The goal of this project was to optimally sort waste material in the operating room (OR) environment and divert waste such that streams of low-cost disposal, including recyclable material, could be maximized. Using the Lean Six Sigma method, we followed 5 steps to define, measure, analyze, improve, and control. Descriptive statistics were used to describe OR characteristics during the study period. Two-sample Student t test with assumption of unequal variance was used to compare the daily weight of solid waste, regulated medical waste, and recyclable waste between the 2-week baseline period and the 2-week implementation period.

The weight and number of bags of solid waste decreased by 12% and 6% per OR per day, respectively. For regulated medical waste, the weight and number of bags decreased by 59% and 61% per OR per day, respectively. Recycled-material weight and number of bags increased by 19% and 45% per OR per day, respectively. This work emphasizes the importance and feasibility of implementing a program of appropriate waste segregation in the OR not only to improve safety in disposal practices but also to minimize institutional disposal costs and reduce the environmental footprint generated by the healthcare sector.

**Keywords:** Operating room, RECOR, recycled material, waste streams.
the change, improving the process, and controlling the implementation of the newly adopted process. Lean Six Sigma is a lean method frequently used in manufacturing or healthcare organizations and relies on a collaborative team effort to improve performance by systematically removing wasteful steps or processes. This method is based on frontline user initiatives; it is carried out by process improvement projects, and it emphasizes change based on analysis of quantitative data.9,10

For the purpose of this project, the following steps were taken: (1) evaluation and audit of waste streams and identification of barriers to effective and efficient segregation of waste; (2) survey of frontline users (stakeholders) in the OR to identify barriers as well as to contribute ideas for remedying any obstacles to proper waste segregation; (3) on the basis of the data collected and input received, design and introduction of a new waste system in the anesthesia area to facilitate and optimize waste segregation; (4) education of staff through modules, printed materials, posters, and in-services; and (5) posting of metrics of success once the buy-in period was complete.

Defining the Problem. First, we identified 4 types of waste streams: solid waste (landfill), RMW, pharmaceutical waste, and recyclable waste. At our institution, recyclable waste is considered to be clean paper, plastic, and empty unbroken glass, such as much of the packaging surrounding medical supplies. Pharmaceutical waste is considered to be any form of medication that is no longer needed, is partially used, or is contaminated and cannot be returned to the pharmacy, with the exception of controlled substances. Regulated medical waste is considered to be items saturated, soaked, or dripping with blood or other potentially infectious bodily fluid. Solid waste would include items that do not fall into any of these categories, such as lightly contaminated material and nonrecyclable items.

Measuring the Endpoints. As part of the evaluation process, we reviewed hospital-wide waste volume and costs of disposal as reported directly from environmental services reports. In addition, we collected data during a baseline period by weighing bags of waste (solid waste, pharmaceutical, and sharps waste streams, with practical examples of objects commonly used and disposed in the OR) in kilograms per day and counted number of bags of waste per day in each of the waste streams in 16 ORs over a 2-week period. We also counted the cumulative number of sharps boxes disposed at the end of the 2-week observation period. The daily sorting and weighing of bags during the data collection periods was accomplished by volunteer research assistants. Of note, a dedicated pharmaceutical waste system was not available during the baseline period; therefore, this waste stream was not included in our calculations. For development of improvement strategies, stakeholders directly involved in the waste process (OR nurses, surgeons, surgical technicians, anesthesia providers, anesthesia technicians, and environmental services) were interviewed in focus groups (10 groups total). These focus groups assessed motivation, attitudes, and barriers to improved recycling and segregation of waste streams.

At the completion of the focus group interviews, an email survey was distributed among the entire OR staff (anesthesia and surgical residents, nurse anesthetists, attending surgeon and anesthesiologist, and other OR personnel). The survey structure consisted of a set of questions to test baseline knowledge, as well as open-ended questions to acquire additional knowledge of the level of motivation and barriers to improve recycling and decrease improper waste.

Analyzing and Improving the Process. Based on the data collected and the needs evaluation, we designed a freestanding ergonomic waste station for anesthesia areas that allowed a safe and streamlined process for identification and appropriate segregation of waste streams. We designed and posted clear signage on the individual receptacles and larger wall-mount posters to provide overall guidance. The improvement process also included adding receptacles for pharmaceutical waste elimination, and resizing of the receptacles for solid waste, sharps waste, and recyclable waste, according to their respective needed volumes.

An extensive educational campaign targeting stakeholders and frontline users was then initiated. The education program included presentations through live interactive, small-group sessions detailing the rationale of the change with opportunity to express concerns and ask questions, formal seminars detailing the proper triage of waste, and email distribution of educational material to all current OR staff. The content of the learning modules included the following topics: education on the financial and environmental impact of waste generation and guidance on what constitutes solid, RMW, recyclable, pharmaceutical, and sharps waste streams, with practical examples of objects commonly used and disposed in daily OR activities.

Controlling the Implementation of the Process. Following the program implementation and after the education process had reached most OR personnel, we collected postintervention data. Again, daily weights and number of bags in each waste category were collected during 2 consecutive weeks. After 20 weeks of implementation, we administered a postintervention survey of the stakeholders to assess knowledge and obtain feedback. Finally, we posted the waste reduction data for all stakeholders to review in the OR main entrance.

Statistical Analysis. Descriptive statistics were used to describe OR characteristics during the study period, including volume of cases and number of rooms open from 7 AM to 5 PM, during the baseline and the intervention period. Two-sample Student t test with assumption of unequal variance (Satterthwaite approximation for degrees of freedom) was used to compare the daily weight
Results

• Waste Streams. During the study period, we observed a substantial change in solid waste, RMW, sharps, and recyclable waste in weight (Figure 1) and by number of bags (Figure 2) per day. Daily weight of solid waste decreased in the intervention period compared with the baseline period (P < .01, Table), a reduction of 12% in the 16 ORs evaluated. The number of solid waste bags per OR per day also decreased comparing baseline and intervention periods (P = .02). Regulated medical waste decreased in weight by 59%, comparing the baseline with the intervention period. The number of bags of RMW decreased (P < .01) as well, a reduction of 61% between baseline and intervention periods. The weight of recyclable waste increased from a mean (± SD) of 0.89 ± 0.50 kg to 1.06 ± 0.55 kg per OR per day (P < .01), an increase of 19% from baseline to the intervention period. Similarly, the number of bags of recyclable waste increased from 0.64 ± 0.34 to 0.93 ± 0.56 (P < .01), an increase of 45% between baseline and intervention periods.

Sharps waste was evaluated in terms of volume rather than weight. During the intervention period, we downsized the sharps collection box in the anesthesia area from 15.2 L (4 gallons) to 7.6 L (2 gallons). On average, the 15.2-L sharps box in the baseline period was replaced every 10 days (approximately 4.5 kg when full). In the intervention period, the 7.6-L sharps box was replaced every 12 days or longer (approximately 2 kg when full). These data indicate a greater than 50% reduction in sharps waste comparing the baseline with the intervention period.

• Users’ Knowledge Survey. During the baseline period, 143 staff members returned the questionnaire, and 164 returned the questionnaire in the intervention period, a response rate of 30% and 29%, respectively (Figure 3). There was a significant improvement in the knowledge of proper waste triage. The largest change was achieved in the correct disposition of empty glass bottles/vials. In the baseline period, 37% of respondents incorrectly indicated that glass bottles/vials should be disposed in boxes for sharps (37%) and only 33% correctly indicated that glass bottles should be recycled. However, in the intervention period, only 19% indicated glass bottles/vials should be disposed in sharps boxes and 58% responded correctly. Likewise, although in the baseline period only 54% of respondents indicated that they would recycle always or most of the time, this percentage increased to 92% in the intervention period (Figure 4).

Discussion

In this study we found a substantial amount of misconception in the proper disposal of several items of waste material in the various waste streams. After identification...
of barriers to proper disposal, we observed a substantial improvement in the behavior associated with proper segregation of waste. The largest change occurred in RMW and sharps waste. Overall, this resulted in reduced volume of solid waste, RMW, and sharps waste, and increased the volume of recycled material in 16 OR suites of a large urban academic center.

Because the cost of disposal for RMW, sharps, and solid waste is much higher than recycling, we anticipate direct cost savings to the institution associated with the reduction of RMW, sharps boxes volume and their turnover, and solid waste. Moreover, these savings do not account for personnel cost, labor for sterilization, water use, and additional costs associated with the reduction in volume of sharps waste. An important aspect of appropriate segregation is not only related to improved safety of handling of hazardous material but also improvement of compliance with regulatory requirements for pharmaceutical waste, and appropriate disposal of controlled substances. Our intervention included the introduction of a container for the disposal of small-volume pharmaceutical waste containing a solidifier that allows making the substances nonretrievable and unrecognizable. This secure, convenient, and responsible form of disposal is in compliance with US Drug Enforcement Administration regulations and guidance for the standard of destruction of controlled substances, so that diversion can be prevented. Once the substances are rendered nonretrievable, they are no longer subject to the requirements of the Drug Enforcement Administration.11

It is imperative that surgeons, anesthesia providers, nursing staff, surgical technicians, OR personnel, administration, and environmental services staff are all engaged for these types of initiatives to be successful.

This article shows the successful implementation of the Lean Six Sigma method and how anesthesia providers can take a leadership role in designing and managing a process improvement project aimed at reducing hospital waste. In today’s healthcare environment, hospital leaders are searching for opportunities to decrease expenses and should look to frontline users to identify areas of unnecessary waste. Lean Six Sigma emphasizes that solutions are generated from frontline users who

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**Table.** Change in Volume and Weight of Waste in the Different Disposal Streams

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline period</th>
<th>Intervention period</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid waste</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight/day/OR, kg</td>
<td>4.3 ± 1.5</td>
<td>3.8 ± 1.7</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Number of bags</td>
<td>1.7 ± 0.5</td>
<td>1.5 ± 0.6</td>
<td>0.02</td>
</tr>
<tr>
<td>Recyclable waste</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight/day/OR, kg</td>
<td>0.89 ± 0.50</td>
<td>1.06 ± 0.55</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Number of bags</td>
<td>0.64 ± 0.34</td>
<td>0.93 ± 0.56</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Regulated medical waste</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight/day/OR, kg</td>
<td>0.46 ± 0.10</td>
<td>0.19 ± 0.06</td>
<td>0.02</td>
</tr>
<tr>
<td>Number of bags</td>
<td>0.20 ± 0.03</td>
<td>0.08 ± 0.01</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>
work in the process, and it helps make the changes sustainable. Many of the solutions implemented in this project were a result of the focus group sessions and surveys emailed to stakeholders.

There are several limitations to this study. These results could have been due to the Hawthorne effect; that is, personnel changed their actions because they were being observed. However, the changes introduced by the intervention appeared to be sustained in later observational data collection. The baseline and intervention collection periods were relatively short, and we assumed that the periods of data collection were representative of the activities during 1 entire year. Because we did not find substantial differences in the number of cases (463 baseline and 457 intervention) and turnovers between the 2 random periods, we believe that the 2 samples might indeed be adequately representative. The response to our knowledge surveys was low. It is possible that among the multiple tasks that providers receive daily, this was not perceived as a high-priority issue. However, this project is an initial effort to emphasize and raise awareness regarding judicious disposal practices benefiting the environment, increasing the safety of the workplace, allowing compliance with regulatory requirements, and resulting in a reduction of use of constrained financial resources.

In conclusion, this study found a positive effect on reduction in unnecessary high volumes of costly waste streams and was successful in diverting waste toward less expensive and more environmentally friendly waste streams. As financial pressures and the environmental and health effects of waste and carbon emissions receive more attention, we encourage institutions to take on such process improvement initiatives to make reductions in their waste processes. Not only is proper segregation of waste and increased recycling favorable for the environment and for community health, but it also allows safe disposal of hazardous material and controlled substances in compliance with regulatory requirements. Additionally, such initiatives open the conversation about decreasing the generation of waste overall, and many may find themselves being more judicious in their individual practices. Developing important partnerships with nursing, administrative, and environmental services leaders is paramount to the success of such an initiative.

REFERENCES
11. Drug Enforcement Administration. 21 CFR Parts 1300, 3101, 3014 et al. Disposal of Controlled Substances; Final Rule.

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DISCLOSURES
The authors have declared they have no financial relationships with any commercial interest related to the content of this activity. The authors did not discuss off-label use within the article.

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