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Interventions to Reduce Surgical Waste Burden: A Systematic Review

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Background: Operating suites are significant drivers of waste, pollution, and costs. Surgeons can help fight the climate crisis by implementing innovative strategies aimed at mitigating the environmental impact of surgical procedures and decreasing operational costs, and moving toward a more sustainable healthcare system. This study aims to review the literature describing interventions that reduce surgical waste.

Methods: PubMed, Cochrane, and Embase were searched. Studies reporting interventions to reduce operative waste, including emissions, energy, trash, and other, were included. Case reports, opinion-based reports, reviews, and meta-analyses were excluded. Study quality was rated using MINORS and Jadad scales. Data were extracted from each study to calculate waste on a per case basis. Narrative review of studies was performed rather than meta-analysis.

Results: The search yielded 675 unique hits, of which 13 (level of evidence: I–III) met inclusion criteria. Included studies were categorized by intervention type in relation to the operating and procedure room. Three studies evaluated provider education initiatives, three evaluated setup of instruments, two evaluated single-use items, four evaluated technique changes, and one evaluated surgical venue. Seven studies reported significant reductions in disposable surgical waste throughput, and seven reported significant reductions in cost.

Conclusions: The results of this systemic review demonstrated the effectiveness of surgical waste reduction initiatives in reducing waste volume, cost, and carbon emissions. Within plastic surgery, minimal surgical packs resulted in reduced gross waste and cost while promoting patient satisfaction in hand surgery, supporting the continued development and implementation of such initiatives in a surgical context.
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INTRODUCTION

The climate crisis is driven by the massive production of carbon dioxide and other greenhouse gases, threatening the existence of every species on earth.[1] Human and planetary health are interconnected, as climate change may lead to devastating impacts on health, such as increased heat-related mortality, increased distribution of disease vectors, and elevated levels of air pollutants.[2] Healthcare is a massive contributor to the carbon footprint, with large amounts of energy consumed by hospitals and clinics, and massive amounts of waste produced daily in the care of patients.[3] In 2019, the estimated cost associated with healthcare-produced waste in the United States was estimated to be $760 billion to $935 billion, with waste representing 30% of the total healthcare spending.[4] Healthcare spending has continued to increase over the years, surpassing other countries, warranting attention toward healthcare waste reduction initiatives. For these reasons, addressing climate change requires everyone, including surgeons, to consider adjustments to help mitigate potential impacts. Operating suites are significant drivers of healthcare-associated waste

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production and contribute to environmental pollution and increasing healthcare costs. Surgical waste disposal processes impose large environmental, financial, and energy burdens on society. One study of three hospitals found that their operating rooms produced on average 267,829 kg of waste per year.[5] The US Environmental Protection Agency writes that solid waste has numerous negative effects on health and environment, including contaminating groundwater, releasing methane, and destroying natural habitats.

Numerous surgical waste reduction interventions have been implemented in recent years, but their utility is unclear.[6] Hospitals and clinics working to reduce their waste and carbon footprint need clear instructions on how this can be achieved. Despite the obvious importance, many surgical teams are hesitant to change without published evidence for practices and innovations. There have been many studies and nonresearch publications examining operating room waste production. However, few look at implementable strategies and their immediate effects. Despite the increase in interest, there is no consensus on what surgeons should be doing to reduce their waste, and therefore, a thorough review of the existing literature is warranted. This systematic review aims to shed light on recent interventions designed to reduce surgical waste.

Takeaways

Question: What interventions are effective at reducing surgical waste?

Findings: Thirteen studies were included for review. Three studies evaluated provider education initiatives, three evaluated setup of instruments, two evaluated single-use items, four evaluated technique changes, and one evaluated surgical venue. Seven studies reported significant reductions in disposable surgical waste throughput, and seven reported significant reductions in cost.

Meaning: Surgical waste reduction initiatives that incorporate new recyclable materials, custom surgical packs, "green" procedural changes, or provider education initiatives seem to be efficacious in reducing gross waste volume, cost, and carbon emissions, supporting the continued development and implementation of such initiatives in a surgical context.

METHODS

The authors conducted a systematic review of English language articles reporting original data related to an intervention's effect on reduction of waste, including emissions, energy, trash, and other forms of waste, in the operating room or during any surgical procedure. The PROSPERO database was searched to ensure that no similar studies had been published, and the study was subsequently registered with PROSPERO (Registration #: CRD42022330698). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines were followed in the design and reporting of this systematic review.[7] The following databases were searched: Embase, PubMed, and Cochrane Library. Search strings were developed from Medical Subject Headings. (**See table, Supplemental Digital Content 1**, which displays PubMed search terms and search details. **http://links.lww.com/PRSGO/D442**.)

Inclusion and exclusion criteria were created before screening. Inclusion criteria required that articles evaluated an intervention's effect on reduction of solid waste in the operating room and had a measurable waste outcome. Only English language original research articles were included. Case reports, opinion-based reports, congress abstracts, meta-analyses and other reviews, and nonresearch articles were excluded. Articles excluded were those that did not demonstrate a focus on specific waste reduction interventions or contain any quantitative data.

Abstracts and titles were screened by two independent reviewers (C.Y. and K.M.-F.). Full reports of relevant studies were screened for inclusion criteria. Disagreements between reviewers were resolved by discussion. An independent scorer (M.P.) rated the quality and bias of the selected articles using either the Jadad or MINORS scale.[8,9] Data were collected using a prespecified list for sample size, specific intervention, outcome measure, outcome results, randomization, and specialty focus. Data were extracted from each article to calculate waste on a per case basis. Given the heterogeneity in the interventions and outcome measures, data synthesis for meta-analysis was not performed, and a qualitative narrative of the results was produced.

RESULTS

The initial database search yielded 675 total results: 293 results from PubMed, 166 from Cochrane, and 256 from Embase. After excluding 40 articles due to duplication, 635 articles were screened based on abstract and title. Fifty-nine articles were selected, of which 11 were removed due to retrieval issues, and 48 articles were selected for full-text review (Fig. 1). Of the 48 articles screened, 13 met inclusion criteria. Twenty-two were excluded for wrong study design, 11 were excluded due to the measurement of a different primary outcome, one was excluded due to level IV evidence, and one was excluded due to language criteria. The included studies were published in the years 2010 to 2023, and the represented fields included anesthesia (8%), gastroenterology (8%), orthopedic surgery (38%), plastic surgery (15%), general surgery (23%), and ENT (8%). Narrative assessment was used to categorize study intervention types. The major themes underlying the selected articles included provider education, change in instrument setup, new technique, use of single-use items, and location of procedure. Table 1 summarizes the studies by intervention type.

The present systematic review found that the majority of published studies on interventions to reduce operative waste reported reductions in surgical waste volume, cost, or carbon emissions. Three studies focused on educational interventions, four studies were directed at changing surgical techniques, three studies focused on reducing or implementing a patient-specific instrumentation setup, two studies aimed to reduce single-use devices, and one study focused on comparing the surgical cost and waste

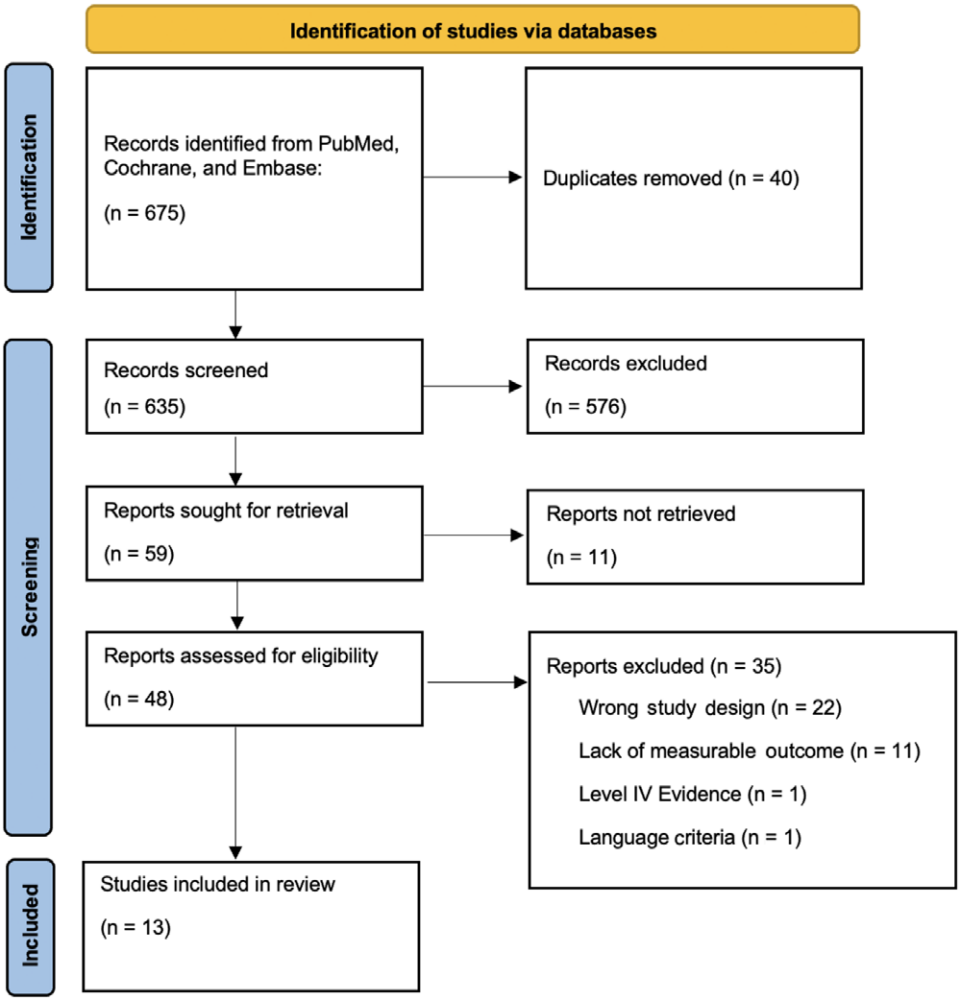

Fig. 1. Flowchart demonstrating the selection and eligibility, screening, and final inclusion processes for OR waste studies. Thirteen studies were selected for qualitative and quantitative review.

production of procedures taking place in different settings. Table 2 summarizes the outcome measures and decrease in waste measurement of the studies. Seven of the studies analyzed reported significant reductions in disposable waste throughput, and seven reported significantly reduced cost. Of the studies that reported significant reduction in waste, three were educational, one was in surgical technique, two were in instrument setup, and one was in surgical venue.

DISCUSSION

Although primary outcomes focused on reductions in waste and cost, additional outcomes investigated by seven of the total studies included differences in usage of single-use devices, patient complications, operating times, and reduction of instrumentation setup. Adamczyk et al,[10] who focused on standard versus Savings through Lowering of Instrumentation Mass setup, also measured differences in patient-related outcomes such as surgical complications. The Savings through Lowering of Instrumentation Mass setup was associated with cost and waste savings, but no differences in operating room time, complication rate, or blood loss were found, demonstrating that a minimalist approach can be safely implemented. In a study by Huet et al,[11] using single-use instruments (SUIs) instead of conventional ancillary instruments (CAIs) lead to logistic advantages. For example, the management of SUIs was faster at the pharmacy, the implants and instruments were at the surgeon's fingertips, and there was ease of storage. Finally, Rougereau et al[12] found that their change in technique to use ChloraPrep led to a lower mean protocol duration than with Betadine prep.

The largest reduction in waste was found with a change in the surgical venue. Carr et al[13] saw an 86.4% waste reduction per case when performing an open carpal tunnel release procedure in a clinic setting with monitored anesthesia compared with a traditional hospital OR venue. This reduction is likely due to the utilization of reusable towels for draping and the absence of gowns, thereby eliminating the unnecessary waste typically associated with more extensive surgical setups.[14] The expense and volume of medical waste associated with using disposable draping can be substantial but can be reduced significantly by opting for reusable towels with field sterility.[15] In addition to

Table 1. Description of Studies Selected for Systematic Review

Study	Study Design	LOE	Intervention	Intervention Type	Brief Description
Adamczyk et al[10]	Randomized control trial	I	Setup	Reduced instrument setup	Compared total solid waste across total hip arthroplasty procedures utilizing a Savings through Lowering of Instrumentation Mass setup compared with a conventional instrumentation setup
Andrade et al[28]	Retrospective comparative study	III	Technique	New biopsy technique for mediastinal lymph node sampling	Compared the costs and solid waste of mediastinoscopy vs endobronchial ultrasonography with transbronchial needle aspiration for mediastinal lymph node sampling
Carr et al[13]	Prospective observational study	II	Surgical venue	Surgical cost in a traditional hospital operating room or clinic with monitored anesthesia	Compared total waste per case and surgical cost across surgical venues such as a hospital operating room, outpatient surgical center, and a clinic venue
Conrardy et al[29]	Prospective comparative study	II	Single-use devices	Use of reusable items	Analyzed average waste reduction with reusable supplies such as reusable table and mayo stand covers, surgical basins, and surgical gowns
Cunha Neves et al[30]	Prospective interventional study	II	Education	Education seminars and reorganizing waste bin placement	Measured the effect of team education of waste handling and relocation of waste bins on daily endoscopic waste
Denny et al[20]	Prospective interventional study	II	Education	Education modules with practice guidelines	Measured the effect of an educational intervention on the amount of unused anesthesia supplies such as ET tubes and laryngoscope blades.
Huet et al[11]	Prospective observational cohort study	II	Single-use devices	Use of reusable CAIs compared with SUIs	Measured total waste per case and surgical cost for distal radial fracture procedures using CAIs compared with SUIs
Meiklejohn et al[21]	Prospective comparative study	II	Technique	New cold technique for tonsillectomy	Quantified differences in waste and cost of disposable equipment between cold tonsillectomy, monopolar electrocautery tonsillectomy, and coblation tonsillectomy technique
Rougereau et al[12]	Case control study	III	Technique	ChloraPrep vs Betadine solution in surgery prep	Compared the cost and waste of surgical site skin preparation using ChloraPrep with skin cleansing using Betadine surgical scrub and Betadine 5% solution in total hip arthroplasty
Soroceanu et al[27]	Prospective observational study	II	Education	Surgeon education program	Examined the efficacy of an educational program directed at surgeons in reducing intraoperative waste and monthly surgical costs
Teeter et al[32]	Randomized control trial	I	Setup	Patient-specific instrumentation	Compared waste production, surgical cost, and the number of trays utilized across total knee arthroplasty using patient-specific cutting guides and conventional instrumentation
Thiel et al[24]	Prospective comparative study	II	Setup	Reduced instrument setup	Measured total waste reduction and supply cost with the implementation of minimal instrumentation packs for minor hand surgery
Woods et al[33]	Retrospective observational study	III	Technique	Robot-assisted laparoscopy vs conventional laparoscopy	Compared the total carbon footprint differences between laparotomy, conventional laparoscopy, and robotically assisted laparoscopy

a 4.13-kg decrease in waste per case, cost was significantly reduced, patients were more satisfied, and operating times were shorter. Whenever feasible, conducting procedures in a clinic environment with minimal draping should be considered to reduce waste. Additional actions outlined by Wu et al[14] that aim to reduce waste production within surgical venues include limiting the use of anesthetic gasses with high contribution to greenhouse gas emissions by selecting less environmentally damaging inhaled anesthetics and using total intravenous anesthesia when possible. Furthermore, turning off anesthesia equipment and additional operating room machinery not in use can significantly reduce the electrical energy consumed by surgical venues and overall reduce hospital costs.[14]

The smallest reduction in waste per case postintervention was seen with the implementation of reusable CAIs versus SUIs for osteosynthesis of distal radius fractures. Huet et al[11] recorded an overall 7% decrease in mean total waste per case with the use of single-use instrumentation. Differences in mean cost and operating times between procedures utilizing CAIs and SUIs were found to be nonsignificant. Despite the lack of significant

Table 2. Outcome Measures and Decrease in Waste Data

Study	Sample Size	Outcome Measures	% Decrease in Waste Measurement	Decrease in Waste per Case, kg	Reason Not Included in Synthesis	MINORS or Jadad* Score
Adamczyk et al[10]†	80 Cases	Waste reduction per case	—	1.61		3*
Andrade et al[28]	148 Cases	Kilogram solid waste	72.3% decrease mean total waste	1.3		12
Carr et al[13]†	20 Cases	Surgical cost and waste weight produced per venue	86.4% waste reduction per case in a clinic setting with monitored anesthesia compared with a traditional hospital OR venue	4.13		16
Conrardy et al[29]	119 Cases	Total weight of disposable items	64.5% reduction in disposable waste	2.15		10
Cunha Neves et al[30]†	357 Cases	Total waste, regulated medical waste, landfill waste, recycled plastic, recycled paper	12.9% decrease in mean total waste	0.1		16
Denny et al[20]†	37 ORs	Unused anesthesia supplies	57.1% decrease in weekly waste of anesthesia-related material	—	No weight in kilogram provided	13
Huet et al[11]	103 Cases	Case duration, radiological measurements, and cost comparison between the use of CAI and SUI	7% in mean total waste	1		14
Meiklejohn et al[31]	60 Cases	Total mass, volume, and cost of disposable equipment for each technique	—	1.272		12
Rougereau et al[12]	30 Cases	Cost of consumables, cost of waste disposal, and cost of time taken to perform the procedure	79.8% decrease mean total waste	0.233		18
Soroceanu et al[27]†	1304 Cases	Presence of intraoperative surgical waste, monthly surgical waste costs	9.9% decrease in waste	—	Waste was reported in percentages	14
Teeter et al[32]†	50 Cases	Waste production per case, cost per case, and the number of trays utilized per case	4.9% reduction in mean total waste	0.5		3*
Thiel et al[24]†	178 Cases	Total waste and cost per year	13% decrease in total mean waste	0.31		16
Woods et al[33]†	150 Cases	Kilogram solid waste	38% decrease mean total waste	11.1		12

* The use of Jadad score rather than MINORS Score. The Jadad score assesses the quality of randomized controlled trials, whereas the MINORS score assesses the quality of nonrandomized surgical studies, which can include both comparative and observational studies.
†A statistically significant decrease in waste.

difference in cost and operating times, the easy accessibility, feasible storage, and decrease pharmacy time associated with SUIs were found to improve efficiency in the operating room.[11]

This study represents a comprehensive review of the existing literature on surgical waste reduction initiatives with clearly defined and measurable outcomes, contributing to the newly emerging body of research in this area. In recent years, there has been increased awareness and discussion surrounding the topic of waste generated by medical and surgical procedures.[6,16,17] Healthcare-associated waste in general has been known to impose significant financial and environmental burdens on both healthcare systems and society at large.[18,19] There has been an increasing number of studies as awareness has increased, but to date, there has not been a review comparing and summarizing these studies. This study shows that the vast majority of surgical waste reduction initiatives that incorporate new green or recyclable materials, custom surgical packs, "green" procedural changes, or provider education initiatives effectively reduces gross waste volume, healthcare cost, or carbon emissions, although some may be more effective than others. These data present an evidence-based framework that may serve as a reference for the development of physician-led initiatives addressing surgical waste reduction.

Although the modification of surgical kits and reorganization and reprocessing of surgical procedures and instruments may significantly reduce waste production, such initiatives may face significant organizational and bureaucratic obstacles. For example, Denny et al[20] found obstacles with provider logistics and communication and suggested an all-inclusive and recurring approach of waste reduction education to all anesthesia providers, such as nurse anesthetists, anesthesia residents, and student registered nurse anesthetists to avoid communication gaps. Carr et al[13] were able to perform their study by still following hospital guidelines and clinic procedure room guidelines, such as full sterility, in accordance with facility policies.

Although surgeons hold a significant role in promoting waste reduction initiatives within the operating room, making these systematic changes requires the collective participation of all stakeholders in the healthcare process. To mitigate logistical challenges, hospitals should consider creating a multidisciplinary green committee to evaluate holistic approaches to waste reduction and

create protocols and guidelines to implement these procedures. These committees should aim to direct waste reduction and improve surgical efficiency through standardizing procedures, sets, sutures, and implants. Such standardization can lead to shorter operative times; reduced use of anesthesia gases; reduced OR electricity; and, consequently, less surgical waste.[13] Wormer et al[21] found a 5800-kg decrease in medical waste, a 234,000-kg decrease in CO_2 emissions, and savings of $92,000 per year at their institution after the implementation of their Green Operating Room Committee. Hospital administrators stand to benefit from lower costs and improved financial outcomes, whereas patients may experience shorter operations and reduced hospital stays. As suggested by Lee et al,[22] the leadership of these committees should be committed to fostering the participation of providers, hospital staff, and patients alike, creating a cohesive and informed community focused on sustainable practices. With these collective efforts, the interventions focused on environmental sustainability can expand beyond the operating room.

Within plastic and hand surgery, there is an opportunity and necessity to green the OR. Cosmetic procedures have increased 22% for the past two decades nationally and increasing rates of medical tourism have driven the demand for cosmetic procedures. Thus, there is a need to adapt plastic surgery to the ongoing threats of climate change and to decrease costs.[23] Thiel et al[24] found that wide-awake hand surgery with a minimal custom pack of disposable surgical supplies produced less waste and cost in supplies per case than sedation and local anesthesia with the standard pack. Additionally, patients who underwent wide-awake hand surgery reported greater satisfaction with their anesthetic choice. Furthermore, Albert et al[25] examined the disposable items and instruments designated for various plastic and hand surgery procedures, such as breast augmentation, abdominoplasty, carpal tunnel release, and other common procedures. They also interviewed plastic and hand surgeons to identify instruments opened but unused during procedures. After creating custom minimal packs, they found that cost and waste were reduced. These results underscore the effectiveness of OR waste reduction within the field of plastic surgery.

Reductions in hospital expenses from improvements in waste management may not immediately improve healthcare costs for the patient. Nonetheless, initiatives that emphasize education for the surgeon and surgical team on appropriate waste disposal and processing methods can significantly reduce healthcare expenditures with less upfront opportunity cost. Statistics on hospital waste prevention and management indicate upwards of 20-fold increases in cost related to the disposal of hazardous waste compared with nonhazardous hospital waste.[26] Provider education instructing staff how to correctly organize waste into appropriate containers may be an optimal starting point to reducing waste production in the operating room, given the results from Soroceanu et al.[28] Educational programs can be expanded to create committees focused on the recycling of OR materials by educating staff on proper recycling and segregating regulated medical waste to reduce medical costs associated with waste disposal and overall generation of environmental pollutants.[14]

There are several limitations to this review. Data on the reporting of other carbon reduction initiatives, such as facility-level changes in electricity and water use, were not specifically elicited in this study. Furthermore, there may be a significant number of hospital or provider-led initiatives to reduce waste that are not reported in the scientific literature. Also, given the wide variability of waste reduction initiatives, our categorization of surgical waste reduction initiatives into broad groups does not capture all the potential paradigms through which such initiatives can be implemented. Moreover, the endpoints identified in each of the analyzed studies differ, making quantitative comparison of study outcomes difficult. This inconsistency adds to the call for standardization of the design and reporting of future surgical waste reduction initiatives. Nonetheless, the findings of this review support the continued development and implementation of surgical waste reduction initiatives.

In response to the insights gained from this review, our practices have adopted a minimal draping technique for small, skin-only procedures. The acceptance of minimal draping in hand surgery suggests its potential applicability and benefits in other surgical procedures. Additionally, the establishment of the sustainability initiatives at our home institution marks a significant step toward embedding these practices into the healthcare system's operations. This committee is tasked with evaluating and promoting effective waste reduction strategies, underscoring a proactive stance on environmental sustainability and its integration into clinical care.

A complete understanding of the clinical, economic, and environmental implications of surgical waste reduction interventions will inform the development of systems-level initiatives that redirect healthcare resources to areas of need while enhancing patient care and physician efficiency. Future surgical waste reduction initiatives should incorporate standardized implementation and reporting methods to ensure accurate monitoring of their completion and follow-up. In doing so, they can truly shed light on the benefits and consequences of interventions designed to reduce surgical waste.

CONCLUSIONS

This systematic review found that surgical waste reduction initiatives that incorporate new green or recyclable materials, custom surgical packs, "green" procedural changes, or provider education initiatives seem to be efficacious in reducing gross waste volume, cost, and carbon emissions. Surgeons can attempt to take some of the following actions to reduce waste in their operating rooms. They can educate their surgical team on appropriate waste disposal and processing methods to reduce waste production in the operating room, and they can implement a minimalist approach to instrument setup to reduce the use of redundant and underutilized instruments, decreasing the number of instruments. Furthermore, they can reduce the use of single-use

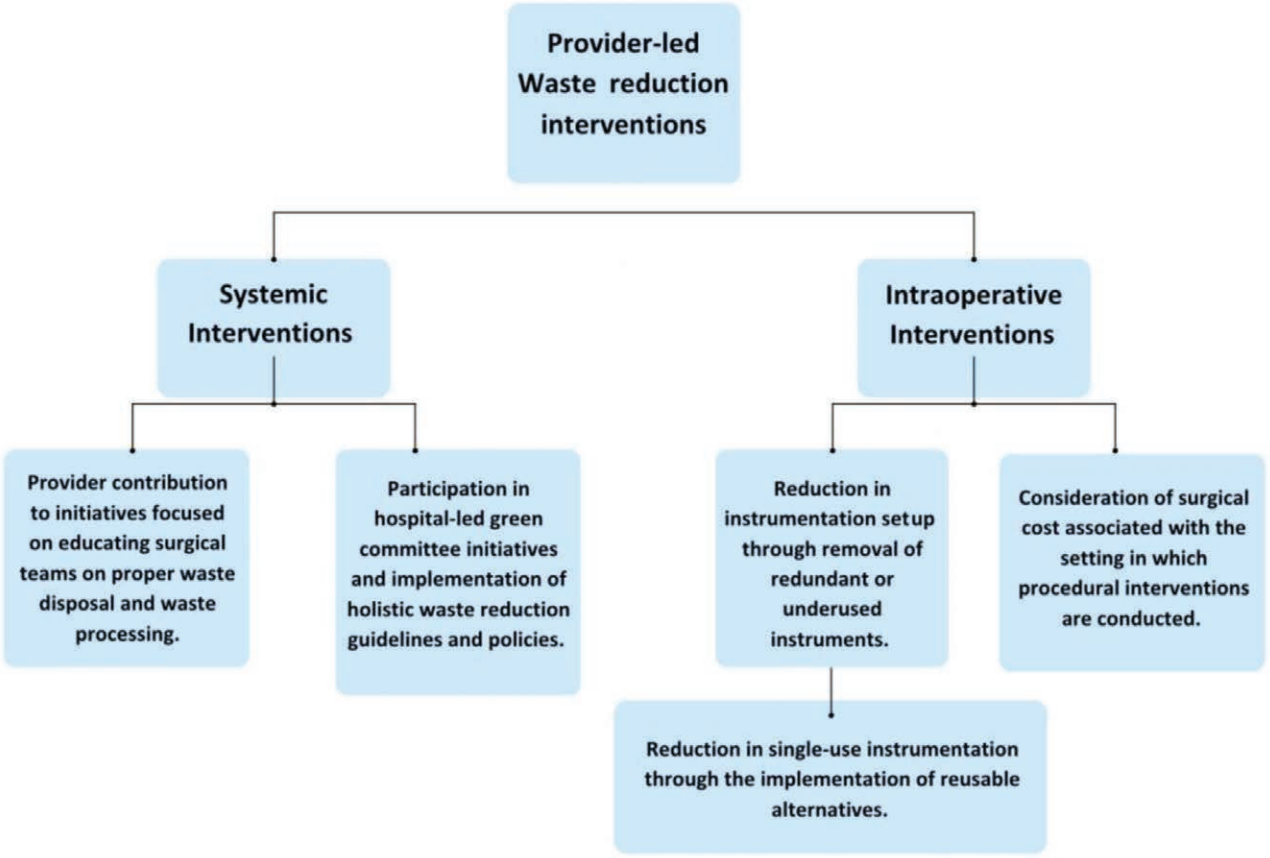

Fig. 2. Flowchart summarizing recommendations to reduce OR waste.

devices to decrease the amount of disposable surgical waste throughput, or they can compare the surgical cost and waste production of procedures taking place in different settings to find the most efficient and sustainable option. These recommendations are summarized in Figure 2. Surgeons have an important duty in determining areas of waste within their specialty and educating their surgical team on means to decrease refuse while increasing reusables. As awareness of the healthcare system's role in its contribution to waste grows, surgeons should determine areas of improvement available to combat rising healthcare costs and environmental concerns.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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