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Using Education to Promote Waste Segregation and Waste Reduction in the Operating Room: A Quality Improvement Initiative

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Abstract

Background: The operating room (OR) is known to be one of the largest producers of medical waste and of the surgical specialties, orthopedic surgery tends to the largest portion of this. Waste from the OR can be mitigated by recycling non-contaminated materials. This reduces the number of raw materials needed to create new products, decreases landfill use, and lowers hospital costs.

Local Problem: It was observed that a gap in knowledge existed related to recyclables in the OR of a large medical center in New England. Also, it was observed that there was potential for waste and recycling to be more accurately segregated and for blue wrap to be separated from general recycling.

Specific Aims: The aim was to increase circulating nurses' and surgical technologists' confidence in knowledge of recyclables in the operating room. Additionally, the aim was to increase the proportion of recycling by 15%, increase the accuracy of recycling to 95%, and increase the accuracy of blue sterilization wrap segregation to 100%.

Methods: The Plan-Do-Study-Act (PDSA) model was used for implementation. Pre- and post-education waste audits of primary total knee arthroplasties were performed to assess recycling, blue wrap, and waste. Pre- and post-education surveys were utilized to assess staff confidence.

Interventions: An educational presentation was given to orthopedic surgical service circulating nurses and surgical technologists. Additionally, a visual poster board was displayed in the staff breakroom.

Results: Survey data indicated an increase between pre- and post-education confidence in staff, which met the specific aim. Waste audit data showed a 26% increase in pre-operative proportions of recycling and an approximate 4% decrease in blue wrap by weight. There was a decrease in recycling accuracy by 6.6% but an increase of about 25% in the accuracy of blue wrap segregation post-intervention.

Conclusion: Education for a subset of perioperative staff aided in increased confidence in recycling in the OR. Further improvements in staff confidence, recycling, and blue sterilization wrap segregation throughout surgical specialties may be possible through additional education and physical resources.

Keywords: total knee arthroplasty, recycling, blue sterilization wrap, waste reduction, waste management, waste audit, nurse, education, confidence, quality improvement

Introduction

Healthcare produces an extraordinary amount of waste. While the healthcare sector seeks to improve the population's health, it is the second most energy-consuming industry and unfortunately, accounts for 10% of the United States' greenhouse gas emissions (Eckelman and Sherman, 2016). Further, within the sector, operating room waste is known to contribute 20 to 30% of a hospital's overall waste stream (Kwayke et al., 2011). It is estimated that of the 4 billion pounds of waste produced in the healthcare sector per year and between 800 million to 1.2 billion pounds of waste could be from the operating room (Kwayke et al., 2011).

Problem Description

In 2011, the macrosystem joined the initiative "Greening the Operating Room" organized by Practice Greenhealth (Ramer, 2011). The microsystem's vision includes a "commitment to continuous improvement... and the most efficient use of resources" ("Perioperative Services", 2023). However, it was not evident throughout the 26 operating suites that recycling best practices were being utilized and therefore the most efficient use of resources was not being practiced.

Recycling within the operating room (OR) ultimately becomes the responsibility of the circulating nurse and surgical technologist. This is because they control the non-sterile field as well as manage what comes off the sterile field. It was observed anecdotally that many of these staff members expressed frustration over recycling in the operating room because of a lack of clarity and changing guidelines. After many changes, their frustration grew to the point that they gave up their efforts to recycle either partially or altogether.

In addition to this observation, it was also observed that amongst the waste produced per surgical case, only a small proportion was recycled. However, not all potentially recyclable items were being recycled and waste would also be added to the recycling bag. As well as not being sorted correctly, there was no additional receptacle for general recycling as opposed to blue wrap. Finally, no data existed to quantify the amount of waste and/ or recycling generated by the operating room, thus perpetuating the difficulty of understanding improvements or failures of recycling initiatives.

Because of the severity of the current state, a group of staff members initiated a committee to improve the recycling operation. Additionally, a nurse educator confirmed that recycling would be encouraged as a quality initiative for this project. Therefore, the purpose of this project was to increase the percentage of waste that was recycled compared to general waste through the education of the circulating nurse and surgical technologist. This initiative also sought to improve nurses' and surgical technologists' confidence in their knowledge of recycling in the OR.

Available Knowledge

Certain specialty services and operations in the surgical theater account for more waste than others. It is purported that orthopedic surgery, specifically arthroplasty, accounts for significantly more waste than other services. However, it is unclear exactly how much waste is being produced in these cases. This is significant because, between 2012 and 2020, an average of 152,912 primary total knee arthroplasties (TKAs) occurred per year in the United States (Siddiqi et al., 2021).

This literature review seeks to determine trends in waste streams from orthopedic surgeries, specifically primary total knee arthroplasties. Waste streams of interest are recyclable materials as well as general and clinical waste. Additional studies of interest include those where staff educational programs on waste segregation or sustainability were implemented or revised.

Search Methods

On April 10, 2023, a literature search was initiated to identify existing studies related to recycling and waste streams in the operating room. Specifically, this search was targeted toward the orthopedic surgery service. This author utilized the search engine Elton B. Stephens Company (EBSCO*host*) to conduct this search. The five databases searched included the following: Medical Literature Analysis and Retrieval System Online (MEDLINE), Academic Search Complete, Cumulated Index for Nursing and Allied Health Literature (CINAHL Complete), Cochrane Database of Systematic Reviews, and GreenFile.

The limiters applied to this search included 'peer-reviewed' articles only as well as publications in the English language. Additionally, the search was confined to publication between January 1, 2012, and the present. The search was expanded by applying equivocal subjects. The following Boolean phrase was used to search for relevant articles: (medical waste OR waste management OR waste reduction OR sustainability OR environmental sustainability) AND (orthopedic surgery OR orthopaedic surgery) AND (recycling OR recycle OR recycled) NOT (anesthesia OR gas OR ventilation).

The search resulted in eight articles that were screened for subject relevance and rigor of evidence. These articles included subject contents of recycling or waste stream in the orthopedic operating room. Studies examining the environmental sustainability of anesthesia or anesthetic gases were excluded. If surgeries within the orthopedic service were specified, only studies involving joint arthroplasties were included. Finally, studies with interventions that included educational components were prioritized.

One article was removed from the review due to it being a waste audit (data collection) without any intervention. Further, this article only focused on rotator cuff repairs and knee arthroscopies. One article was removed as it was about lean practices in orthopedic surgeries and reducing 'waste' but not about physical waste management. Two additional articles were excluded because of the lack of rigor and no systematic review process. Namely narrative review processes were used to examine various aspects of environmental sustainability throughout the healthcare system.

Further, a Google Scholar search was performed to identify articles that may have not been found through the database search. This search was meant to increase the scope of the review to any unpublished studies and reduce publication bias. An additional 11 articles were discovered and screened with the same inclusion and exclusion criteria. Of these, one systematic review and one case series were included in this review.

Review of Literature

Of the six studies reviewed, two were Level 1 systematic reviews and four were Level 4 case, cohort, or cross-sectional designs according to the hierarchy of evidence pyramid (Evans, 2003). Each of the Level 4 studies completed waste audits. One study was solely on primary total knee arthroplasties, one focused on both primary total knees and hips, one evaluated all orthopedic subspecialties, and the other focused on the operating room in general. These are described in greater detail as follows.

Stall et al. (2013) conducted a surgical waste audit of five primary total knee arthroplasties in February 2010 in a hospital in Canada. The authors sought to accurately depict and quantify waste from total knee arthroplasties and subsequently identify the most impactful ways to manage that waste (Stall et al., 2013). All five TKAs were performed by the same surgeon at the same hospital. Waste was collected and then segregated into 6 streams: regular waste, recycled plastics, biohazard waste, linens, sharps, and blue sterilization wrap. The data obtained included the volume and weight of each category per case. Unique to this study, each of the items collected was also cataloged. This provides a comprehensive list of the types and quantities of each item that contributes to each waste stream.

This study only calculated percentages for each waste stream from the average weights of waste per category were calculated. These were determined to be the following: 8.6 kilograms (kg) of regular waste, 0.3 kg of recyclables, 2.5 kg of biohazard, 1.6 kg of blue wrap, 7.8 kg of linens, and 0.3 kg of sharps (Stall et al., 2013). When linens and sharps are excluded, the result was an average of 13 kg of total waste per TKA case. This meant that 14.4 % of the total waste was recycled when sharps and linens are excluded. Recycling was in the form of blue wrap (12.1%) and plastic recyclables (2.2%) (Stall et al., 2013).

This study design was highly specific to one surgeon at one institution and detailed statistical analysis is not performed, both of which limit the application of this study. The authors acknowledged that 14.4% of waste that was recycled was considerably low (Stall et al., 2013). This places an increased burden on the regular waste stream, but also drives up hospital costs and increases public health risks from landfills and pollution. This is also true of biohazard and regular waste when not properly segregated due to the high financial and ecological expense of biohazardous material (Stall et al., 2013). Stall et al. (2013) recommend not only implementing a formal recycling program, but also engaging stakeholders in proper waste segregation, discussing decreasing packaging with suppliers, and developing a team of environmental steward champions (Stall et al., 2013).

Lee and Mears (2012) conducted an early waste audit study that hypothesized that most waste from primary total hip and knee arthroplasties could be recycled. Waste was collected over two months from one operating room where one surgeon performed 10 primary total knee arthroplasties and 10 total hip arthroplasties. The study does not disclose where the surgeries took place, but the authors were identified as being associated with Johns Hopkins University/ Bayview Medical Center. The cases that were selected were identified prospectively. For each surgery, the waste collection was performed as it was passed off the sterile field. This was separated by contaminated and uncontaminated waste where any plastic or paper recyclables came from uncontaminated waste. Contaminated waste was defined as anything that had "directly or indirectly come into contact with body fluid, blood, or tissues" (Lee & Mears, 2012). All segregated materials were then weighed and then disposed of per hospital.

With regards to total knee arthroplasty, quantitative results included a total waste average of 33.2 pounds per TKA procedure. Uncontaminated waste from total knee replacements accounted for 27.4% of total waste or 9.9 pounds per case on average. Of this, 7.3 pounds were potentially recyclable materials and accounted for 22.0% of the total waste (Lee & Mears, 2012). These materials included paper and plastic packaging. However, the 2.2 pounds (21.8%) of uncontaminated waste that was not recyclable was not specified.

The authors ultimately recommend that blue sterilization wrap have its waste stream. However, this recommendation was limited by the authors alluding to blue sterilization wrap being considered an uncontaminated waste product but not clarifying what proportion of the 2.2 pounds this is (Leer & Meers, 2012). The link provided to the conflict-of-interest disclosures did not link to the authors' statement of conflict of interest, which could be impactful. Another limiting effect of this study was that no advanced statistical analysis or measures of significance were reported on the data, making it difficult to draw conclusions based on quantitative evidence. Further, the study design of one surgeon, in one operating room, in one hospital performing prospectively chosen arthroplasty cases makes the data increasingly difficult to generalize. But sthe authors demonstrate that between 22.0% and 27.4% of waste from primary total knee arthroplasties has the potential to be recycled (Leer & Meers, 2012). This serves as additional data to predict what proportion of waste in these cases might be recyclable.

Kooner et al. (2020) sought to determine the amount of waste compared to recycling material in the preoperative and operative periods in orthopedic subspecialties at a tertiary hospital in Alberta, Canada. The preoperative period began when case carts were opened and ended after the patient's surgical site was prepped. The operative period was defined as after the skin was prepped and finished after the room was cleaned (Kooner et al., 2020). The six subspecialties of orthopedics included arthroplasty, sports, pediatrics, foot and ankle, trauma, and upper extremity.

Kooner et al. (2020) hypothesized that the arthroplasty subspecialty had the greatest total amount of waste produced. They also hypothesized that most of the preoperative waste can be recycled. In total, fifty-five procedures were evaluated over 1 month, and of those, fourteen cases were arthroplasty. It was found that arthroplasty had the highest mean mass of recyclable materials in the preoperative stage (2017.1 grams). This accounted for 86% of the total recyclable materials per case (Kooner et al., 2020). Additionally, the percentage of total recyclable waste (both pre-and intraoperatively) from an arthroplasty case was significant ($p < 0.05$) at 33.5% compared to any other subspecialty. Unfortunately, the amount of non-recyclable waste, biohazard waste, and total waste from arthroplasty per case was also significantly more ($p < 0.05$) compared to all other subspecialties (Kooner et al., 2020).

Limitations of the Kooner et al. (2020) study include that it was performed in Canada where the impact of hospital waste is less compared to the United States, waste segregation was not observed, and surgeries were picked in advance to fit a subspecialty descriptor (Kooner et al., 2020). Additionally, more arthroplasty cases (n=14) were evaluated compared to any other specialty (i.e., pediatric cases, n=4). Further, the pediatric cases included several spine deformity cases which generate a larger amount of waste than other procedures due to their duration and complexity (Kooner et al., 2020).

While arthroplasty has the highest percentage of recyclable materials, Kooner et al. (2020) define recyclable items as “noncontaminated plastics, cardboard, and various wrapping materials” (Kooner et al., 2020). Because the types of wrapping materials are not defined including blue sterilization wrap, the generalizability of this study was limited in that respect. Further, the study does not differentiate the cases within the subspecialties, which makes it difficult to determine specific surgeries that contribute to overall waste in that subspecialty. What is implied from this study, however, is that the preoperative period for arthroplasty procedures might be the most fruitful for targeting waste segregation/ recycling efforts.

Wyssusek et al. (2016) sought to evaluate the proportion of general, clinical, and recycling waste from a 21-room operating suite at a tertiary hospital in Australia. After the initial evaluation, a waste segregation program was implemented, and later a true recycling program was implemented. Their goal was to analyze cost savings from their improved waste management practices (Wyssusek et al., 2016).

In September 2009 a waste audit was performed daily for the entire operating suite over four weeks pre-intervention. After the baseline data was collected, an educational program and policy were implemented to guide waste segregation between clinical and general waste. After one month of trialing this intervention, a second four-week waste audit was conducted in November 2009. In 2013, a recycling initiative was implemented. This identified general waste that was recyclable such as cardboard, blue wrap, and hard plastics (Wyssusek et al., 2016).

After the first waste audit, Wyssusek et al. (2016) determined that 100% of waste was clinical waste. But, in November 2009 after the implementation of the waste segregation movement, 33% of waste was clinical and 66% was general waste. Following the implementation n of a recycling program in 2013, 18% of waste was clinical, 26% was general waste, and 56% was determined to be recyclable. This reduced the amount of total waste by over 50% (Wyssusek et al., 2016). It was important to note that statistical analysis was not performed or published on this data. However, based on the calculation of a 7:1 cost ratio of clinical waste to general waste, Wyssusek et al. (2016) estimate that this reduction in clinical waste saved the hospital $10,200 per month.

Attitude towards waste management was identified as one of the biggest barriers to this recycling project. However, Wyssusek et al. (2016) identify behavioral change strategies, naming champions, and providing education as elements that contributed to positively enforce the confidence of the staff members to succeed. Unfortunately, Wyssusek et al. (2016) do not mention any qualitative or quantitative measures as it relates to staff members' perceptions or confidence in waste management. Implications for further studies include those that quantify the change in staff beliefs or understanding of waste management may be useful to assist in the standardization of waste management strategies, at least at the local level.

Self-reported limitations of the study by Wyssusek et al. (2016) include that waste audits were performed for the entire OR over four weeks. Within this time frame the caseloads and quantities of each type of case during the audit period were not considered. This indicates that a potential reason for differing results might be due to the overall volume or types of cases. However, due to the drastic reduction in clinical waste, and because of the lengthy period it was measured over, it seems unlikely that this has a great effect on the overall outcome of the study.

Phoon et al. (2022) conducted a scoping review of the literature to understand sustainability practices in orthopedic surgery as well as the environmental impact of orthopedic surgery. The authors of this systematic review utilized preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines. The databases MEDLINE, Embase, and PubMed were searched to reveal 2665 articles for screening and 13 were selected for review. Of these articles, nine studies reviewed waste management through segregation practices. Phoon et al. (2022) noted barriers to initiating and implementing change among OR staff. While a lack of infrastructure for recycling was most cited, a lack of knowledge and unclear guidelines were also noted by OR staff as barriers to engaging in waste segregation and recycling (Phoon et al., 2022).

Two of the most prominent results from the literature review by Phoon et al. (2022) include the need for standardization of waste management practices across all operating rooms as well as the need to accompany this implementation with clear policies and collaborate with stakeholders throughout the change process. These conclusions were based on the limitations uncovered by Phoon et al. (2022). This is because the studies reviewed had no single, standardized way of evaluating waste management or implementing a program. More specifically, Phoon et al. (2022) demonstrated that the sample size and design from the current literature need to be homogenized to make more accurate comparisons between studies and provide a meta-analysis of the effect. Additionally, no studies describe the long-term benefit of environmental sustainability practices or the safety or efficacy of these practices.

Interestingly, the findings of Phoon et al. (2022) were similar to that of Slutzman et al. (2023). Slutzman et al. (2023) also completed a systematic review utilizing the PRISMA framework to review all published waste audit studies performed in the healthcare sector to inform ideal audit guidelines. The team conducted a literature review across five databases including MEDLINE, Embase, Inspec, Scopus, and the Web of Science Core Collection (Slutzman et al., 2023). This search resulted in 2398 studies, where 156 were ultimately screened using rigorous methods to decrease bias. Qualitative data such as type of publication, country of origin, audit details, and audit methodology were extracted from each article (Slutzman et al., 2023).

Slutzman et al. (2023) determined that the most sought-after reason for conducting waste audits was to improve the quality of waste policies and practices (74% of articles). This was followed by a desire to decrease waste, inform regulatory policy, then increase or improve waste diversion/ recycling (Slutzman et al., 2023). The methodology of audits was also investigated. The most common way to audit waste was to weigh it directly (86%) whereas the least common was to count items to obtain weight (2%). Other topics that were investigated included data recording procedures, waste sorting methods, and facility characteristics (Slutzman et al., 2023). Additionally, waste audit protocols put forth by agencies both in healthcare and other sectors were evaluated. This study confirms that Practice Greenhealth, a national organization boasting stewardship promotion in the healthcare sector, does not provide a waste auditing tool, although they recommend that a waste audit be conducted at each institution seeking to improve waste management (Slutzman et al., 2023).

Slutzman et al. (2023) in their review did not find a reliable, standardized waste audit tool available nationally or internationally for the healthcare industry. However, based on their literature, they propose a standardized tool using a framework for an environmental life cycle assessment under the rigorous guidelines of the International Organization for Standardization (ISO). This suggested waste audit, if applied widely to all waste audits, would improve study design and reliability as well as enhance the ability to compare and synthesize the data for meta-analyses (Slutzman et al., 2023).

It was proposed that further assessment of cost analyses of waste per procedure and analyses of clinical/ patient outcomes are necessary to determine the impact of waste management, reduction, and/ or recycling throughout healthcare. This includes impacts on public and environmental health (Slutzman et al., 2023). Limitations of this study include the exclusion criteria such as not reviewing studies where questionnaires were utilized instead of a direct audit. Also, only articles in English were retrieved, which eliminated 66 additional studies from the review (Slutzman et al., 2023).

Evidence Synthesis: Waste Audits

Collection Methodology. Various methodology of waste audits was included in the non-review articles. These methods included collection as follows: (1) general, biohazard, and recycling from pre- and intraoperatively (Kooner et al., 2020), (2) general and clinical waste measured post-operatively (Wyssusek et al., 2016), (3) regular waste, linens, sharps, blue wrap, plastics, and biohazard measured post-operatively as well as cataloged by item (Stall et al., 2013), and (4) contaminated and uncontaminated waste collected as it was passed off the sterile field (Lee & Mears, 2012). The measurement of waste occurred over a given number of cases between 5-10 total knee arthroplasties and 14 non-specified arthroplasty cases. The fourth study performed a waste audit over a given period (4 weeks) for the entire operating suite. Two studies were conducted at tertiary hospitals in Canada, one study was conducted at a tertiary hospital in Australia, and the fourth study did not disclose the specific hospital or operating center but was presumed to be in the United States.

Study Design. The only pre- and post-education/ policy change waste audit was conducted by Wyssusek et al. (2016). These first and second waste audits evaluated clinical and general waste percentages. The change was demonstrated from the first audit to the second. However, a limitation of this specific study included that the third waste audit was conducted three years after the second waste audit. While this is important to understand the sustainability of the program, the data collected from the second waste audit was used to validate successes in the implementation of the new recycling program. For this reason, it was unclear if unspecified changes between the second waste audit and third waste audit occurred which impacted the study results. Further, the findings are difficult to generalize to the prospective study as a recycling program did not already exist at the hospital where Wyssusek et al. (2016) conducted their quality improvement initiative.

Data & Significance. Except for the itemized catalog of waste products, all other measures were weights and volume of waste. The percentage of the average amount of recyclables from total waste per primary total knee case ranged from 14.4- 22% (Lee & Mears, 2012; Stall et al., 2013). When non-specific arthroplasty cases within the orthopedic service were evaluated 33.5% of total waste was found to be recyclable per case and 86% of this was generated in the pre-operative stage (Kooner et al., 2020). After the implementation of recycling practices by Wyssusek et al. (2016), 56% of all operating waste was recyclable.

These findings vary greatly, especially as one of the TKA-specific studies does not explicitly say if the calculation of the 22% potentially recyclable materials included blue sterilization wrap whereas the 14.4% figure does contain blue sterilization wrap. The large range of percentages of recyclable materials from total waste makes it difficult to predict what the actual number might be from primary total knees at this author's site. Further, the only data that was statistically analyzed for significance ($p < 0.05$) was found in the study by Kooner et al. (2020). This meant that the 33.5% of recyclable materials from arthroplasty cases was significant compared to other orthopedic surgery subspecialties when pediatrics was excluded. Unfortunately, this study does not specify the types of arthroplasty cases that were evaluated, and therefore it cannot be concluded if 33.5% was an accurate prediction of recyclable percentages for primary total knee arthroplasties.

Evidence Synthesis: Staff Education

Methods. All the reviewed studies discussed staff education or training on waste segregation, waste management, or environmental sustainability. Unfortunately, each study did so anecdotally; there was no formal discussion of measured quantitative or qualitative behavioral changes in staff as it relates to these topics. Further, no studies evaluated education with pre- and post-educational assessments, hence creating a gap in the literature.

The limited mentions of approaches and methods utilized to educate staff included the following verbiage: behavioral change theory, project teams, champions, mentorship posters as well as “education on environmental issues, waste management, and cost savings” (Wyssusek et al., 2016). Opportunities for discussions and formal training on waste segregation paired with specific policy changes were also suggested as ways to support positive changes in the orthopedic surgery environment (Phoon et al., 2022). While staff confidence was not measured, it was anecdotally ‘affirmed’ through regular meetings throughout waste segregation change processes (Wyssusek et al., 2016).

The lack of evidence-based models related to changed behavior for recycling programs in the operating rooms suggests that this was not a well-studied area. Study designs involving accurate and reproducible details of staff education are needed to determine if the methods of education are impactful. Further, data from pre- and post-education sessions might provide insight into the measurable degree of behavior change or modification.

Barriers. Discussed actual barriers to the implementation of waste segregation and recycling include lack of infrastructure (Phoon et al., 2022). These include recycling facilities or programs but may also include physical equipment within the OR, such as designated recycling bins to encourage these practices. Alternatively, perceived barriers by staff include a lack of knowledge and unclear waste disposal guidelines (Phoon et al., 2022). This suggests that focusing on education and guidelines may have the largest impact on waste management changes when a recycling program exists.

Implications for Quality Improvement

Based on the two studies reviewed specific to primary total knee arthroplasties, it was estimated that between 14.4 and 22% of total waste produced is recyclable. However, other studies, not specific to primary total knees, suggested that 33.5% of all waste produced per arthroplasty case are potentially recyclable materials. Recommendations for successful waste segregation programs or waste audits were made. This included physical modifications such as an additional bin for uncontaminated items and clear guidelines for sorting (Lee & Mears, 2012). Another suggestion included focusing on the preoperative period for maximizing recycling (Kooner et al., 2020; Wyssusek et al., 2016). Finally, standardized approaches to waste audits, as well as formal protocols and policies, increased understanding of the global waste problem in healthcare as well as compliance by staff (Stutzman et al., 2023; Wyssusek et al., 2016).

With regards to behavior change, education, and improvements in confidence amongst staff members as it relates to waste management in total knee arthroplasty cases, no quantifiable data was found in this search. Additional information regarding this topic is necessary to inform the most effective method to implement the waste management program while increasing staff confidence in their knowledge and abilities. Further, this program must be reproducible for reliable results that can translate and apply to additional quality improvement initiatives. Future projects must bridge the gap between staff education and sustainable practices in the orthopedic operating room.

Rationale

The PDSA model was utilized to assess this quality improvement project at each stage; the PDSA model assists in testing change (IHI, 2023). PDSA is a cyclical model that stands for Plan-Do-Study-Act. Once one PDSA "cycle" is completed, another begins. In the first "plan" stage, waste audits of three primary total knee arthroplasties performed by the same surgeon were conducted. Additionally, a pre-education survey of orthopedic service nurses and surgical technologists' knowledge regarding recycling in the operating room as well as self-rated confidence in the individual's knowledge of OR recycling was collected.

In the "do" stage, education was disseminated to the same nurses and surgical technologists on what is recyclable in the pre-operative stage. This education was provided based on a review of the literature as well as local and in-house recycling guidelines. After this educational session, a post-education survey to measure self-rated confidence was given. Next, to also study the change, identical waste audits of three primary total knees with the same surgeon were performed. This data was analyzed before the final "act" stage, where it was determined if this education led to increased recycling and increased confidence in the staff. At this juncture, results were disseminated to perioperative services at the macrosystem and faculty at the University of New Hampshire. Based on the results, the "act" stage may suggest expanding this project to other surgical services or may alter educational information or the plan for quality improvement. Either of these initiatives would be carried out in further PDSA cycles.

Specific Aims

The global aim of this project was to improve waste management, specifically recycling, in the operating room. This process began when the surgical technologist and circulator began to open sterile instruments for a case and the process ended when the patient was brought into the operating room. Through working on this process, it was expected that the proportion of recycling to overall waste would increase and that the accuracy of the items being put in recycling would increase. It was important to do this work as operating rooms produce a significant amount of waste, there is ambiguity around what is recyclable, and no data from the microsystem existed to quantify the current state of the problem.

By June 22, 2023, in the operative suites with cases performing primary total knee arthroplasties, pre-operative recycling would increase in percentage from overall waste and the percentage of waste that is recycled correctly will increase. The specific aims included the percentage of pounds of recycling from total waste. These would increase by 15%, and the accuracy of recycled material segregated from waste would increase to 95% from an average of 92.2% (baseline waste audit 1: 102 out of 116 items; baseline waste audit 2: 28 out of 29 items). Additionally, the percentage of the five blue wraps that were separated from regular recycling would increase from 0% to 100%. Further, circulating nurses and surgical technologists who work in primary total knee arthroplasty cases would report increased confidence in managing waste and recyclables in the OR.

Methods

Context

This quality improvement project took place at a large non-profit, 396-bed, level-1 trauma center in West-Central New Hampshire. This macrosystem has a perioperative unit in the main building that consists of 26 operating suites that are utilized by 10 different surgical specialties. The perioperative service is one of the largest departments in the macrosystem. There are 63 full-time registered nurses (RNs) and 32 full-time certified surgical technicians (CSTs) as well as 46 non-permanent staff including 23 RNs and 23 CSTs.

By May 2023, an average of 1550 surgeries were performed each month with 90-95% of these occurring on weekdays. This meant that there were typically 50-60 cases scheduled each weekday. While up to 60% of surgical cases did not have a pre-operative diagnosis, of those that did, primary osteoarthritis of the knee, hip, or shoulder was the second most common pre-operative diagnosis after grouping malignant neoplasms, masses, and nodules. Therefore, general surgery and orthopedic surgery were the two busiest services.

Cost Benefit Analysis

The implementation by this writer, as well as the measures of the pre-and post-education states of the staff and waste, would not have an actual monetary cost as this project is part of a master's thesis. Further, it was planned that the visual board would not have associated costs as it would be completed using recycled materials. There was no cost associated with completing data collection and analysis. Surveys were completed using RedCap online software used by the hospital and education was disseminated in person.

However, there was a cost associated with time spent by the nurses and surgical technologists completing surveys (5 minutes each) and completing an educational session (30 minutes). In addition, a maximum of 5 minutes for each total knee arthroplasty case is spent adjusting to segregating materials into the proper waste stream. Each primary total knee was scheduled for 165 minutes, and between 0 and 4 cases occur per day. For a staff nurse with an approximate hourly rate of $35, this quality initiative would cost $26.25 per nurse who had one total knee case per day. For a staff surgical technologist with an approximate hourly rate of $24, this quality initiative would cost $18 in time spent under the same circumstances. It was estimated that it shouldn't more than 5 cases practicing proper waste segregation to establish competence.

Per each primary total knee case, there were three, 18-inch by 18-inch double-ply sterilization wraps, one 24-inch by 24-inch double-ply sterilization wrap, and one 30-inch by 30-inch doubly-ply sterilization wrap used. These items were not reusable. As an estimate, their initial costs were $0.83 $1.20, and $1.60 per wrap, respectively, for heavyweight-type wraps sold by medical supply companies (Pipeline Medical, LLC., 2023). This meant that per primary total knee case, approximately $5.29 was potentially spent on the blue wrap. If this wrap was not put in the proper receptacle for separate processing, it went to the landfill or incineration with other clinical waste, which contributed to carbon emissions, additional energy utilization, and landfill space utilization which harms the local ecosystem as well as impacts planetary health. There were about 200 primary total knee cases performed by this surgeon per year, amounting to an estimated $1,058 in these types of blue wrap annually for primary TKA cases.

However, if diverted from the landfill or incineration, blue wrap could be baled at the macrosystem utilizing a special machine that the organization owns. The bales of blue wrap were sent out and repurposed into shopping totes and other supplies. Because of this, the macrosystem could profit financially from the collection of the blue wrap, thereby reducing its operating margins. The receiving companies would also profit in opportunity costs from utilizing the repurposed material.

Interventions

A visual board using physical recyclable items and blue sterilization wrap found in the operating room was created and displayed in the breakroom. Education on waste segregation, proper recycling techniques, and waste management suggestions was provided in person at a monthly, orthopedic surgical service meeting. These interventions were designed to target nurses and surgical technologists because of their highly influential role in waste segregation.

Study of Interventions

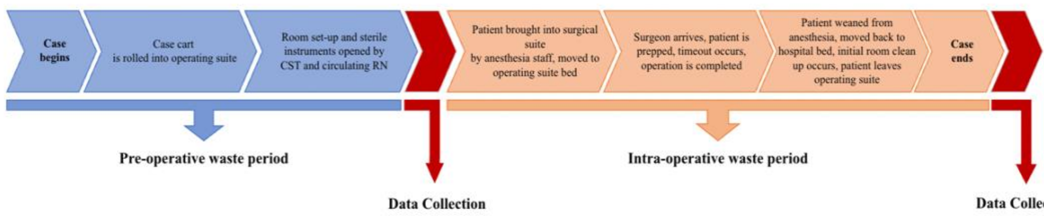
Waste Audit

On June 9th, 2023, and June 22nd, 2023, three waste audits occurred for three randomized, primary total knee arthroplasty procedures performed by one surgeon. Each primary total knee arthroplasty by that surgeon during that scheduled week was assigned a number and a number generator was used to elicit three numbers correlating with the assigned case. The three randomly selected cases were audited in the following fashion.

Between the time the case cart was rolled into the room, and before the patient entered the operating room, a waste audit occurred for the "pre-operative" period. Waste, recycling, and blue sterilization wrap were measured by weight and counted by item (waste, recycling, or blue wrap) while linens, sharps, biohazards, and liquid waste were not measured. Once items were counted, they were correctly into their respective bag and re-weighed. From the time the patient was in the room, to the time the patient left the room was considered the "intra-operative" period. Measurements of waste and biohazard weights were taken. If any bags for recycling or blue sterilization wrap were present, they were carefully inspected for contamination, weighed, counted by item, re-sorted, and then re-weighed.

Figure 1

Timeline and Collection Periods of Waste Audit During Total Knee Arthroplasty



Note. Detail of pre-operative and intra-operative waste collection periods and data collection points during a total knee arthroplasty waste audit.

Pre- and Post-Intervention Survey

On April 28, 2023, a survey was electronically distributed to nurses (RN) and surgical technologist (CST) members of the perioperative staff and a post-education survey was distributed on June 16, 2023 after the educational component was presented. Additional questions were asked about their employment status (traveler or staff), role in the OR (RN, CST, RN who also scrubs), the surgical service they work with the most (list of all specialties), if they recycle at home (yes/ no), if they recycle in the OR (yes/no), their perceived barriers to recycling in the operating room (time, staff, knowledge, resources, none, or other), and their self-rated confidence in their knowledge about what is recyclable in the OR (Likert-scale).

Measures

Waste Audit

Bags of clinical waste, recycling, and blue sterilization wrap were weighed individually using a hand scale to determine pounds of waste. Items put in designated recycling and/ or blue wrap bags were itemized. If any bags of recycling or blue wrap were produced, the bag of recycling was sorted to determine the frequency and percentage of pieces of material that were correctly segregated into the recycling. Intra-operative waste was not sorted due to its potentially infectious nature. The pre-intervention results were compared to the post-intervention results.

Pre- and Post-Intervention Survey

The primary variable compared between surveys to determine the efficacy of the intervention was staff self-reported confidence in recycling in the operating room. This was measured on a 5-point Likert scale. Comparison of pre-and post-intervention surveys was done for those who identify as staff who primarily work for the orthopedic surgical service.

Operational Definitions

Biohazard waste - waste saturated by bodily fluids, tissue, or other infectious materials.

Blue Sterilization Wrap ("blue wrap" or pan "filters") – blue-colored, porous polypropylene wrap used for sterilization and/ or filtration when items are reprocessed.

Clinical waste ("waste") – waste that may have interacted with bodily fluids, tissue, or other infectious materials.

Confidence – belief in one's ability and knowledge, especially to execute a task.

Non-recyclables – Styrofoam, paper towels, plastic (external) sterility indicator tabs, internal sterility indicators, cotton swabs, gauze, foil wrappers, betadine bottles, white tissue wrap (internal wrap of some blue-wrapped instrument packs).

Recyclables – Tyvek, hard plastics #1-7 greater than 2x2 inches, non-stretchy plastic films, cardboard, boxboard, paper.

Waste Management – monitoring and ensuring the placement of items into the correct waste stream.

Waste Segregation – the act of sorting waste according to its properties.

Waste Stream – each type of waste grouped together enabling its respective treatment process (i.e. biohazard, clinical, blue wrap, recyclables).

Analysis

All data were analyzed using Microsoft Excel. Data from the waste audits were in pounds of waste produced per pre-operative time frame per case. Measurements included pounds per waste stream and the total weight of recyclable and non-recyclable waste per pre-operative time per case. Averages of the three cases with standard deviations were calculated for pre- and post-intervention waste audits. A student's t-test was used to calculate statistical significance with an acceptable *p*-value of less than 0.05. Additionally, the contents of the recycling and/ or blue sterilization wrap bags were sorted for the percentage of appropriate material for that waste stream. This statistic's pre- and post-education audit results was calculated via t-test.

Internal validity and reliability of the surveys will be computed in Microsoft Excel using Pearson correlation and Cronbach's alpha tests. Surveys had qualitative and quantitative data which was analyzed for staff demographics to demonstrate pre- and post-education confidence, recycling practices, as well as potential barriers to practicing recycling. Data not rated on a Likert Scale was analyzed as categorical data and reported as mean, standard deviation (SD), and range. Pre- and post-education self-rated confidence data analyses (of the 5-point Likert scales) were done using a 2-sample t-test (de Winter and Dodou, 2010). Likert scales are generally reliable and 5-point Likert Scales have a reliability of 90% (Louangrath, 2018). A 2-sample t-test was performed as opposed to the Mann-Whitney-Wilcoxon test because de Winter & Dodou

(2010) demonstrated an equivalent power and almost equivalent error rate for both tests (Winter & Dodou, 2010).

Ethical Considerations

This author was employed by the macrosystem at the time of this study. Additionally, this author completed a 300-hour nurse practicum clinical rotation within perioperative services at the microsystem. This may have been a source of response bias due to the relationship between the project lead and the participants. However, this study, nor the author, were not funded or subsidized for this project. The microsystem leadership were motivated to improve waste management and suggested this quality initiative. Because of the microsystem's motivation, there were also a dedicated team of staff working on recycling initiatives. It is unclear how these initiatives may have impacted the scope of this study as work occurred in parallel.

A proposal for this project was reviewed by the University of New Hampshire Department of Nursing Quality Review Committee, which determined this project met the criteria for a quality improvement project and therefore exempt from full Institutional Review Board (IRB) review. A copy of the proposal was sent to the macrosystem's director of nursing education and the microsystem's vice president. Appropriate edits were made prior to beginning data collection.

Results

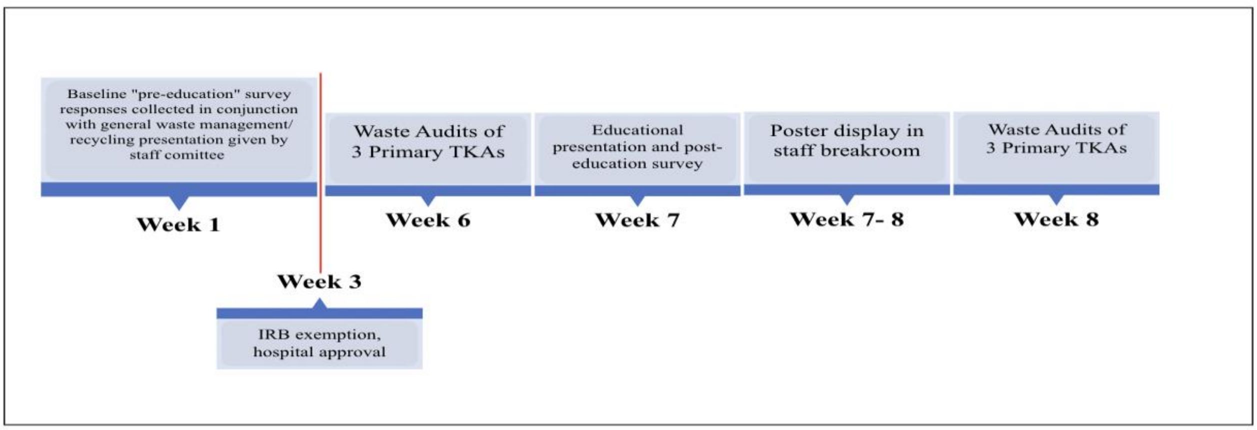
Results

The pre-education survey was distributed on April 28th, 2023. Next, IRB exemption, macro-, and microsystem approval were completed on the week of May 21st. To assess the current state of the microsystem, three waste audits were conducted on June 9th, 2023, and June 23rd, 2023 (Figure 2). To complete these it was necessary to purchase a digital luggage scale.

Of note, in the proposal, the personal cost for the project was discussed as being $0.00. However, the actual personal cost incurred was $8.99 for a *Travelon* digital luggage scale (style #12775) to weigh bags of waste, accurate to ± 0.2 pounds. For the intervention itself, it also became necessary to purchase additional materials. These included posterboard and cardstock which were purchased for $16.98 to create a visual display for staff education and the breakroom. This total personal cost amounted to $25.97.

Figure 2

Timeline of Quality Improvement Project



The waste audit of a primary total knee arthroplasty occurred six times, with three cases audited pre-intervention and three cases audited post-intervention. Three cases were audited one day one week prior to the educational intervention and three cases were audited one day one week after the educational intervention. All cases were performed by the same surgeon. On days when these cases occurred, the surgeon utilized two operating suites. Cases were staggered so that when one was finishing, the next would begin. This meant that of the waste audits, two of the three cases occurred in one OR (first and last) and the second case would occur in the second surgical suite.

In the proposal, it was stated that randomization would be used to determine which cases were audited. However, for the pre-education waste audit, there were only three primary total knee cases that day, so no randomization calculator was used. For the post-education waste audit, the calculator was used to determine three out of the four cases to audit that day which happened to be the first, second, and third case of the day.

Because pre-operative waste does not have potential for contamination with bodily fluids, the collected waste, after initial weights, was readily separated and inventory was taken to determine accuracy. It was then re-sorted to calculate the potential distribution of weights across the waste streams. However, again, this total calculation was limited by the contamination of waste in the intra-operative waste period to determine the accuracy and meaningful outcomes.

Surveys

The preliminary, pre-educational survey was distributed at an all OR staff meeting on April 28th, 2023. This was given at the end of an educational presentation on waste management by perioperative staff members belonging to a specialty recycling committee. This presentation was not prepared or contributed to by this author. This survey was given at this specific time to establish baseline confidence in knowledge for this study. For this project, only results from those who completed responses and identified themselves as working with the orthopedic service the majority of the time were included.

The post-educational survey was given at the end of the presentation to the orthopedic service group of CSTs and RNs on June 16, 2023 by the project lead. This group met every third Friday of the month for 15 to 30 minutes and typically only consisted of those who were scheduled for work that day. These were also staff who were not needed to work for earlier scheduled cases or urgent cases. Of the seven attendees, only six responded to the survey.

It was observed that all pre- and post-education survey takers were regular staff, except for one traveler RN who took the pre-education survey. A slight majority of nurses (57%) took the pre-education survey whereas there was an even split of CSTs and RNs who took the post-education survey (Table 1). However, in the post-education survey group, there were more nurses who identified as nurses who also scrubbed (33%) compared to none in the pre-education group.

Table 1

Demographic Data

Demographics	**Total Sample (n=7) n (%)**		**Total Sample (n=6) n (%)**	
Role	**Pre**		**Post**	
Staff CST	2	(29)	3	(50)
Staff RN	4	(57)	1	(17)
Staff RN who also scrubs	0	(0)	2	(33)
Traveler CST	0	(0)	0	(0)
Traveler RN	1	(14)	0	(0)
Traveler RN who also scrubs	0	(0)	0	(0)

Note. Demographic data from pre- and post-education surveys.

It was observed that a large majority of respondents in both pre- and post- groups (71% and 83%, respectively) cite recycling at home (Table 2). Further, 100% of both pre- and post-educational groups reported recycling in the OR. However, of the six participants, only five responded to a follow-up question on the frequency of their recycling in the operating room. On a visual analog scale of 0 to 100, the frequency to which the respondents recycle in the operating room was a mean of 44.40 (*SD* 16.90, Range 0-100).

Table 2

General Recycling Habits

Recycling habits	**Total Sample (n=7) n (%)**		**Total Sample (n=6) n (%)**	
Do you recycle at home?	**Pre**		**Post**	
Yes	5	(71)	5	(83)

No	2	(29)	1	(17)
Do you recycle in the OR?				
Yes	7	(100)	6	(100)
No	0	(0)	0	(0)

Table 3

Staff Recycling Habits in the OR (Visual Analog Rating)

Recycling habits	Mean	SD	Range
On average, how often do you recycle in the OR?	44.40	16.90	0-100

Note. Self-rated by post-educational survey participants(n=5) on a visual analog scale.

Participants of the pre-education survey were able to select barriers that they faced with regards to recycling in the operating room. There were no limits to the number of selections they could make. The top-ranking barriers each had four selections (57%) by the 7 participants. These included time, training, and physical resources. All participants selected at least one barrier to recycling in the OR. Unfortunately, no opportunity was given for comment in the 'other' category, leading to an incomplete understanding of this data (Table 4).

Table 4

Barriers to OR Recycling

Barriers	Total Sample (n=7) n (%)	
What barriers to you face with regards to recycling in the OR?		
Staffing	2	(29)
Time	4	(57)
Training	4	(57)
Physical resources (bins, bags)	4	(57)
Other	1	(14)
None	0	(0)

Note. Collected in the pre-education survey.

Finally, pre- and post-education confidence was assessed in both surveys. In the pre-education survey, confidence was assessed on a 5-point Likert scale with answers including 1-not confident at all, 2- a little confident, 3- neutral, 4- somewhat confident, 5- very confident. For n=7 respondents, confidence in the knowledge of what is and isn't recyclable was a mean of 2.29 (*SD* 0.76, Range 1-5).

In the post-education survey, confidence was re-assessed regarding confidence before and after the presentation on the same scale. For the six participants, confidence in the knowledge of what is and isn't recyclable prior to the presentation was a mean of 3.50 (*SD* 0.84, Range 1-5). However, after the presentation, the participants on average rated their confidence a mean of 4.00 (*SD* 1.27, Range 1-5).

The change in post-education participants' self-reported confidence resulted in an increase which had a non-statistically significant p-value of 0.219 ($p < 0.05$) and a Pearson correlation coefficient of 0.945 (Table 6). Of note, internal validity for the post-intervention survey was measured using Cronbach's alpha. A value of 0.93 was found when evaluating Likert items. This indicated high internal consistency among responses.

Table 5

Self-Reported Confidence (Likert-Scale)

Confidence	**Mean**	**SD**	**Range**
Pre[1]			
How confident are you in your knowledge of what is and isn't recyclable in the OR?	2.29	0.76	1 - 5
Post[2]			
How confident were you in your knowledge of what is and isn't recyclable in the OR *prior* to the presentation?	3.50	0.84	1 - 5
How confident are you in your knowledge of what is and isn't recyclable in the OR *after* the presentation?	4.00	1.27	1 - 5

[1]Pre-education survey response (n=7)
[2]Post-education survey response (n=6)

Table 6

Inferential Statistics for Post-Intervention Survey Self-Reported Confidence

T-Test (p) comparing pre- and post-education confidence*	0.219
Pearson Correlation Coeff (r)	0.945

* Statistical significance, $p < 0.05$

Waste Audits

Recycling and Blue Wrap Weight. As observed in Table 7, the mean total weights of pre- and post-intervention waste audits was similar (33.07 lbs *SD* 0.99 and 32.60 lbs SD 1.80, respectively). Mean pounds of recycling were higher in the post-intervention waste audit (5.47 lbs SD 1.10) than in the pre-intervention audit (2.93 lbs SD 3.36) but the range of recycling for the pre-intervention waste audit was much greater (0-6.6 lbs compared to 4.4- 6.6 lbs).

Table 7

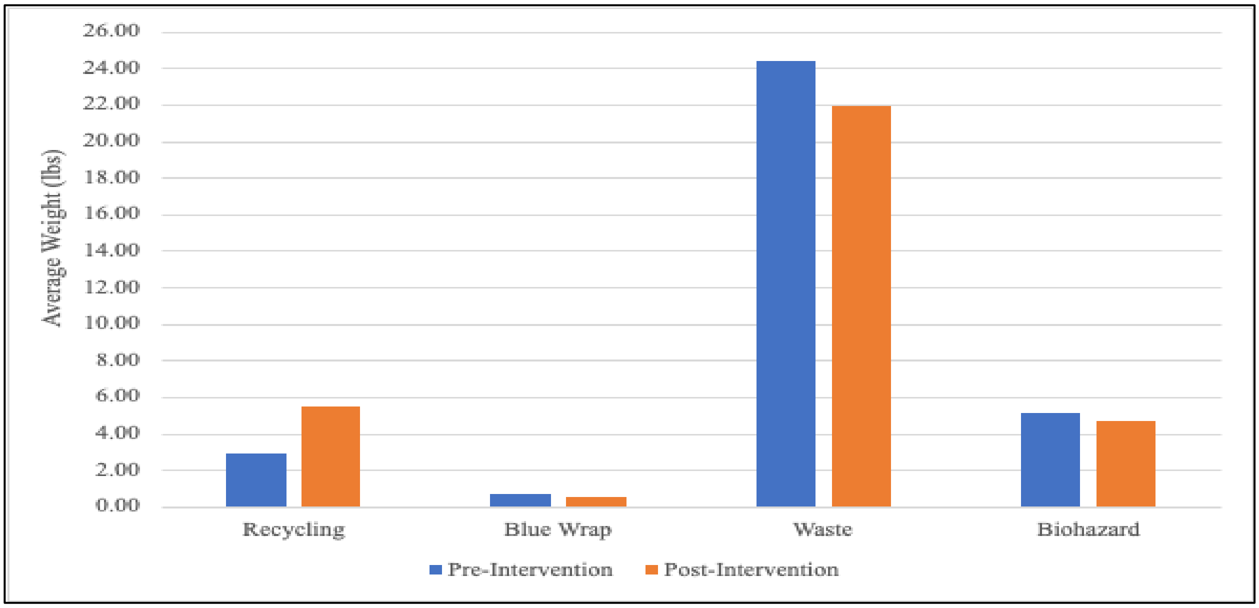
Comparing Pre-and Post-Intervention Total Weights

Total Waste (lbs)	Mean	SD	Range
Pre- Intervention			
Total	33.07	0.99	32.4 - 34.2
Recycling	2.93	3.36	0 - 6.6
Blue Wrap	0.67	0.70	0 - 1.4
Waste	24.40	6.58	20.4 - 32
Biohazard	5.07	5.21	0 - 10.4
Post- Intervention			
Total	32.60	1.80	30.8 - 34.4
Recycling	5.47	1.10	4.4 - 6.6
Blue Wrap	0.53	0.46	0 - 0.8
Waste	21.93	3.03	19.8 - 25.4
Biohazard	4.67	4.09	0 - 7.6

Finally, mean pounds of blue wrap were slightly lower in the post-intervention waste audit (0.53 lbs *SD* 0.46, Range 0- 0.8) than in the pre-intervention waste audit (0.67 lbs *SD* 0.70, Range 0- 1.4). These results are observed in Figure 3. Notably, the total amount of waste decreased and the total amount of recycling increased.

Figure 3

Mean Total Pre- and Post- Intervention Weights



Pre-operative period waste audit data demonstrated a slightly higher total weight of 4.73 lbs (*SD* 0.58, Range 4.4-5.4) pre-intervention and 5.20 lbs (*SD* 0.20, Range 5-5.4) post-intervention (Table 8). Figure 4 demonstrated that post-intervention recycling (3.93 lbs *SD* 1.62, Range 2.2-5.4) was more than pre-intervention (2.33 lbs *SD* 2.40, Range 0-4.8). However, blue wrap was slightly less.

Table 8

Comparing Pre- and Post-Intervention Pre-Operative Weights

Total Waste (lbs)	Mean	SD	Range
Pre- Intervention			
Total	4.73	0.58	4.4 - 5.4
Recycling	2.33	2.40	0 - 4.8
Blue	0.67	0.70	0 - 1.4
Waste	1.73	1.55	0 - 3.0
Biohazard	0	0	0

Post-Intervention			
Total	5.20	0.20	5 - 5.4
Recycling	3.93	1.62	2.2 - 5.4
Blue	0.53	0.46	0 - 0.8
Waste	0.73	1.27	0 - 2.2
Biohazard	0	0	0

Figure 4

Mean Pre-Operative Pre- and Post-Intervention Weights

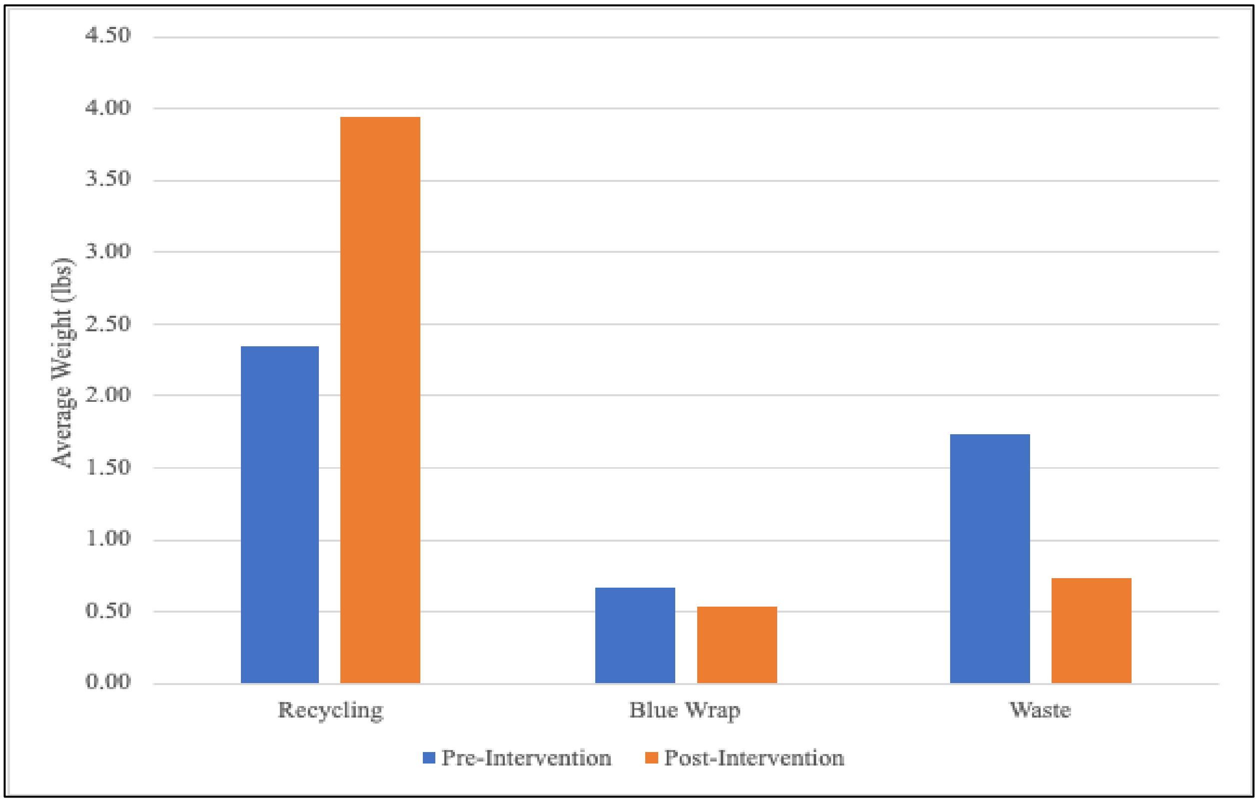


Table 9 demonstrated that the actual increase in mean weight of recycling between pre- and post-intervention waste audits accounted for a significant percentage of the overall pre-operative collection. In fact, there was nearly a 25% increase in the mean weight of recycling between pre- and post-intervention waste audits. While nearly 20% of this was previously waste, there was also a decrease in the total mean weight contributed by blue wrap. This decrease was about 4% from pre- to post-intervention.

Table 9

Comparing Pre-Operative Collection Period Waste Distribution of Weights and Frequencies

	Total Sample (n=4.73) n (%)		Total Sample (n=5.20) n (%)	
Waste Type	**Pre- Intervention**		**Post- Intervention**	
Recycling	2.33	(49.30)	3.93	(75.64)
Blue Wrap	0.67	(14.08)	0.53	(10.26)
Waste	1.73	(36.62)	0.73	(14.10)
Biohazard	0	(0)	0	(0)

Note. Comparing pre-intervention and post-intervention from pre-operative collection period measurements.

Recycling and Blue Wrap Accuracy. If waste from the pre-operative collection period was *perfectly* segregated into the appropriate waste stream, it was assumed to be done so with about 100% accuracy. This was referred to as potential weight. Comparing the pre-intervention actual mean weights with the potential weights, the potential weight of recycling was less (actual: 2.33 lbs *SD* 2.40, Range 0- 4.8 and potential: 1.73 lbs *SD* 1.27, Range 1.0- 3.2) (Table 10). However, the blue wrap had a slightly higher potential mean weight compared to the actual weight (potential: 0.93 lbs *SD* 0.12, Range 0.8 – 1.0 and actual: 0.67 lbs S*D* 0.70, Range 0- 1.4).

Post-intervention actual recycling (3.93 lbs *SD* 1.62, Range 2.2-5.4) was similar to the calculated mean potential recycling (3.13 lbs *SD* 0.12, Range 3.0-3.2). Post-intervention blue wrap had a lower actual mean weight compared to the pre-intervention (0.53 lbs *SD* 0.46, Range 0-0.8) and the potential post-intervention blue wrap weight was similar to the previous potential (1.00 lbs *SD* 0.2, Range 0.8-1.2).

Table 10

Comparing Actual and Potential Pre-Operative Collection Period Total Weights

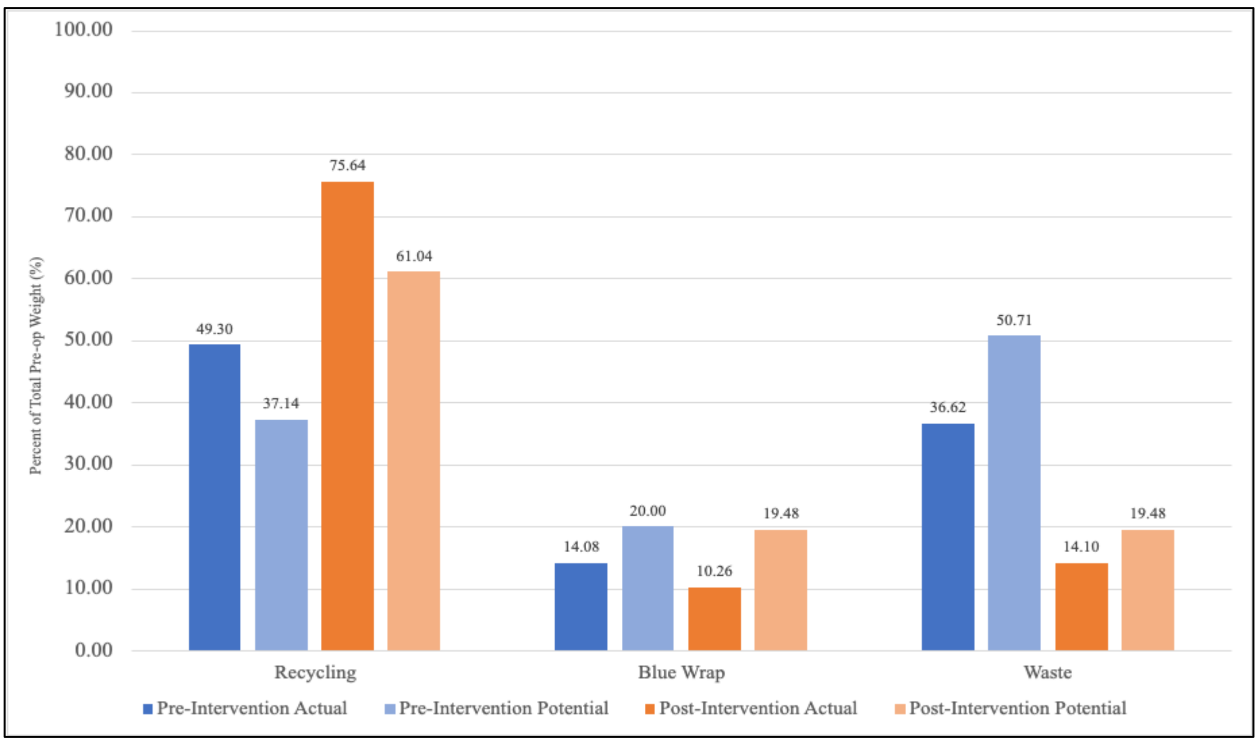
	Actual Weight (lbs)			Potential Weight (lbs)		
	Mean	SD	Range	Mean	SD	Range
Pre- Intervention						
Recycling	2.33	2.40	0 - 4.8	1.73	1.27	1.0 - 3.2
Blue Wrap	0.67	0.70	0 - 1.4	0.93	0.12	0.8 – 1.0

Waste	1.73	1.55	0 - 3.0	2.37	0.06	2.3 – 2.4
Biohazard	0.0	0.0	0.0	0.0	0.0	0.0
Total	4.73	0.58	4.4 - 5.4	4.67	0.46	4.4 – 5.2
Post- Intervention						
Recycling	3.93	1.62	2.2 - 5.4	3.13	0.12	3.0 - 3.2
Blue Wrap	0.53	0.46	0 - 0.8	1.00	0.20	0.8 - 1.2
Waste	0.73	1.27	0 -2.2	1.00	0.20	0.8 - 1.2
Biohazard	0.0	0.0	0.0	0.0	0.0	0.0
Total	5.20	0.20	5 to 5.4	5.13	0.42	4.8 - 5.6

When compared by percent of potential and actual weights, pre- and post-intervention trends were that actual recycling distributions were higher than calculated potential distributions (Figure 5). Additionally, blue wrap had lower actual distributions than potential, and waste had lower actual distributions than potential. The margins between pre- and post-intervention actual and potential distributions are almost equal.

Figure 5

Actual and Potential Percent Distribution of Recycling, Blue Wrap, and Waste by Weight



Note. For pre-operative collection periods

Discussion

Summary

For this quality improvement project, the specific aims were to increase the pre-operative proportion of recycling by 15%, increase the percentage of blue wrap separated from recycling by 100%, and increase the accuracy of recycled materials to 95%. For the staff, the specific aim was to increase their reported confidence in knowledge about recycling items in the operating room. These specific aims were driven by a global aim of improving waste management, specifically recycling, in the operating room. Key findings included an increase in recycling by weight, an increase in blue wrap separation accuracy, and an increase in staff confidence in recycling.

Key Findings

Recycling and Blue Wrap Weight. The aim was for the percentage of pre-operative recycling by weight (in pounds) to increase by 15%. First, the pre-operative proportion of recycling increased from 49.30% to 75.64%. This exceeds a 15% increase, in fact, this is an increase of 26.34%. Therefore, the intervention was successful in meeting the specific aim of increasing the proportion of recycling by 15%. Additionally, the aim for blue wrap was to increase the percentage of segregation by 100%. When considered by weight (lbs) in the pre-operative period, the proportion of blue wrap segregated decreased from 14.08% pre-intervention to 10.26% post-intervention. Therefore, the intervention was unsuccessful in meeting the specific aim of increasing the percentage of blue wrap that was segregated.

Recycling and Blue Wrap Accuracy. Another aim was for the percentage of items that were correctly segregated into recycled and blue wrap bags to increase. The accuracy of recycled items correctly segregated into the 'recycling bag' would be 95% (increasing from a baseline measurement of 92.2%) and blue wrap items would be correctly segregated 100% of the time.

For pre-intervention waste collections, different cases had different "methods" to waste separation. For the pre-operative waste period, Case 1 established a bag for blue wrap, but not for recycling. This case correctly separated 75.75% of the blue wrap and 0% of recycling. Case 2, established a bag for recycling, but not for blue wrap. Case 2, correctly separated 0% of blue wrap and 60.71% of recycling. Finally, Case 3 established both a blue wrap and a recycling bag. Case 3 correctly separated 97.44% of recycling and 15.38% of blue wrap.

For post-intervention waste collections, different cases still had different methods. For pre-operative waste collection periods, Case 1 had a recycling and blue wrap bag. This case correctly separated 93.02% of recycling and 83.78% of the blue wrap. Case 2, established a bag for recycling, but not for blue wrap. Case 2 correctly separated 62.80% of recycling and 0% of blue wrap. Finally, Case 3 established both recycling and blue wrap bags and correctly recycled 25.42% and 81.58% of blue wrap.

When comparing pre-intervention (Case 3) to post-intervention (Case 1 and Case 3) waste collections, where recycling and blue wrap were both collected, recycling separation accuracy decreased by an average of 38.22% between pre- and post-intervention. Blue wrap segregation accuracy increased from pre- to post-intervention in the pre-operative period by an average 67.30%. Of note, no blue wrap was collected in any of the post-operative data collection periods. When comparing cases based on the methodology of segregation, the specific aim for recycling or blue wrap was met when pre- and post-intervention data is compared in this fashion.

However, when cases are not discriminated for by method of waste management, for pre-operative collection, an average of 77.77% of recycling was correctly separated pre-intervention and an average of 71.17% was correctly separated post-intervention. This was a decrease of about 6.61%. Likewise, when the methodology of each OR team was not considered for blue wrap in the pre-operative collection period an average of 29.52% of blue wrap was correctly segregated in the pre-intervention data collection whereas an average of 54.87% of blue wrap was correctly segregated post-intervention. This was an increase of 25.35%. Nevertheless, the intervention was not successful in meeting the specific aim of 100% accuracy in blue wrap segregation or 95% accuracy of recycling segregation.

It was difficult to make conclusions about the accuracy of waste segregation in this QI project as depicted by the different ways each team for each case chose to manage their waste. Additionally, while there was a stark increase in the percentage of blue wrap items correctly segregated (25.35%), the decrease in recycling segregation might be accounted for by the differences in team members and/ or methodologies used to segregate waste. For example, Case 2 of the post-intervention arm had three bags in the pre-operative waste collection period. They considered these all to be (100%) recycling and had no waste bags whereas all other cases from pre- and post-interventions only had one bag of recycling, if any.

Together, the three bags of "recycling" weighed 5.4 lbs. But when these were re-sorted for accuracy, 1.2 lbs (22.22%) was determined to be waste, 1.0 lbs (18.52%) were determined to be blue wrap, and the remaining 3.2 lbs (59.26%) were recycled. Therefore, while 100% of the 61 recycled items were correctly recycled, 0% of the 38 blue wrap items were correctly segregated and 0% of the 65 waste items were correctly segregated. This demonstrated that the measurement of the accuracy of recycling and/ or blue wrap alone cannot depict the function of the waste management system.

Staff Self-Rated Confidence in Recycling. The specific aim was for the circulating nurses and surgical technologists who work in primary total knee arthroplasty cases to report increased confidence in managing waste and recyclables in the operating room. Prior to the presentation, the mean was 3.50 (*SD* 0.84, Range 1-5) for the six participants. However, after the presentation, the participants on average rated their confidence a mean of 4.00 (*SD* 1.27, Range 1-5). This increase, while not considered statistically significant, meant that participants, on average, went from reporting their confidence between 'neutral' to 'somewhat confident' in their knowledge of recycling in the OR to 'somewhat confident'. This is consistent with anecdotal literature findings that staff education, teachings, and presentations have aided in building stronger waste management programs (Wyssusek et al., 2016).

Interpretation

Association Between Intervention and Outcomes

Despite the educational intervention, a self-rated increase in confidence among staff, and increases in weight and percentage of recycling, an average of 82% of waste was still inaccurately segregated into recycling or blue wrap waste streams post-intervention.
While staff self-reported confidence did increase from pre-intervention to post-intervention, it was not statistically significant. Further, while the weight and percentage of pre-operative recycling increased from pre- to post-intervention, the percent accuracy of segregation decreased. Conversely, the weight and percentage of pre-operative blue wrap decreased, but the percent accuracy increased. Of note, post-intervention waste weight and percentage decreased, but post-intervention segregation accuracy was found to be 18%.

It was anticipated that educational intervention would increase accuracy among recycling and blue wrap segregation. However, it was also observed that the subject matter of recycling evoked a wide variety of responses from staff enthusiasm to repulsion. As mentioned in *Key Findings* section on post-intervention Case 2, this case had a much different method to waste management than any other. Unfortunately, this was largely due to the attitude towards recycling. While this staff member attended the education intervention, the same individual stated, "I do not recycle". Consequently, this became a larger event and impacted the weights and accuracy more due to the small sample size.

Comparison to Current Literature

To the knowledge of the project lead, this is the first quality improvement initiative comparing pre- and post-education staff-rated confidence in recycling knowledge. No other studies regarding recycling and blue wrap accuracy are known. But, of the findings that relate to those from the literature review, the findings are most consistent with those of the Lee & Meers (2012) study. Lee & Meers (2012) discuss that for an average 'standard' (primary) TKA, 33.2 lbs of waste were generated and similarly this study determined that 32.83 lb (SD 1.32) of waste were generated per primary TKA (n=6). Lee & Meers (2012) note that 22% of the cases' total waste was recyclable, accounting for 7.3 lbs total. Pre-intervention, total recycling was 2.93 lb (SD 3.36) or 8.87% of the total case waste. Post-intervention, total recycling was 5.47 (SD 1.10) or 16.77% of the total case waste. Different from the present project, Lee & Meers (2012) include blue wrap in their recycling counts. When blue wrap is added to this project's recycling pre- and post-intervention totals, the percentages are 10.89% and 18.40%, respectively.

These findings, however, are not consistent with those of findings of Stall et al. (2010). When sharps are excluded from calculations by Stall et al. (2010), as these were not accounted for by this project, the total average waste was 28.6 lbs. Again, when sharps are excluded, 3.52 lbs or 12.31% of the total average waste was blue wrap and only 0.66 lbs or 2.31% of the total average waste was recycling. Even when the total blue wrap and recycling are combined to compare to Lee & Meers (2012) study, the combined percentage of total waste is 14.62%. While this is still higher than this project's pre-intervention percentage of recycling, it is mostly accounted for by blue wrap alone.

Impact on People and Systems

This project benefited the microsystem by providing education and visuals for staff and obtaining concrete data for future PDSA cycles of recycling improvement projects. Additionally, this project may have aided in closing a gap in knowledge of recycling in the context of orthopedic specialty surgical staff in the OR. The PDSA-cycle methodology of this project allows for additional iterations to be performed so that an effective, perioperative-wide recycling training program may be enacted successfully.

Limitations

Waste Audit

This project is limited in generalizability to one surgeon performing primary total knee arthroplasties using one type of equipment and replacement system at the macrosystem. No standardized waste audit tool was used which also limits generalizability, however, literature was reviewed for best practices when completing waste audits. Data were collected from a low number of total of cases (six), which was largely limited by the fact that only one project lead was performing the data collection.

This may also lead to imprecise item counts as no one was available to provide an additional count of items or supervise these counts. Items were also counted in a waste room where other staff would pass through to dispose of case waste. This posed some distraction to the item counting process. If this occurred and it was thought that a miscount had occurred, then a recount was performed. Further, the luggage scale was only valid to ± 0.2 lbs. Bags were re-weighed three times each to ensure that measurements were accurate.

Staff Survey

The first survey was given as a baseline measurement of staff confidence after an educational presentation by other staff members who work in perioperative services. The second survey was given after the educational presentation by this project lead to determine pre-education to post-education self-rated confidence differences. One flaw of the project design is that all the orthopedic staff who took the first survey were not the same staff who took the second survey. Therefore, these two groups cannot be paired.

However, the second survey does capture the pre- and post-education self-rated confidence differences which can be paired as aggregate data. Further, not all the staff who attended the education were those who were circulating or scrubbing cases that were audited. These days were selected by when the surgeon was performing primary TKAs and not by who would be working those days as this was not scheduled as far in advance.

Conclusions

Usefulness and Sustainability

The findings of this quality improvement project provided insights into staff perceived barriers and self-rated confidence in the knowledge of recycling in the operating room. Additionally, waste audit data were, to the knowledge of this project lead, the first of its kind for this microsystem and demonstrated the current state of the local issue. Further, this project continued important dialogues around a topic that many staff members are actively working to address.

Implications for Practice

This project highlighted a need for further standardization of recycling and waste management strategies in the operating room. Despite attempting to standardize waste audit strategies (one surgeon, one type of surgery, etc), the waste management strategies of each case team were very different. No documentation, procedures, policies, or guidelines for operating recycling exist outside of a small poster depicting recyclable items that were posted in some of the operating rooms.

Consideration should be given to the creation of a standardized policy or procedure for waste management and segregation in the operating room. If created, this information would be accessible to everyone through the policy website and help to eliminate disagreements about what is and is not recyclable. Further, it would aid in training and creating a reproducible environment.

Spread to Other Contexts

As previously discussed in *Limitations*, the findings of this project are limited in generalizability to primary total knee arthroplasties by one specific surgeon at one macrosystem. However, the concept of measuring pre- and post-intervention (education) measures of confidence or knowledge can be applied in any setting. In fact, pre- and post-intervention measurements should be applied regardless of setting to gauge the efficacy of teaching and staff comprehension, especially in high-stakes environments like healthcare.

Next Steps

Staff survey data from the pre-intervention suggested that the top existing barriers to recycling in the OR include time, physical resources, and training. This project demonstrated that continuing education can positively impact staff confidence. Therefore, it is suggested that additional time is designated for hands-on training with clear guidelines to assist in increasing staff confidence in their knowledge of recycling. Additionally, improvements in accuracy and a decrease in staff perceived barriers in physical resources would be possible through the allocation of resources for one additional bin per OR. This would allow for an increase in recycling and blue wrap segregation weight and accuracy.

Reduction of medical waste, especially medical waste from the operating room, is an important topic given the current environmental state. Through continued, targeted efforts in waste segregation and waste management in the operating room, a large proportion of medical waste can be diverted from landfills, with the opportunity to lower hospital operating costs. Continued education has demonstrated the potential to aid with this, but additional projects, standardized procedures, and resources are needed to achieve more impactful results.

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