>1,532.80</td>
<td>2,559.78</td>
</tr>
<tr>
<td>Laryngoscope handles</td>
<td>1,542.94</td>
<td>698.69</td>
<td>844.25</td>
</tr>
<tr>
<td>Laryngoscope blades</td>
<td>1,577.24</td>
<td>726.26</td>
<td>850.98</td>
</tr>
</tbody>
</table>

Regarding laryngoscopes, the average weekly number collected during phase 1 was 20.8 handles and 28 blades. In phase 2 an average of 8.3 handles and 11.8 blades were collected per week. This represented a waste reduction of 60.1% and 57.9%, respectively.

In area 2, the smaller surgical unit (11 ORs), the average weekly number of ET tubes collected during phase 1 was 17.8 ET tubes. For phase 2, supplies collected averaged 8.3 ET tubes per week. This represented a waste reduction of 53.4% of ET tubes per week. For laryngoscopes an average of 7 handles and 9 blades were collected per week. In phase 2 an average of 6.1 handles and 7.9 blades were collected per week. This corresponded to a waste reduction and cost savings of 12.9% and 12.2%, respectively.

The overall average weekly waste production data for ET tubes and LBHs demonstrated a significant reduction after the educational intervention (Figure 4). Significance was also established when the investigators compared weekly waste reduction per 100 surgeries (Table 1). Average (SD) weekly waste for ET tubes was significantly reduced from 26.7 (10.7) to 10.0 (6.1) from before to after the intervention (P < .001), representing a 62.6% reduction. For every 100 surgeries performed, average weekly ET tube waste decreased from 11.5 (4.5) to 5.2 (3.4, P < .001). Similarly, a significant reduction in the average weekly waste was observed for LHs (15.9 [8.1] vs 7.2 [3.1], P = .004, a 54.7% reduction) and for LBHs (21.5 [11.0] vs 9.9 [4.4], P = .004, a 54.0% reduction). The average weekly waste per 100 surgeries of LHs and LBs decreased, respectively, from 6.2 (2.0) to 4.0 (2.0, P = .006) and from 8.4 (2.9) to 5.4 (2.5, P = .006).

Costs of the average weekly waste production from both surgical units, derived using the aforementioned averaged market prices, are shown in Table 2. The cost of opened and unused ET tubes totaled $4,092.58 during phase 1 and $1,532.80 during phase 2. This represents a cost savings of $2,559.78 over the 8-week postintervention period. The economic savings from reduced ET tube waste when calculated per 100 surgeries equates to $965.66. Regarding LHs, the costs lost from opened and unused LHs during phase 1 totaled $1,542.94, and $698.69 during phase 2. Cost savings from LHs amounted to $844.25. Per 100 surgeries, cost savings was $213.49. Finally, the cost of opened and unused LBs during phase 1 totaled $1,577.24, and $726.26 during phase 2. Cost savings from LBs amounted to $850.98. Cost savings of LBs per 100 surgeries totaled $220.08.

Discussion

This study saved an average of 16.7 ET tubes, 8.7 LHs, and 11.6 LBs per week from being wasted. The data from this study validate the efficacy of waste reduction strategies. Consistent with published research findings, this approach reduces the healthcare system’s ecofootprint and expenditures without compromising quality of care.

The effectiveness of an educational intervention to elicit this effect was also established. However, the data suggest that a single individual presentation or message to influential stakeholders may not be sufficient. The 2 educational presentations to staff were performed 1 and 2 weeks before the start of phase 2 data collection, and each lasted approximately 30 minutes. The economic cost of creating this educational digital slide presentation can be measured in labor hours, which totaled approximately 4 to 5 hours. After data from the first week were gathered, the drop in waste relative to phase 1 data was less than expected. To address this concern, the study authors sent weekly emails to anesthesia providers in both surgical units with reminders of the initiative and progress updates. Subsequently, a significant drop in weekly waste was observed compared with week 1. For the remaining 7 weeks, ET tube waste in area 1 and area 2 dropped by an average of 59% and 71%, respectively. Likewise, LHs dropped by an average of 47% and 36% in areas 1 and 2, and LBs dropped by an average of 43% and 24%. These
data indicate that continuing education and reminders are essential to produce substantive change in practice habits.

Average weekly waste estimates could not be directly compared between areas 1 and 2 because area 1 had greater than twice the number of ORs than area 2. Additionally, a high degree of variability in caseload within and between areas 1 and 2 makes waste comparisons problematic to interpret. Of note, during the study period, collection of waste was assessed for 8 weeks during phase 1 in area 1. In area 2 the collection of waste did not start until week 5; therefore, only 4 weeks' worth of waste during phase 1 were included in analysis. Following the educational intervention (phase 2), the collection of waste was assessed for the full 8 weeks in both surgical areas. To accommodate for this divergence in data between phase 1 and phase 2, data were presented as weekly averages, and statistical significance was nonetheless maintained.

There are several limitations to this study. During phase 2, there was a 1-week collection period from March 21, 2018, through March 27, 2018, that was not included in the study. At the time of collection, it was noted that the numbers of ET tubes and LHBs in area 2 were more than double the amount of items collected at any point throughout either phase 1 or phase 2. On further inquiry it was discovered that a support technician from the Anesthesia Department had placed ET tubes and LHBs from a different surgical unit into the collection bin in area 2. This individual admitted doing so because of personal frustrations with the volume of waste that was occurring but denied having altered the data at any other point in the study. The decision was made to omit this week of data for both surgical units and extend the phase 2 collection period by 1 week.

A second limitation of this study was the reliance on Anesthesia Department support technicians to consistently gather the specified supplies. The type of supplies and the location of the collection bin were frequently communicated with the support technicians. It is possible, however, that a small to moderate amount of opened and unused ET tubes and LHBs were not placed in the collection bin and therefore not included in the study.

Finally, an additional limitation relates to provider logistics and communication. A large number of anesthesia providers work throughout this medical facility, and many of them float between surgical units. Direct communication of the initiative via the weekly emails sent to the anesthesia providers in both units did not include those who were randomly floated to areas 1 and 2 during the study periods. This is due, in part, to unpredictable staffing changes that can occur at any time throughout each day. Without comprehensive inclusion of all anesthesia providers, including anesthesiologists, Certified Registered Nurse Anesthetists, anesthesia residents, and student registered nurse anesthetists on the email list and as part of the educational intervention, this limitation is virtually unavoidable. There is a high probability that with an all-inclusive and recurring approach of waste reduction education, the amount of preventable waste would be further reduced.

In the future, a wide range of studies could be conducted that emphasize the importance and legitimacy of this research. For example, a study to ascertain the lasting effects of an education intervention on waste reduction would be valuable. A periodic staff satisfaction survey might be successful in identifying a decline in compliance with waste reduction and, therefore, the need for additional or alternative interventions. Research could also be done to establish the true economic and/or environmental cost of all preventable anesthesia equipment waste. For instance, investigators might conduct a descriptive study detailing anesthesia waste and/or the environmental impact of this waste. Any research project designed to address the growing burden of hospital waste would add valuable knowledge to promoting the serious nature of this issue.

The current challenges of healthcare in the United States include efforts that attempt to balance cost reductions with uncompromised patient care. Although patient care is guided by principles aimed at improving safety and quality, efforts to curtail the environmental impacts of these undertakings are often neglected or postponed. The results of this study demonstrate one simple method of reducing anesthesia's ecofootprint without harming patient care. This is relevant to the future of healthcare in several ways. The environmental and economic cost savings potential of this approach is substantial, and it begins with hospitals providing and reinforcing waste reduction education to their employees. Even at facilities with smaller case volumes, the per capita advantages are meaningful in reducing unproductive expenditures and healthcare costs as a whole. Additionally, such initiatives open the conversation about what we can do personally to reduce waste. Throughout this study, numerous anesthesia providers went out of their way to express gratitude that an attempt was being made to reduce OR waste. Countless other anesthesia providers privately affirmed they were much more cognizant of the packages and equipment they were opening, even beyond ET tubes and LHBs.

The sheer volume of waste being produced cannot possibly continue unabated for both environmental and economic reasons. The Hippocratic Oath states, “First, do no harm.” Yet, it is ironic that by doing our very best to protect the health of our patients, we are coincidentally contributing to a dilemma that threatens the very individual, community, and society we seek to protect. In the future, healthcare systems can look to this research and others like it, as proven examples of the value of educational interventions designed to decrease healthcare costs through waste reduction.
REFERENCES


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