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Environmental Sustainability Initiatives in the Operating Room

A Scoping Review

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The global healthcare industry has a substantial environmental footprint and therefore has a responsibility to decrease its impact. Changes to increase sustainability will only occur if healthcare providers (HCPs) and decision-makers understand and incorporate environmentally conscious practices in the operating room (OR). This scoping review aimed to assess hospital initiatives undertaken to support environmental sustainability in the OR, with a focus on HCP and hospital decision-maker beliefs and perceptions related to sustainability. A scoping review was conducted using Embase and PubMed. Searches were performed to identify relevant studies published between January 2011 and November 2022. A total of 163 publications were included: 10 systematic literature reviews and 153 original research articles. Most studies reported department-wide sustainability measures (waste reduction, staff education, etc), which were evaluated by the reduction in generated waste and energy, emission of greenhouse gasses, and costs. Despite up to 97% of HCPs noting willingness to improve sustainability within practices, up to 80.9% of HCPs stated that they lacked the necessary training and information. In conclusion, this research highlights a recent increase in interest about sustainability initiatives in the OR and that HCPs and surgical staff are not only willing to participate but also have suggestions on how to minimize the environmental impact of the OR.

Keywords: carbon footprint, electrosurgery, environmental impact, hospital management, medical device, operating room, operating theatre, surgery, surgical device, sustainability, sustainability initiatives

INTRODUCTION

Climate change, high greenhouse gas (GHG) emissions, waste generation, and nonrenewable energy consumption place the global environment at risk and necessitate the implementation of sustainable practices worldwide across a broad range of industries. The healthcare industry has been shown to have a substantial global carbon footprint.[1] If the global healthcare sector were a country, it would be the fifth largest emitter of GHG on the planet, with a carbon footprint of approximately 4.4% of global net emissions, or 2 gigatons (4.41E+12 lbs) of carbon dioxide (CO_2), per year.[2] Hospitals have multiple direct and indirect operations that draw on a continuous supply of energy, heat, and water. They also purchase large amounts of supplies requiring both delivery and waste disposal. As a result of this, hospitals consume more energy per square meter than all other categories of nonresidential buildings.[3]

The global increase in volume of healthcare waste is widely overlooked.[4,5] In the United States alone, more than 4 billion pounds of healthcare waste is generated annually, mainly consisting of single-use products and sterile packaging, 20% to 33% of which is generated in the operating room (OR).[6–8] Given the energy and waste-intensive nature of hospitals, efforts are being made to evaluate how hospitals can become more environmentally sustainable.

Multiple countries are attempting to quantify and reduce the environmental impact of their healthcare systems. In the most prominent example, a National Health Service analysis from 2019 showed that the National Health Service carbon footprint was an estimated 25 megatons (5.51E+10 lbs) of CO_2, a 26% decrease from 1990, despite a 17% increase in the national population and the doubling of provision of care.[3] The significant decrease in CO_2 was determined to be mainly due to decarbonization of the energy system.[9] Globally, hospitals are working toward reducing their carbon footprint by reducing carbon emissions, medical waste, and water usage.[10]

A robust review of the scientific literature would be extremely useful for an evidence-based understanding of sustainability initiatives that hospitals and healthcare systems are currently pursuing. This scoping review sought to identify goals and initiatives that hospitals and healthcare systems have undertaken to support environmental sustainability, specifically within the OR setting. To accomplish this, we assessed healthcare provider (HCP) and decision-maker beliefs and perceptions related to the concept of sustainability and identified environmental sustainability-focused initiatives, comparing metrics across them to quantify their impact.

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MATERIALS AND METHODS

Eligibility Criteria

This scoping review focused on identifying studies published between January 2011 and November 2022 that describe HCP perceptions of environmental sustainability within the OR as well as the goals and initiatives undertaken by hospitals and healthcare systems to support a reduced OR environmental footprint. The scoping review was limited to English language studies, without geographical limitations. Study eligibility criteria are reported in Supplemental Table 1, see http://links.lww.com/AOSO/A356.

Data Sources and Search Strategy

This protocol-driven scoping review was conducted by health economics and outcomes researchers with expertise in conducting literature searches using the electronic databases Embase (embase.com) and PubMed (PubMed.com). Search algorithms for each database were built using medical subject headings and Emtree terms, as well as free-text terms using the appropriate Boolean syntax. Searches for sustainability or environmental papers used terms such as "sustainability," "carbon footprint," and "climate change," and searches for environmental metrics used terms such as "greenhouse gas," "emission," and "waste" (Supplemental Table 2, see http://links.lww.com/AOSO/A357). To further focus this study within the OR setting, electrosurgery device-related terms such as "surgical device" and "operating room," were included, as 80% of surgeries use electrosurgical devices.[11]

Study Selection

Duplicates across the 2 databases were removed and all screenings were performed using Covidence, a review software (Covance, Melbourne, Australia). The remaining list of citations was first screened for relevancy by title and abstract, then via full-text screening. Both levels of screening were conducted per outcome, study design, and geographical, temporal, and database criteria (Supplemental Table 1, see http://links.lww.com/AOSO/A356). Screening of titles and abstracts was conducted by one researcher and validated by another. After excluding duplicates and a full-text screening, all remaining studies were retrieved and reviewed by 2 independent reviewers. Any discrepancies or conflicts that arose during the screening process were resolved by a third reviewer or via mutual discussion. The reference lists of all included systematic literature reviews and meta-analyses were hand-searched to find any additional articles pertaining to the topics of interest. After full-text screening, a complete list of included and excluded citations was generated, including reasons for exclusion.

Data Extraction

Data were extracted using a customized evidence grid in Microsoft Excel. Data extractions were conducted by one researcher, and all extracted data were validated by a second researcher. Data elements included in the final evidence grid are reported in Supplemental Table 3, see http://links.lww.com/AOSO/A358.

RESULTS

Study Selection

The search strategy identified a total of 3534 studies. After excluding duplicates, 2497 papers were screened for title and abstracts, and 300 papers were included for full-text screening. Ultimately, 163 studies were included in the scoping review with 137 papers excluded due to reasons including out-of-scope study designs (eg, narrative reviews).

Study Characteristics

Of the 163 studies included, 10 were systematic literature reviews. Geographic regions are shown in Figure 1B. Study designs included 74 prospective, 21 retrospective, and 11 cross-sectional observational studies, 46 other study designs, including 26 life cycle assessments, 12 product audits, and 6 budget impact and cost-effectiveness studies, 10 systematic literature reviews, and 1 randomized control trial (Fig. 1A). Of the primary articles included in this manuscript, 119 papers solely focused on sustainability metrics used to measure the impact of hospital initiatives, 26 papers solely studied the environmentally conscious beliefs and perceptions of HCPs and key decision-makers in the hospital and OR setting, and 8 primary articles examined both sustainability metrics and the beliefs and perceptions of HCPs. Key takeaways from the scoping review are provided in Table 1.

HCP and Decision-Maker Beliefs and Perceptions

HCP and Decision-Maker Attitudes Toward Environmental Sustainability Initiatives

Over 90% of surgeons and surgical trainees were concerned about the threat of climate change and between 55% and 97% were willing to adjust their practices to improve sustainability.[12–15] Among nurses and administrators, 71% agreed that healthcare systems should enact more practices that reduce the OR carbon footprint.[16] There was a strong consensus among surgeons and nurses that existing regulatory guidelines are contributing to excessive waste given the strict adherence to following manufacturer's policies, which specify a single use for many products.[16]

Perceived Barriers to Environmental Sustainability Initiatives

While HCPs acknowledge the need for more environmentally sustainable practices in ORs, they often encounter barriers to adopting these protocols. The most common barriers cited by HCPs across all studies (ie, those reported by ≥50% of participants in at least one manuscript) are summarized in Table 2 and included: lack of training and information; inadequate recycling facilities; disregard for OR-generated waste; increased cost or unavailability of funds for educational initiatives; inadequate leadership or authority to incite change; lack of awareness or understanding; poor engagement from the host institution; and busy schedules.

Current Environmental Sustainability-Focused Hospital Initiatives

Despite these barriers, a multitude of initiatives have been successfully put into place to mitigate the OR's environmental impact. The most common environmental sustainability-focused initiatives included waste segregation and management (57 studies), quantification and reduction of GHG emissions (57 studies), staff training dedicated to sustainable practices (22 studies), reduction of resource consumption (14 studies), HCP and staff-led sustainability initiatives (8 studies), dedicated recycling initiatives (8 studies), and creating sustainable OR committees (6 studies) (Fig. 2).[10,22] Most of the above studies were published between 2020 and 2022 (Supplemental Table 4, see http://links.lww.com/AOSO/A359). A majority included quantification and reduction of GHG (41/57, 71.9%), creating sustainable OR committees (4/6, 66.7%), staff training dedicated to sustainable practices (14/22, 63.6%), and waste segregation and management

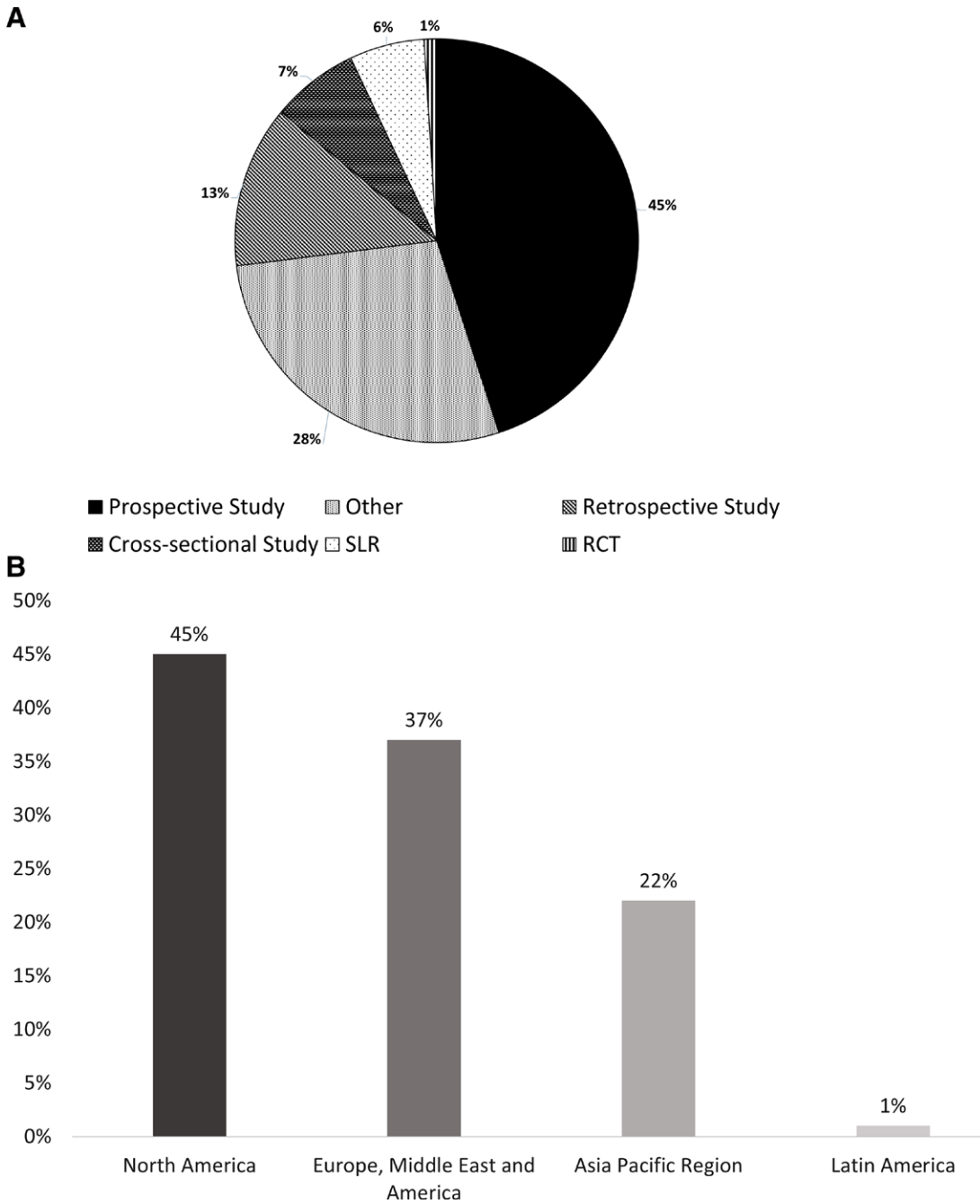

FIGURE 1. Distribution of study types and distribution of studies across regions. A, Distribution of study types included (prospective, retrospective, cross-sectional, systematic literature review, randomized control trial, and other). *Other study types include life cycle assessments, product audits, and budget impact and cost-effectiveness models. B, Distribution of included studies by geographic region (North America, Latin America, Asia-Pacific, Europe, Middle East, and Africa). Omitted from this figure are studies encompassing multiple regions (3%) and studies that did not report regions of origin (2%).

(34/57, 59.6%). A minority of studies focused on reduction of resource consumption (5/14, 35.7%), HCP and staff-led sustainability initiatives (2/8, 25.0%), and dedicated recycling initiatives (1/8, 12.5%).

Metrics Used to Determine the Impact of Hospital Sustainability Initiatives

Metrics used to determine the impact of hospital initiatives included waste reduction, segregation, and reuse, reduction in emissions of GHG, and cost savings due to implemented sustainability practices. Across the literature, many studies incorporated multiple quantifiable metrics in conjunction with one another to determine sustainability success (eg, the amount of physical waste generated by each procedure and its impact on GHG emissions and energy usage).[23]

Initiatives Focused on Waste Reduction, Segregation, and Reuse

Published literature reported that proper identification, reduction, segregation, and recycling of waste could significantly reduce the amount of waste generated in ORs and hospitals.[10,22] Studies quantifying waste generation, reduction, or segregation are summarized in Supplemental Table 5, see http://links.lww.com/AOSO/A360.

TABLE 1.

Key Takeaways From the Scoping Review

Key Takeaways:

(1) After an extensive literature search and exclusion per preidentified criteria documented in a protocol, 163 studies were included in the final data.
(2) The majority of studies were published between 2020 and 2022 (the 3 years before the start of the study).
(3) Categories of environmental sustainability initiatives included: quantification and reduction of GHG; creating sustainable OR committees; staff training dedicated to sustainable practices; waste segregation and management; reduction of resource consumption; HCP and staff-led sustainability initiatives; and dedicated recycling initiatives.
(4) The purpose of this scoping review was to identify goals and initiatives that hospitals and healthcare systems have undertaken in order to support environmental sustainability within the OR setting by:
- Understanding HCP and decision-makers beliefs related to the concept of sustainability:
  (i) The vast majority of HCPs and key decision-makers were concerned about sustainability in the OR and indicated a desire to adjust their practices to increase sustainability.
  (ii) Barriers to environmental sustainability included lack of training and information, inadequate recycling facilities, disregard for OR-generated waste, increased cost or unavailability of funds for educational initiatives, inadequate leadership or authority to make change, lack of awareness or understanding, poor engagement from the host institution, and busy schedules.
  (iii) Despite these barriers, HCPs and hospital administrators have begun to implement ecofriendly OR measures, including recycling single-use devices, batteries, and other waste, reducing biohazardous waste, incorporating reusable gel OR padding, and using waterless scrubs.
- Comparing metrics of environmental sustainability-focused initiatives:
  (i) Measures to decrease waste generation (eg, implementing reusable tools and decreasing water and electrical usage) and to reduce waste through proper sorting and recycling had a substantial impact on decreasing environmental impact.
  (ii) GHG emissions have been decreased by measures such as providing information on the carbon footprint of anesthetic gasses, implementing telehealth, decreasing the number of wasteful procedures (ie, avoidable biopsies and colonoscopies), and choosing lower-impact surgical devices.
  (iii) A large cost saving was described for hospitals that sorted waste correctly and properly trained surgeons on reducing waste.
(5) OR committees have been successfully created to enforce environmentally conscious procedures and have been shown to substantially reduce the amount of waste over a short period of time.
(6) Additional research is warranted to further understand the impact on the environment resulting from these initiatives, explore additional metrics for capturing this impact, and evaluate how these initiatives affect patient care and costs.
(7) Future initiatives should aim to decrease the negative environmental effects of ORs without sacrificing the health and well-being of patients and providers or substantially increasing costs.

TABLE 2.

Beliefs and Perceptions Reported by HCPs and Staff

Category	Percent of Participants
General beliefs and perceptions reported by HCPs and staff	
Highly motivated in relation to environmental issues in their personal lives	82%[15]; 90%[17]
Concerned about the threat of climate change and saw sustainability of great importance	92%[14]; 92%[18]; 94%[13]
Willing to improve their practices to improve sustainability	55%[12]; 62%[15]; 80.1%, 92%, 94%[19]; 97%[14]
Willing to take time for training in sustainability	73%[17]; 83.8%[18]; 85%[13]
Willing to educate others on sustainability	56%[17]; 67.1%[18]
Open to more guidance on how to improve sustainability of surgical practice	91%[13]
Unaware that the health sector contributed to global greenhouse gas emissions	60%[14]
Unclear about which OR items were recyclable	56.7%[20]
Would consider reusing topical medications	97%[16]
Would consider reusing commercially packaged intraocular drugs for more than one patient	90%–95%[16]
The most common barriers for environmental sustainability cited by HCPs across all studies (ie, reported by ≥50% of participants in at least one study)	
Lack of training and information	60%[13]; 80.9%[18]
Inadequate recycling facilities	49%[17]; 54%[13]; 80.4%[18]
Lack of concern for OR waste	64%[12]; 58%[13]; 78.4%[18]
Increased cost or lack of funding for educational initiatives	27%[12]; 33%[15]; 57%[13]; 72%[21]
Lack of leadership or authority to make change	64%[21]; 66%[13]; 71%[13]
Lack of awareness or understanding	60%[21]; 63%[14]; 67%[12]
Lack of engagement from the host institution	59%[15]
Lack of time	56%[12]; 56%[13]

Waste Audits

Waste audits were one of the key ways to measure waste reduction strategies in hospital settings. One study found that 80% of OR waste in biohazard bags was being improperly sorted into biohazard and that there was no system for recycling plastic material.[24] Over the course of two 5-day OR audits, the Minneapolis Veterans Affairs Health Services found that 231.3 kg (509.9 lbs) of waste was produced each day.[25] In one analysis, after the completion of an internal medical waste audit quantifying the total amount of inappropriately sorted waste, several more initiatives were implemented to reduce improper medical waste management and increase the recycling of plastics.[24] These subsequent initiatives, education on proper waste segregation, the diversion of plastics from trash to recycling, and local community partnerships for recycling cumulatively led to a 26-ton reduction (5.73E+04 lbs) in biohazard waste per month.[24]

Waste Management

Across published literature, HCPs and hospital administrators have begun to implement measures including recycling single-use devices and other waste, reducing biohazardous waste or waste in general, increasing waste segregation (ie, the sorting

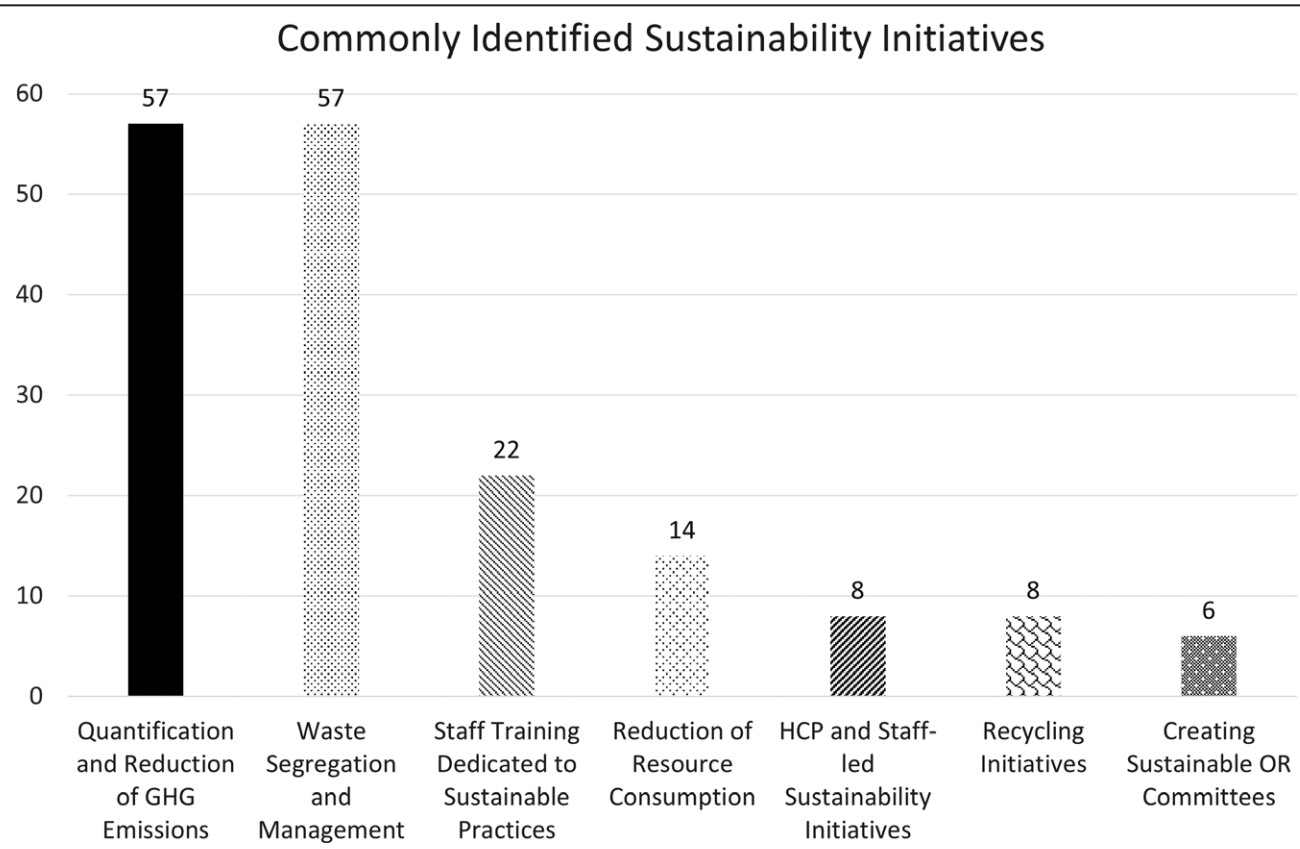

FIGURE 2. Commonly identified sustainability initiatives. Most frequently identified sustainability initiatives across the studies included. If studies mentioned more than one sustainability initiative, they were accounted for in all relevant groups.

of waste into different categories such as clinical waste and nonclinical waste), incorporating reusable gel or padding, and using waterless scrubs (restricting water use during scrubbing by using alcohol-based sanitation measures instead).[8,10,22]

One study determined the amount of plastic waste generated during a flexible ureterolithotomy was 583.3 g (20.6 oz) for surgeons who reused a sterile paper for the C-arm and reduced the procedure to only one aspiration hose (environmentally sustainable practices) versus 1186 g (41.8 oz) using traditional practices, a result that was statistically significant (Kruskal–Wallis test, $P = 0.02$).[26]

Waste segregation and disposal initiatives resulted in a decrease of 14,500 kg (66%) (31,967 lbs) in OR-generated clinical waste (ie, waste with the potential to cause infection or disease).[22] An investigation in which a hospital initiated 4 sustainable OR measures (solid waste reduction, OR recyclables and reusables, energy and water reduction, and charitable donations) showed that 12,860 lbs of medical waste per year was diverted from landfills due to solid waste reduction.[10] Proper waste sorting over a 3-month period reduced the waste-related carbon footprint by 43.6%.[27] One analysis found that among all sustainable initiatives implemented over the course of a year, the optimization of waste sorting had the greatest annual environmental impact.[28] At Prince Alexandra Hospital in Queensland, Australia, waste management measures led to a reduction of 82% in clinical OR waste and a 50% reduction in total OR waste over a 5-year period.[22] By switching to water-soluble anesthetic gel, landfill contributions would be reduced by 2393.3 L (632.2 gallons) per year.[29]

The amount of waste generated in ORs is apparent to the OR staff. In one study, approximately 64% of obstetricians and gynecologists believed that the quantity of trash generated in the OR was excessive.[30] Between 82% and 94% of respondents indicated a desire to recycle at work, 83.8% to 91% of OR respondents indicated a willingness to provide dedicated time to learn to increase recycling practices within the OR, and 56% to 85% indicated a willingness to take time to educate others to increase recycling practices within the OR.[13,17–19] However, 56.7% of participants in one study reported being unclear about which OR items were recyclable.[14,20] Additionally, multiple studies cited that between 58% and 78% of HCPs lacked concern for OR waste.[12,13,18] These contradictory statements show that among HCPs, there is a mixed sentiment regarding OR waste control and recycling and their responsibility toward them.

Resource Management

Initiatives that centered on reduced resource use focused primarily on decreasing water and electrical energy usage among OR staff.[10] A study conducted in South Africa found that using alcohol scrubs, having an assistant open and close water taps during scrubbing, and adjusting the angle of the standard elbow tap to enable the surgeon to open and close water taps easily can substantially reduce water consumption.[31] Prior to implementing a campaign on reduction in water consumption, one investigation found that converting to alcohol scrubs would save 2.7 million liters (713,264.5 gallons) of water annually and observed that after the campaign, alcohol scrub usage increased among staff from 22% to over 80%.[10] After implementing energy-related interventions in 5 hospitals over a 5-year period ranging from lighting upgrades to occupancy sensors, the average reduction in energy use was 27.2 kBtu (28.6 MJ) per square foot per year on average with reductions across 5 hospitals ranging between 3.1% and 24%.[32] Another analysis found that after implementing occupancy sensors in the ORs and switching lighting from automatic to manual while the OR was occupied, there was a yearly reduction of 717 metric tons (1.58E+6 lbs) of CO_2 equivalent (CO_2eq) and yearly savings of $53,075.[24]

Reduction in GHG Emissions

Studies quantifying CO_2 emissions from OR procedures or tools are presented below in Supplemental Table 5, see http://links.lww.com/AOSO/A360.

Hospital-Specific GHG Emissions

Hospitals are a significant contributor to GHG emissions, including emissions of CO_2 from different types of OR procedures, landfills from medical waste, energy usage, and procurement of surgical and nonsurgical materials, etc. GHG emissions generated from hospital activities can contribute to ozone layer depletion, either directly or through atmospheric interaction. Single-use materials such as needles, blades, used gloves, and cotton gauze result in a large portion of emissions related to ozone depletion.[30] However, the most frequently cited sources of OR-generated GHG emissions are anesthetic gases such as desflurane, which have the most significant environmental impact. Active initiatives are being taken to quantify and reduce GHG emissions due to anesthetics. One such initiative includes staff education, specifically among anesthetists and anesthesia departments alike.[5,33] Another study noted that only a small proportion of Canadian anesthesia residency programs incorporated a curriculum to teach residents about the environmental impact of anesthetic gases, with 83% of surveyed residency program directors indicating they had no plans to expand the curriculum to include this knowledge.[34] However, studies involving education initiatives targeted at anesthesia providers have found decreases in the carbon footprint associated with anesthetic gases.[5,33] After implementing an information campaign aimed at anesthesia providers and setting up sustainable working groups over a 5-year period, the estimated decrease in the CO_2eq over 100 years was 3800 tons (8.4E+06 lbs) per year.[33] A similar study found that after implementing hospital-wide staff education on anesthetic gases, alongside further behavioral and systematic changes, the number of desflurane bottles purchased decreased by 95.6% between 2016 and 2021.[5] In one study, 92% of respondents agreed that anesthesia-related products and procedures had an important environmental impact, while another stated that 60% of surgeons were unaware that the health sector contributed to GHG emissions.[14,18]

Telehealth and Reduction in GHG Emissions

Modern healthcare has shifted from an almost exclusively analogous system to also include a digital healthcare system, including telemedicine, mobile health, online appointments, access to digital medical reports, etc. Telehealth initiatives are assessed not only by how many patient miles and GHG emissions are saved but also by the amount of waste avoided.[35] Since this recent surge in telehealth, particularly since the COVID-19 pandemic, CO_2 emissions have decreased by 688,317 lbs of CO_2eq in 1 year and by 1957 tons (4.31E+06 lbs) of CO_2eq in the year 2020, with 11.3 kg (24.9 lbs) of GHGs saved per patient.[35–37]

Choice of Equipment or Procedure and Reduction in GHG Emissions

The carbon footprint of OR procedures differed depending on the type of surgery, the instrumentation being used, and the direct or indirect processes involved.[38,39] The carbon footprint estimated distribution for a single atrial fibrillation catheter ablation was 76.9 kg (169.5 lbs) CO_2eq, 26% of which was for the anesthesia workstation (including medication), 39% for catheters, 1% for product use, 17% for other disposable materials, 8% for sheaths, and 9% for patches.[40] The carbon footprint of a washer and disinfector and steam sterilizer used for surgical instruments was 3.7 kg (8.1 lbs) CO_2eq per cycle and 12.1 kg (26.6 lbs) CO_2eq per cycle, respectively.[39] Emissions per phacoemulsification case were 151.9 kg (334.8 lbs) CO_2eq on average, equivalent to the carbon footprint of a 1-hour flight.[41] A paper by Power et al[42] reported that total CO_2eq emissions generated from minimally invasive surgeries were estimated at 355,924 tons (7.85E+08 lbs) per year with 303 tons (6.68E+05 lbs) of CO_2eq being directly attributed to the procedure itself. A single interventional radiology procedure yielded 41.5 kg (91.5 lbs) CO_2eq per procedure, and 501 procedures (the approximate number performed in 1 year) produced 20.7 tons (4.56E+04 lbs) of CO_2eq emission.[43] The estimated carbon footprint of wasteful procedures, such as avoidable biopsies and colonoscopies, was 233 kg (513.7 lbs) CO_2eq per week.[44] When comparing the carbon footprint of laparoscopic, robotic, abdominal, and vaginal hysterectomies, robotic hysterectomies were associated with increased GHG emissions.[23] CO_2eq was reduced by 22.9% when surgical drapes and gowns were substituted for the reusable counterparts.[38] The carbon footprint of using a hybrid version of 3 types of instruments routinely used in laparoscopic cholecystectomies combined was approximately a quarter of using the single-use equivalents (1756 g vs 7194 g CO_2eq) (61.9–253.7 oz) per operation.[45] However, these studies only reported waste generated by single-use devices within the OR, without considering postoperative patient care and other factors that contribute to the generation of waste.

Cost Savings as a Benefit of Environmental Sustainability

Although the main goal of the included studies was to improve environmental sustainability, many studies also reported cost savings due to waste management initiatives, reduction in energy, and material consumption. Hospitals have been successful in saving costs by implementing initiatives such as educating OR staff on sustainability practices in the OR, recycling single-use devices, and decreasing energy use.[8,10,32]

Wormer et al[10] reported that the implementation of "Green OR Initiatives" for one hospital resulted in an annual cost savings of $158,000 with a projected savings of $60,000 per year from a 75% reduction in a red bag (ie, biohazardous) waste. The spine surgeon-education program took place between 2012 and 2014 and aimed to decrease the 9 reasons for operative waste, the largest of which was surgeon-related factors (ie, the surgeon changed his or her mind, the surgeon chose another manufacturer's device, or the surgeon determined the anatomy warranted another instrument size). This program substantially reduced the cost of operative waste in spinal orthopedics by 64.7% in 2013 and 61% in 2014, and spinal neurosurgery by 49.4% in 2013 and 45.2% in 2014.[46] Other reasons for operative waste, including intentionally opened or not implanted, wrong size opened, compromised integrity or sterility, opened did not use, opened by mistake, product failure or broken product, physician insistence, and over tapped (ie, screw loosened), all decreased to zero by the end of 2014.[46] According to McGain et al, using single-use laryngoscope blades cost approximately AUD $10,000 more than recyclable blades. While there are costs associated with implementing environmentally conscious protocols (such as training of staff and extra time spent by staff), these costs are minor compared to the long-term savings realized by hospitals.[17,32]

OR Committees in Environmental Sustainability

The creation of green OR committees has been successful in supporting environmentally conscious strategies, establishing residency programs and fellowships focused on sustainability, training medical staff to execute low-waste approaches, and enforcing general rules and mandates for environmentally conscious procedures. However, only 6 of the studies included a focus on the impact of green OR committees, making this a less common OR strategy. Despite the low number of publications,

OR committees have proved inherently effective by showing a substantial reduction in the amount of clinical waste over a short period of time. One study evaluated a multidisciplinary green OR committee over the course of 4 years, over which a 75% decrease in biohazard waste was observed, 12,000 lbs (6 tons) of solid waste diverted from landfills, and an overall $158,000 increase in annual savings for their hospital.[10] Another green OR committee found that enacting recycling and waste segregation initiatives over a 6-year period led to an 82% reduction in clinical OR waste and $7807 in savings per month.[22]

DISCUSSION

Sustainability initiatives in healthcare have been a topic of growing importance in recent years. This research highlights the increase in implementing environmentally conscious approaches in the OR, and that HCPs and OR staff are not only willing to participate in these initiatives but also have suggestions on how to further minimize the OR environmental impact. Therefore, it was useful to summarize the most recent literature focused on the intersection of environmental sustainability and hospital practice.[22,47] This scoping review highlights an increase in the number of publications from 2011 to 2022, with over 50% of the included papers published from 2021 to 2022. Additionally, the number of publications on sustainability initiatives grew by over 300% between 2011 and 2022, which further indicates that more hospital leaders, HCPs, and researchers are studying how to reduce waste and GHG emissions in the OR setting globally.

A component of assessing the success of sustainability programs is to evaluate the beliefs and perceptions of HCPs in the OR setting. Across most studies, HCPs agreed that environmentally sustainable efforts in surgical space are crucial, and many were willing to adjust their routines and practices accordingly. Although HCPs and key hospital decision-makers recognized the importance of incorporating energy-efficient protocols in the OR setting, there was hesitancy among hospital staff members due to perceived barriers. This further supports the paradox among surgeons stated by Meyer et al,[12] that although 95% of surgeons agreed to a willingness to change the OR workflow in order to reduce waste, barriers including lack of awareness, concern, or time decreased their ability to do so. Many other studies mentioned either lack of staff education or awareness as a barrier to efforts toward creating a green OR and mentioned staff education as a solution to reducing the carbon footprint of ORs. Given the evidence, any educational material created and delivered to the OR should include all key stakeholders across levels and functions, such as physicians, surgeons, hospital administrators, frontline staff, trainees, OR leadership, etc. This is to ensure that there is representation from both clinical and administrative parties and that all staff members are properly trained and aligned in their roles. Additionally, involvement from all levels of staff would demonstrate that environmentally sustainable protocols are a priority OR-wide and mitigate another common barrier, the shortage of leadership involvement in these protocols. Ideally, educational strategies should model a 2-pronged approach: a high-level overview of environmentally sustainable measures in the OR and more detailed, staff-specific training focused on each staff member's role in the OR to enable and ensure the success of these measures.

Resources important for implementing sustainability initiatives to reduce waste included dedicated recyclable waste, which could include in-house recycling facilities and dedicated waste bins for noncontaminated recyclable waste and hazardous waste. Waste in hospitals and healthcare facilities is generally sorted into color-coded bins, with different colors representing a different waste stream or type. The color selected for each waste stream or type and the items that are categorized into each waste stream or type differs from region to region, causing healthcare staff to err on the side of caution and dispose of objects into the infectious waste (ie, waste that may cause punctures or cuts, and that have been used in animal or human care or treatment) stream, thus causing an unnecessary increase in infectious waste generation. Many studies found that diverting noninfectious waste from the more impactful disposal methods used for infectious waste to landfills or recycling could decrease both the net waste produced (by 50% in one study) and the carbon footprint.[4] It is an instance where the simple measure of providing clear signage on recycling and nonrecycling receptacles could greatly increase environmental sustainability in the OR. This is also an example of how waste audits are utilized not only to establish the broad environmental impact of current OR activity but also can serve as a baseline for further targeted initiatives. Additionally, by reducing the amount of packaging associated with surgical tools and devices, surgical device manufacturers can set an example and become global leaders in sustainability.[8]

Although the main goal of sustainability initiatives in the OR was to improve environmental outcomes, studies also reported that they achieved cost savings by implementing waste reduction, and segregation, appropriate recycling and labeling of waste products, reduction in energy and water consumption, and other similar strategies. Therefore, implementing new sustainability initiatives offered tangible cost savings for the hospitals. Additionally, among the studies included, patient outcomes were maintained despite increased sustainability efforts. However, focus on the impact of sustainability efforts on patient outcomes can be further evaluated in the future.

To maximize the impact of these environmental sustainability initiatives, the authors recommend that OR staff or surgeons identify key stakeholders at various levels (surgeons, nurses, facilities, administration or management, leadership, etc) who can help champion and spearhead initiatives on OR sustainability, ultimately forming a cross-functional steering committee to accommodate wide stakeholder involvement. Once key stakeholders have been identified, objectives and goals that are specific, achievable, and can be sustained should be defined. Additionally, metrics for evaluation and a system for reporting and tracking success in achieving sustainability initiatives must also be implemented. Sustainability initiatives should be tracked and measured to determine the environmental impact (eg, decrease in the amount of waste, increase in OR recyclables and reusables, decrease in water and electrical energy usage, and decrease in CO_2eq emissions) and associated cost savings. This could also involve an assessment of current efforts and capabilities within the OR, conducting a regular audit to understand what has already been accomplished and areas for development. Small but significant changes, such as the correct labeling of waste, the increased training of OR staff on environmental sustainability, and appointing a designated position for waste management, could drastically increase the sustainability of the OR regardless of geographic setting. Increased educational opportunities for OR staff should be available through training programs either within the hospital setting or through external organizations, such as professional societies. Collaboration between suppliers and hospitals should be encouraged to contextualize and measure the true impact of sustainability measures in the healthcare industry. Future research is needed in this nascent, rapidly evolving space to continue evaluating and quantifying the comprehensive impact of sustainability initiatives, the practicality of their implementation, and the longevity of HCP and staff-led initiatives versus those enacted by hospital administrators.

While there is a growing movement toward adopting environmentally conscious initiatives, sustainability remains a nascent field in many geographies and there is a lack of long-term data quantifying the benefits of such initiatives. One of the limitations of this manuscript was that the publications included were heterogeneous and thus the measurements and models used for GHGs, waste, and other quantifiable metrics

were different between studies and difficult to compare directly. Literature gaps included a lack of studies on the long-term impact of environmentally sustainable measures undertaken by hospitals etc. There was also a lack of studies discussing past and current successful "green initiatives" and attested lessons learned by OR staff and leadership. Studies discussed direct cost savings associated with the implementation of sustainability practices; few noted potential indirect costs affecting hospital training programs resulting from new practices. To evaluate the impact on environmental sustainability, it is important to study the generation of waste holistically and include pre-, peri-, and postoperative health outcomes and total life cycle assessments while conducting audits studies in order to understand the true comparative impact of various products, procedures, or initiatives on healthcare.

CONCLUSIONS

This research highlights a recent increase in implementation of sustainability initiatives in the OR, and that HCPs and surgical staff are not only willing to participate but also have suggestions on initiatives to minimize the environmental impact of the OR, such as reducing GHG emissions and waste. Additional research is warranted to further understand the impact on the environment resulting from these initiatives, explore additional metrics for capturing this impact, and evaluate how these initiatives affect patient care and costs. Future initiatives should aim to decrease the negative environmental effects of ORs without sacrificing the health and well-being of patients and providers or substantially increasing costs.

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