Surgical Team Attitudes Toward the Use of Biodegradable Instruments in the Operating Room

Ali Hammad Ali Ahmed Jasim Alghadhban[1], Ahmed Hammad Ali Ahmed Jasim Alghadhban[2]

[1]*I.M. Sechenov First Moscow State Medical University*
ahaajag@gmail.com
[2]*University of sharjah*

KEYWORDS

Recycling, Sustainability, Operating room, Waste management, Environmental

ABSTRACT

Significant amounts of waste are produced by the healthcare industry, notably in operating rooms (ORs), which contributes to the worsening of environmental degradation on a global scale. The purpose of this study was to evaluate recycling techniques utilised in operating rooms across a variety of surgical specialties around the world, with the objective of identifying important obstacles and potential for improvement. There are a number of factors that make it difficult to put recycling ideas into action, including governmental restrictions, insufficient education, difficulty in leadership, and organizational issues. The successful completion of projects involves the implementation of specialized recycling activities that concentrate on particular materials, such as blue wrap and polyethylene terephthalate plastics. These initiatives are supported by the participation of leadership and the established procedures. The findings of the investigation highlight the importance of implementing a comprehensive strategy that incorporates regulatory reform, education, and strategic alliances with businesses in order to successfully contend with these difficulties. Through the implementation of effective recycling practices in operating rooms, healthcare facilities are able to integrate waste management with broader environmental sustainability goals, thereby decreasing their impact on the environment and improving their resource efficiency.

Overview of environmental challenges in healthcare.

There has been a growing recognition that healthcare institutions are among the most major contributors to environmental pollution and waste generation on a global scale (1-4). Hospitals are responsible for one percent of the solid waste produced in affluent countries such as the United States, Australia, and the United Kingdom, and they are also responsible for as much as two percent of the annual greenhouse gas emissions (2, 5, 6). The transition from reusable to single-use plastic products, which was motivated by worries about the spread of infectious diseases, has made this problem far worse, resulting in a significant rise in the amount of waste that is produced. There has been an increase in the amount of waste produced in the healthcare industry all over the world, which has necessitated a reevaluation of operations and a focus on waste minimization while maintaining sterility and quality requirements (7,8).

Waste in operating rooms: A global perspective

Operating rooms, often known as ORs, are a substantial contributor to hospital waste, since they produce an excessive quantity of waste that accounts for around 20–33% of the overall refuse that is generated by hospitals (9-13).
Waste from hospitals is separated into a number of different waste streams, and each of these waste streams requires a unique set of procedures for neutralization, safe treatment, and disposal. As a result of the fact that a sizeable portion of hospital waste is comparable to that of domestic garbage and can be recycled or repurposed, there are prospects for large cost reductions. The incorrect categorization of garbage as "clinical" or hazardous results in inefficient recycling practice and increased expenses associated with disposal. An inadequate sorting process and a lack of information are widely acknowledged to be the primary factors contributing to the incorrect classification of waste. Educational activities and trash segregation programs have been shown to be beneficial in enhancing the proper disposal of garbage and resulting in significant cost savings for healthcare institutions (11, 14-19).
Operating rooms are identified as a unique opportunity for focused waste reduction programs, which can result in environmental advantages and financial savings (2, 11-12). This is because the hunt for "green hospitals" recognizes operating rooms as a unique potential. An all-encompassing approach is required in order to lessen the negative effects that trash has on the environment. This includes reducing the overall amount of garbage through education and conscious consumption, properly sorting waste, and making the most of the 5Rs, which are to refuse, reduce, reuse, repurpose, and recycle. It is imperative that all of this take place while avoiding poor waste management in order to prevent injuries to either patients or hospital workers (12).

A culture of resource conservation is fostered when surgeons and other operating room staff are given leadership roles. This not only highlights the need of environmental consciousness in healthcare settings, but it also gives healthcare workers the opportunity to demonstrate their leadership (20).

The function and objective of the sustainability in surgical practice (SSP) task force

All throughout the world, people are concerned about climate change, which poses a threat to human health that threatens to end the world. There is a correlation between sustainability and the well-being of individuals, families, and communities internationally. There is a considerable impact that the healthcare industry has on the global carbon footprint, which accounts for more than five percent of the emissions of greenhouse gases. Additionally, the sector is responsible for 8.5% of the total greenhouse gas emissions that are produced in the United States. In order to lessen the severity of these effects, immediate intervention is required. A substantial amount of trash is produced and a significant amount of energy is consumed in the operating room, which has a significant impact on the sustainability of healthcare organizations (20).

The European Commission initiated the European Green Deal in December 2019, with the intention of achieving the goal of making Europe the first continent in the world to eliminate its greenhouse gas emissions. In 2021, the European Union enacted climate rules that mandated the attainment of climate neutrality by the year 2050 and established a goal to cut net greenhouse gas emissions by at least 55% by the year 2030 in comparison to the levels that existed in 1990 (21). The United States Department of Health and Human Services (HHS) launched the White House-HHS Health Sector Climate Pledge in 2022, with the goal of reducing emissions by fifty percent by the year 2030 and reaching net zero emissions by the year 2050. This was done in recognition

of the fact that the health sector is responsible for eight and a half percent of the greenhouse gas emissions in the United States. Hospitals, suppliers, insurance firms, group purchasing groups, pharmaceutical and device manufacturers, and professional medical and surgical societies such as SAGES (22) were among the entities that signed the statement. The document was signed by a large number of institutions. The National Academy of Medicine of the United States of America, in collaboration with the federal government and other healthcare organizations, launched a Grand Challenge for the purpose of decarbonizing the United States Health System (23).

The Sustainability in Surgical Practice (SSP) Taskforce was established (24), which was initially established in honor of the significant contributions that both the EAES and SAGES organizations have made to the advancement of surgical excellence and sustainability. The primary objectives of this alliance are to educate surgeons and their teams, as well as to engage with strategic partners in order to develop and maintain practices that reduce the environmental impact of surgical procedures, particularly in the context of minimally invasive surgery.

Green operating rooms: Significance and impact

Over the course of countless decades, there has been a consistent pattern of rapid technological advancements and ongoing scientific progress. Despite this, the idea of sustainability has only just begun to garner attention, despite the fact that it has become equally important. Sustainability and leadership in surgical climate efforts should be prioritized in the healthcare industry because surgery is included in this category. The establishment of Green Operating Rooms is a key step toward the implementation of medical procedures that are environmentally responsible, ethical, and effective. In order to advance sustainable healthcare, environmentally friendly operating rooms are absolutely necessary. Because operating rooms are responsible for a substantial amount of waste and emissions of greenhouse gases, they should be given priority when it comes to the implementation of sustainable practices. It is possible to dramatically reduce utility costs, lower expenses, minimize carbon emissions, promote social fairness, and support the core purpose of healthcare, which is to advance health and well-being (25). This can be accomplished by adopting energy-efficient technologies and waste-reduction initiatives. Through the reduction of harmful emissions and the improvement of indoor air quality, sustainable operational procedures have the potential to deliver advantages to public health and safety. Populations with lower incomes and minority groups are disproportionately affected by these conditions. By adopting sustainable practices and Green Operations Research methodologies, businesses may meet the expectations of their customers and safeguard themselves in an environment that is undergoing rapid transformation (26).

The role of societies and surgeons in promoting and implementing sustainable surgical practices

It is essential for the development of sustainable surgical practices that surgical organizations like EAES and SAGES, which collectively represent more than 10,000 members who are committed to endoscopic and minimally invasive surgery, play a significant role in the advancement of these practices. They have a huge responsibility to share information with surgical teams and surgeons on the influence that surgical procedures have on the surrounding environment. This is especially pertinent to the elective context, and it is connected to the growing utilization of minimally invasive surgical technologies, such as laparoscopy and robotic surgery, in conjunction with an unprecedented reliance on equipment that is only used once (27).

When surgical teams have a thorough understanding of the components that constitute "carbon hotspots" in the operating theater, they are able to adapt methods and implement incremental

changes in order to lower the carbon footprint without sacrificing the quality of care provided to patients. In order to accomplish this, it is necessary to educate the members about the precise contributions that electricity, anesthetic drugs, procedural techniques (open, laparoscopic, or robotic), reusable vs disposable supplies and instruments (including procurement), and surgical waste make to the overall footprint of the procedure. It is possible for societies to advocate for best practices by developing instructional materials, formulating rules, or partnering with other groups and stakeholders. Studies that create data to validate government guidelines and inform practice modifications may be endorsed, funded, and disseminated by surgical societies that are engaged in research and innovation. It is important for surgical societies to work together and take part in global advocacy activities with a variety of stakeholders in order to advocate policies that strengthen climate action and increase climate resilience within the healthcare system (28).

It is of the utmost importance to advocate for improvements that promote recycling procedures while maintaining safety in order to comply with regulatory criteria. The establishment of a firm foundation for institutions would be accomplished by the creation and dissemination of established standards for waste segregation, which would be adapted to the particular environment of operating rooms (29). The significance of educational and training programs that aim to close knowledge gaps and change cultural beliefs on sustainability is comparable. The establishment of criteria and the delineation of objectives for the percentage of materials that are recycled or disposed would provide precise goals for health systems and make it possible to construct competitive measures at both the local and national levels (30).

The public discourse frequently draws attention to a disparity between the quantity of waste that is designated for recycling and the actual quantity that is processed. This disparity is greatly influenced by variables such as the location of the waste and the economic conditions that exist. It is clear from this fact that recycling systems are quite complicated, and that local rules and infrastructure also play a significant role. Despite the fact that it is difficult to ascertain the precise percentages of materials that have been effectively recycled, putting an emphasis on recycling in conjunction with reduction and reuse strategies provides a holistic strategy to minimizing the impact on the environment while simultaneously protecting patient safety (31).

Reforms among healthcare practitioners can be implemented from the top down or from the bottom up, depending on the health system. Leadership that is proactive and the involvement of "green champions" inside healthcare organizations have the potential to catalyze significant organizational changes that are necessary for the implementation of recycling projects.39; In addition, optimizing surgeon preference cards can greatly cut down on waste and expenditures, improve operational efficiency, and lessen the impact that it has on the environment (32).

Strategies for enhancing recycling practices

The results of a recent survey of professionals in the field of colorectal surgery indicate that there is a significant desire to modify existing surgical procedures in order to make them more environmentally friendly and to take part in instructional webinars that are oriented on sustainable practices (33). Surgical professionals have the ability to initiate or direct changes in the operating room, as well as organize or participate in interdisciplinary "green OR" teams within their respective institutions. Targeted interventions in the operating room that efficiently minimize carbon hotspots include reducing the amount of surgical waste, decreasing the amount of disposable equipment used, giving priority to items that can be reused, and optimizing waste segregation in order to maximize recycling and disposal methods. In addition, there are supplementary choices that include decreasing the amount of inhalation anesthetics that are used, as well as enhancing the efficiency of the operating room and the workflow throughout the

perioperative period. One method that has proven to be successful in enhancing the sustainability of surgical procedures is the 10R model of circular economy, which has been endorsed by the combined SSP SAGES and EAES commission. Maintaining a high level of patient care while simultaneously lowering expenses, reducing waste, and improving environmental efficiency are the goals of this initiative. Surgeons may choose to adopt more environmentally friendly ways of life and modes of transportation, as well as virtual alternatives to in-person meetings and conferences, which are known to generate a significant amount of waste and carbon emissions each year from both air and land travel (34). To a significant degree, the carbon footprint of the healthcare system can be significantly influenced by surgeons, surgical practices, leadership within the health system, and industry efforts that are focused at enhancing surgical sustainability.

Advancing sustainability in surgical practice: an imperative for action

The operating room is necessary for providing care to patients, but also has a considerable impact on the surrounding environment. Every single surgical procedure is responsible for the release of greenhouse gases and the depletion of resources. This includes the consumption of energy and the generation of waste. In order to fulfill their core responsibilities, healthcare companies must make environmental sustainability a top priority. It is imperative that medical experts, including surgeons, healthcare workers, anesthesiologists, administrators of health systems, organizations, and regulatory authorities, work together to enhance the dissemination of practices that are successful and based on evidence. It is important that surgical societies serve as the primary repository for information, education, and the dissemination of best practices that are supported by evidence. It does not matter what resources are available; the principles of environmental stewardship are applicable everywhere. The acceleration of advancement will be determined by the combination of transnational collaboration, the sharing of approaches that are exemplary, and the collection of information from various contexts. The operating room presents a number of challenges as well as opportunities. In our capacity as stewards of both health and the environment, we are obligated to bring about a paradigm shift in order to guarantee the long-term viability of both policies and the planet (21).

The National Health Service (NHS), which is the largest publicly financed healthcare system in the world and the primary employer in Europe, bears a significant duty to take the initiative in implementing emission-reduction strategies and to serve as a model for others to follow in terms of best practices. The National Health Service (NHS) is responsible for around 4% of England's overall carbon footprint, which highlights the necessity of taking additional efforts to mitigate its influence on climate change (35).

There is a considerable portion of the National Health Service's carbon footprint that is accounted for by the supply chain, which accounts for 59% of the organization's total CO2 emissions. Because of the high amount of resources that they use, operating theaters constitute a significant contributor to the carbon emissions that are produced in the healthcare industry (36). After conducting an exhaustive study, it was discovered that a single process can produce anywhere from 6 to 814 kilograms of carbon dioxide, which is equivalent to running a conventional gasoline-powered cars for more than 2,000 kilometers. The most significant contributions consist of the acquisition of consumables, the utilization of electricity, and the utilization of anesthetic gases (37).

An Intercollegiate Climate Emergency Declaration was released by the three Surgical Royal Colleges in the United Kingdom in November 2022. This declaration acknowledged that "climate change and anthropogenic environmental degradation pose a substantial threat to both human and planetary health." They demanded immediate action and offered their members assistance in

implementing changes within their operational theaters (38). They requested that immediate action be taken.

The healthcare industry is responsible for around one percent of the total trash generated in the United Kingdom. Operating theaters are responsible for more than fifty percent of the garbage generated by hospitals, highlighting the importance of implementing environmentally responsible waste management techniques (39, 40).

Products that are either disposable or designed for a single use and are used in surgical procedures are recognized as being substantial contributors to the emissions of carbon dioxide. In the most recent decades, there has been a significant increase in the utilization of disposable devices as a result of the growing complexity of surgical systems and procedures. However, there is a dearth of important data indicating the importance of quality and safety when it comes to the use of disposable items (41).

In spite of the fact that modifying the methods of disposal and the materials used in the production of surgical tools can present difficulties, the utilization of surgical instrument packaging that removes the dangers of biohazards and prohibits direct human contact presents a clear and potentially realistic strategy for reducing the amount of waste generated by surgical procedures. Only sixteen percent of the direct trash that was produced by the National Health Service in the fiscal year 2021–22 was recycled, five percent was disposed of in landfills, and the remainder garbage was either burned or treated to other treatment procedures (42). In 2021, the total proportion of waste packaging that was recycled in the United Kingdom was 63%; however, a separate analysis revealed that less than 1% of trash packaging for surgical equipment was assessed to be recyclable (43-46).

It is estimated that the healthcare industry is responsible for 4.4% of the global carbon footprint (47-51). This includes the generation of waste and the consumption of power, both of which contribute considerably to the emission of greenhouse gases. As a consequence of this, various health organizations have set goals to reduce the negative impact that healthcare services have on the environment. It is estimated that the National Health Service (NHS) in the United Kingdom is responsible for between 4 and 5.9% of the total national carbon emissions. As a consequence of this, the National Health Service (NHS) has set goals to attain carbon neutrality by the year 2045 (52-55).

In October of 2020, the National Health Service (NHS) England and the NHS Improvement board came together to ratify a new strategy to combat climate change. The primary focus of this strategy is to reduce emissions from transportation, supply chains, and pharmaceuticals while also putting an emphasis on energy savings. However, the report highlights the shift in employee behavior that has occurred as a result of the COVID-19 pandemic. This shift includes increased utilization of personal protective equipment and heating, ventilation, and air conditioning systems. The most significant reductions in emissions have thus far resulted from the greening of energy grids and the modifications made by suppliers. By highlighting the importance of targeted interventions at the local institutional and personnel levels in the years to come, this discovery highlights the significance of such interventions (57).

As a result of their energy-intensive operations and excessive reliance on materials that are only intended for a single use, operating theaters (OTs) constitute a substantial contributor to the greenhouse gas emissions that are produced by the healthcare industry. According to the findings of a review, a single operation can generate up to 814 kilograms of carbon dioxide equivalent (CO2e), which is equivalent to driving an average gasoline vehicle for 2,273 miles. There is a

certain amount of variability and restrictions in the data that supports the use of focused and localized therapy (58).

In order to establish which activities are relevant, it can be challenging to evaluate the environmental effects of interventions or Life Cycle Assessment (LCA) studies (59). When it comes to the examination of key outcomes, life cycle assessment (LCA) studies may have limitations. These limitations may include the consideration of long-term implications, cost-effectiveness, and the scalability of specific interventions within a healthcare authority. Policymakers are able to examine the social, environmental, and economic implications of an action through the use of the Triple Bottom Line (TBL) approach (60). It is possible that interventions that have both financial and environmental benefits should be prioritized over those that just provide one benefit. The Triple Bottom Line (TBL) paradigm does not rank or evaluate dimensions, which grants policymakers greater autonomy in developing solutions. This is in spite of the fact that there are specific challenges in the healthcare industry, such as the difficulties in evaluating the financial advantages in relation to health. The usefulness of retrospective TBL assessments for healthcare treatments is demonstrated by the National Health Service (NHS) England and other health authorities that support sustainability programs (61), as well as by empirical investigations conducted by Vergunst et al. (60).

A recent systematic review conducted by Almukhtar et al. (61) identified "knowledge" (for example, awareness of sustainable practices) and "environmental context and resources" (for example, personnel shortages, workload, and insufficient recycling facilities) as the primary obstacles that prevent the implementation of environmentally sustainable practices in operating theaters. This is consistent with the findings of the review, which suggested that "environmental constraints" and "staff education" are the intervention elements that are utilized in occupational therapy the most frequently. In order to build a sense of accountability and encourage behavioral transformation among healthcare professionals, targeted training activities are being implemented. These initiatives place an emphasis on the financial implications of particular equipment recommendations. Users are therefore prompted to analyze ecological costs as a result of education regarding the environmental consequences of consumables and equipment, which ultimately results in decisions that are more sustainable and a reduction in waste. Concurrently, environmental restructuring necessitates the implementation of observable changes in both the physical environment and the operational operations.

It is possible to achieve a synergistic effect by combining the concrete changes that are the result of environmental remodeling with the knowledge that is obtained through education. There has been a significant reduction in the amount of surgical waste in North America, Europe, and Asia as a result of the implementation of several initiatives, including waste segregation (62), recycling programs (63), and package simplification (64). By fostering a long-lasting sense of accountability and providing the essential infrastructure to maintain and uphold sustainable practices, this combined approach contributes to the reduction of waste in operational technologies (OTs). Nonetheless, behavioral therapies often necessitate ongoing assistance, reminders, and a conducive setting for sustained effectiveness. The effectiveness of these treatments may rely on the level of engagement and motivation of staff, rendering sustained behavior change a complex and multifaceted endeavor, as indicated by McCarthy et al. (65). It has been determined that the formation of a specialized sustainability committee is an essential catalyst for the promotion of behavioral change in the surgical field (66).

Challenging behaviors, especially those concerning perceived safety (such as the shift to reusable items and the reprocessing of single-use surgical devices), can be effectively executed and

sustained with the assistance of dedicated 'champions.' This method is capable of effectively communicating the safety, effectiveness, and dependability of environmentally responsible actions. Additionally, a committee consisting of multiple staff members can serve as a platform for collaborative dialogue, enabling the exchange of insights and iterative strategies to achieve lasting impact and behavioral change across varied stakeholders (67). Recycling initiatives, primarily implemented through environmental structuring measures such as labeling, colored bins, waste segregation, and the enhancement of existing programs, substantially reduced environmental impact by promoting material reuse and decreasing waste generation. McGain et al. (68) serves as a significant reference in the discussion of recycling solutions within hospital waste management. Comparative research across Australia, the UK/Europe, and the USA reveals that shifting from single-use to reusable anesthetic equipment in Australian hospitals will lead to an unforeseen 9% increase in emissions. In contrast, hospitals in the UK and the USA would experience significant reductions of 84% and 48%, respectively. This notable disparity underscores the critical impact of local industrial and infrastructural factors that determine the environmental effects of recycling activities. Furthermore, integrating the financial aspect into the decision-making process intensifies the intricacy of the matter. The research projected a 46% decrease in the yearly costs of an Australian hospital following the adoption of reusable anesthetic apparatus. A modest hospital in the UK with 10 elective theaters can achieve annual savings of £83,000 by switching to reusable personal protective equipment. This economic perspective confuses the discussion, suggesting that while recycling may yield environmental benefits in specific domains, financial factors may prevail. While interventions employing a singular intervention framework (IF) have demonstrated efficacy, they may lack the synergies produced by concurrently addressing multiple aspects within a holistic approach. This analysis demonstrates that intervention packages comprising multiple IFs have proven notably effective in reducing the environmental impact of surgery by addressing various challenges and incorporating diverse strategies. Numerous programs that combine education, environmental modification, and empowerment have led to substantial waste reduction, improved recycling, and heightened energy efficiency. These packages provide a thorough solution by acknowledging the diverse procedures and stakeholders involved in healthcare settings. The collaboration among several intervention frameworks, including education and environmental modification, has a cumulative effect that amplifies overall effectiveness. Moreover, intervention packages not only modify behavior but also foster a sustainable culture within healthcare, enhancing enduring environmental consciousness among professionals and matching organizational norms with environmentally sustainable practices. Currently, assessing the effects of treatments, even using a credible framework such as TBL, is difficult and may result in misinterpretation; highlighting the pressing need for a tool that can analyze and synthesize many outcomes and contextual factors. The importance of context-specific factors in the execution of interventions is paramount (68).

MacNeil et al. (69) underscore that, as demonstrated in LCA research, a universal solution is nonexistent. Factors such as energy sources, waste management systems, and local conditions significantly impact the environmental outcomes of actions. A 'reduction' strategy consistently emerges as a reliable and efficient approach for global healthcare sustainability and can serve as a foundational principle in the formulation of sustainability interventions.

The environmental impact of waste generated by healthcare facilities, particularly operating rooms, is considerable. This paper highlights the current state and challenges of implementing effective recycling programs in hospital settings. A substantial proportion of recyclable materials is present in OR waste; nevertheless, institutional barriers, such as regulatory challenges and

inadequate information on recycling methods, impede effective waste management solutions. Disparities in recycling practices endure across different geographic areas and institutional structures, despite clear environmental and economic incentives for recycling (66-69).

Importance of recycling in operating rooms

Implementing efficient recycling methods in operating rooms achieves two goals: fostering environmental accountability and ensuring economic viability. The healthcare sector's alignment with global sustainability objectives necessitates the optimization of waste management in operating rooms via recycling as a vital technique. This approach not only mitigates environmental damage but also uncovers potential for substantial cost savings. This evaluation highlights the critical need for forthcoming solutions that integrate extensive recycling initiatives in operating rooms. While not all research explicitly supports recycling legislation, the significant influence of healthcare operations on global waste production positions the sector as a potential leader in environmental preservation (70).

The growing reliance on disposable products is linked to the demand for sterility, despite inadequate evidence showing a reduced risk of surgical site infection with disposables over reusables. Single-use goods intensify non-biodegradable waste, underscoring the need to develop recycling solutions that balance patient safety with environmental responsibility. Such programs may be pivotal in altering organizational culture and practices to promote improved environmental stewardship (71).

Addressing obstacles to recycling in operating rooms.

The findings shed light on a number of significant obstacles that stand in the way of the implementation of recycling procedures in operating rooms. These obstacles include regulatory limits, inadequate knowledge and education, leadership obstacles, safety concerns, and logistical challenges. Because of the interconnected nature of these constraints, the implementation of recycling initiatives that are effective faces major challenges.

In order to overcome the limitations imposed by regulations, it is essential to advocate for innovations that will improve recycling technologies while concurrently ensuring safety. The establishment of a robust framework for institutions would be made possible by the creation and dissemination of standardized waste segregation techniques that are specifically adapted for operating rooms (72). Similar significance is attached to educational and training initiatives that aim to close knowledge gaps and shift cultural perspectives on the topic of sustainability. The establishment of benchmarks and targets for the percentage of materials that are recycled or disposed would provide health systems with defined objectives and make it possible to create competitive measures at both the local and national levels (73).

Reforms among healthcare practitioners can be implemented from the top down or from the bottom up, depending on the health system. The adoption of recycling programs among healthcare organizations can be driven by proactive leadership and the engagement of "green champions" inside those organizations. These changes are important for the adoption of recycling projects. In addition, optimizing surgeon preference cards can greatly cut down on waste and expenditures, improve operational efficiency, and reduce the impact that it has on the environment (74).

Novel solutions and strategic alliances

The processing of materials that were previously considered non-recyclable is being transformed as a result of recent breakthroughs in recycling technology, which means that new chances for efficient waste reduction are being available. The utilization of biodegradable materials, the optimization of garbage segregation stations, and the implementation of exact waste stream tracking are all examples of enhancements that can be implemented to improve these activities.

One of the most important strategies is to establish strategic alliances with manufacturers in order to lessen the amount of packaging and develop products that are environmentally sustainable. It is the goal of these collaborations to extend the lifespan of medical objects by including concerns regarding disposal and recyclability, which will ultimately lead to an advancement in operational sustainability standards (75).

It is possible for healthcare facilities to overcome the difficulties associated with recycling in operating rooms and to successfully integrate their waste management policies with broader environmental sustainability goals if they make use of these strategies. During this transformation, it is necessary to have a coordinated effort at all levels of the healthcare system. This effort should include frontline people, policymakers, and industry players.

Conclusions

It is imperative that the healthcare industry actively promote and put into practice sustainable practices in order to ensure a sustainable future. Among these are the promotion of the responsible utilization of resources, the investigation of alternatives to products that are disposable, and the advocacy for the implementation of environmentally friendly packaging solutions. Reducing the amount of packing and increasing the amount of materials that may be recycled are two excellent ways to keep surgical waste to a minimum. This audit illustrates the numerous sorts of garbage that are generated by a single, easy activity, as well as the huge quantity of waste that is generated by packing. Sadly, there was a lack of adequate labeling for the rubbish, despite the fact that a significant amount of the garbage could be easily recycled. In addition to removing redundant instructional booklets that are widely accessible online, manufacturers should also affix clear recyclability labels to packaging, switch to recyclable materials wherever it is practical to do so, and switch to recyclable materials. It is possible to increase the sustainability of surgical procedures and reduce the environmental impact that occurs during patient care by conducting a local waste audit and analysis.

References

1. Lattanzio S, Stefanizzi P, Dambrosio M, Cuscianna E, Riformato G, Migliore G, et al. Waste management and the perspective of a green hospital: a systematic narrative review. Int J Environ Res Public Health. 2022;19:15812. doi:10.3390/ijerph192315812
2. Wyssusek KH, Keys MT, van Zundert AAJ. Operating room greening initiatives: the old, the new, and the way forward: a narrative review. Waste Manag Res. 2018. doi:10.1177/0734242X18793937
3. Eckelman MJ, Sherman J. Environmental impacts of the U.S. health care system and effects on public health. PLoS One. 2016;11:e0157014. doi:10.1371/journal.pone.0157014
4. Eckelman MJ, Huang K, Lagasse R, Senay E, Dubrow R, Sherman JD. Health care pollution and public health damage in the United States: an update. Health Aff. 2020;39:2071–9. doi:10.1377/hlthaff.2020.01247
5. Lui JT, Rudmik L, Randall DR. Reducing the preoperative ecological footprint in otolaryngology. Otolaryngol Head Neck Surg. 2014;151:805–10. doi:10.1177/0194599814544449
6. Stall NM, Kagoma YK, Bondy JN, Naudie D. Surgical waste audit of 5 total knee arthroplasties. Can J Surg. 2013;56:97–102. doi:10.1503/cjs.015711
7. Kagoma Y, Stall N, Rubinstein E, Naudie D. People, planet and profits: the case for greening operating rooms. CMAJ. 2012;184:1905–11. doi:10.1503/cmaj.112139
8. Laustsen G. Reduce, recycle, reuse: guidelines for promoting perioperative waste management. AORN J. 2007;85:717–22. doi:10.1016/S0001-2092(07)60146-X

9. McGain F, White S, Mossenson S, Kayak E, Story D. A survey of anesthesiologists' views of operating room recycling. Anesth Analg. 2012;114:1049–54. doi:10.1213/ANE.0b013e31824d273d
10. McGain F, Jarosz KM, Nguyen MNHH, Bates S, O'Shea CJ. Auditing operating room recycling: a management case report. A A Case Rep. 2015;5:47–50. doi:10.1213/XAA.0000000000000097
11. Azouz S, Boyll P, Swanson M, Castel N, Maffi T, Rebecca AM. Managing barriers to recycling in the operating room. Am J Surg. 2019;217:634–8. doi:10.1016/j.amjsurg.2018.06.020
12. Fraifeld A, Rice AN, Stamper MJ, Muckler VC. Intraoperative waste segregation initiative among anesthesia personnel to contain disposal costs. Waste Manag. 2021;122:124–31. doi:10.1016/j.wasman.2021.01.006
13. Wu S, Cerceo E. Sustainability initiatives in the operating room. Jt Comm J Qual Patient Saf. 2021;47:663–72. doi:10.1016/j.jcjq.2021.06.010
14. Ali M, Wang W, Chaudhry N, Geng Y. Hospital waste management in developing countries: a mini review. Waste Manag Res. 2017;35:581–92. doi:10.1177/0734242X17691344
15. Martin DM, Yanez ND, Treggiari MM. An initiative to optimize waste streams in the operating room: RECycling in the operating room (RECOR) project. AANA J. 2017;85:108–12.
16. Stonemetz J, Pham JC, Necochea AJ, McGready J, Hody RE, Martinez EA. Reduction of regulated medical waste using lean sigma results in financial gains for hospital. Anesthesiol Clin. 2011;29:145–52. doi:10.1016/j.anclin.2010.11.007
17. Potera C. Strategies for greener hospital operating rooms. Environ Health Perspect. 2012;120:a306–7. doi:10.1289/ehp.120-a306a
18. Francis MC, Metoyer LA, Kaye AD. Exclusion of noninfectious medical waste from the contaminated waste stream. Infect Control Hosp Epidemiol. 1997;18:656–8. doi:10.1086/647693
19. Wyssusek KH, Foong WM, Steel C, Gillespie BM. The gold in garbage: implementing a waste segregation and recycling initiative. AORN J. 2016;103:316.e1–8. doi:10.1016/j.aorn.2016.01.014
20. Babu MA, Dalenberg AK, Goodsell G, Holloway AB, Belau MM, Link MJ. Greening the operating room: results of a scalable initiative to reduce waste and recover supply costs. Neurosurgery. 2019;85:432–7. doi:10.1093/neuros/nyy275
21. Moya E, Bryant SA, Horneck N, Taylor V, Alayleh A, Alawa J, et al. Advancing sustainability in healthcare: a scoping review of global recycling practices in operating rooms. Am J Surg. 2024;116178.
22. U.S. Department of Health and Human Services. Health sector commitments to emissions reduction and resilience. 2024 (cited 2024 Mar 17). Available from: https://www.hhs.gov/climate-change-health-equity-environmental-justice/climate-change-health-equity/actions/health-sector-pledge/index.html
23. Dzau VJ, Levine R, Barrett G, Witty A. Decarbonizing the U.S. health sector: a call to action. N Engl J Med. 2021;385(23):2117–9. doi:10.1056/NEJMp2115675
24. Pietrabissa A, Sylla P. Green surgery: time to make a choice. Surg Endosc. 2023;37(9):6609–10. doi:10.1007/s00464-023-10229-0
25. Elkington J. The triple bottom line. Environ Managem. 1997;2:49–66.
26. Thiel CL, Eckelman M, Guido R, et al. Environmental impacts of surgical procedures: life cycle assessment of hysterectomy in the United States. Environ Sci Technol. 2015;49(3):1779–86. doi:10.1021/es504719g

27. ESCP ECOS-Surgery Study Committee. The European Society of Coloproctology collecting opinions on sustainable surgery study. Dis Colon Rectum. 2022;65(11):1297–300. doi:10.1097/DCR.0000000000002541
28. Trang K, Fung B, Lamb T, Moloo H, Wick EC. Reducing carbon footprint in travel to the American Society of Colon and Rectal Surgeons annual meeting: striking a balance between environmental impact and collaborative opportunities. Dis Colon Rectum. 2024;67(2):197–9. doi:10.1097/DCR.0000000000003037
29. Pietrabissa A, Sylla P. Green surgery: time to make a choice. Surg Endosc. 2023;37(9):6609–10. doi:10.1007/s00464-023-10229-0
30. Sullivan GA, Reiter AJ, Hu A, et al. Operating room recycling: opportunities to reduce carbon emissions without increases in cost. J Pediatr Surg. 2023;58(11):2187–91. doi:10.1016/j.jpedsurg.2023.04.011
31. Wormer BA, Augenstein VA, Carpenter CL, et al. The green operating room: simple changes to reduce cost and our carbon footprint. Am Surg. 2013;79(7):666–71. doi:10.1177/000313481307900708
32. McGain F, Naylor C. Environmental sustainability in hospitals: a systematic review and research agenda. J Health Serv Res Policy. 2014;19(4):245–52. doi:10.1177/1355819614534836
33. ESCP ECOS-Surgery Study Committee. The European Society of Coloproctology collecting opinions on sustainable surgery study. Dis Colon Rectum. 2022;65(11):1297–300. doi:10.1097/DCR.0000000000002541
34. Trang K, Fung B, Lamb T, Moloo H, Wick EC. Reducing carbon footprint in travel to the American Society of Colon and Rectal Surgeons annual meeting: striking a balance between environmental impact and collaborative opportunities. Dis Colon Rectum. 2024;67(2):197–9. doi:10.1097/DCR.0000000000003037
35. NHS England, NHS Improvement. Delivering a 'Net Zero' National Health Service. London: NHS England and NHS Improvement; 2022 (cited 2023 May).
36. NHS England. Reducing the use of natural resources in health and social care. Cambridge, UK: Sustainable Development Unit; 2018 (cited 2023 May).
37. Rizan C, Steinbach I, Nicholson R, et al. The carbon footprint of surgical operations: a systematic review. Ann Surg. 2020;272:986–95. doi:10.1097/SLA.0000000000003226
38. The Royal College of Surgeons of England. Intercollegiate Climate Emergency Declaration. (cited 2024 Jun). Available from: https://www.rcseng.ac.uk/news-and-events/news/archive/intercollegiate-climate-emergency-declaration/
39. BRE Group. BRE UK Report – Waste in the NHS. (cited 2022 Oct). Available from: https://www.bre.co.uk/page.jsp?id=2699
40. Guetter CR, Williams BJ, Slama E, et al. Greening the operating room. Am J Surg. 2018;216:683–8. doi:10.1016/j.amjsurg.2018.07.041
41. Bhutta MF. Our over-reliance on single-use equipment in the operating theatre is misguided, irrational and harming our planet. Ann R Coll Surg Engl. 2021;103:709–12. doi:10.1308/rcsann.2021.0040
42. NHS Digital. Hospital Episode Statistics for England, 2021–22. (cited 2022 Oct). Available from: https://files.digital.nhs.uk/13/C09A72/hosp-epis-stat-admi-proc-2021-22-tab.xlsx
43. Rizan C, Bhutta MF, Reed M, Lillywhite R. The carbon footprint of waste streams in a UK hospital. J Clean Prod. 2021;286:125446.

44. NHS Digital. Estates Returns Information Collection, Summary Page and Dataset for ERIC 2021/22. (cited 2024 Jun). Available from: https://files.digital.nhs.uk/A0/8993B0/ERIC%20-%20202122%20-%20Report%20-%20v3.xlsx
45. UK Department for Environment, Food and Rural Affairs (Defra). UK Statistics on Waste Data – 2022. (cited 2024 Jun). Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1074147/UK_Statistics_on_Waste_dataset_May_2022_accessible.ods
46. Soares CTM, Ek M, Östmark E, Gällstedt M, Karlsson S. Recycling of multi-material multilayer plastic packaging: current trends and future scenarios. Resour Conserv Recycl. 2022;176:105905.
47. Campion N, Thiel CL, Woods NC, et al. Sustainable healthcare and environmental life-cycle impacts of disposable supplies: a focus on disposable custom packs. J Clean Prod. 2015;94:46–55.
48. Tan E, Lim D. Carbon footprint of dermatologic surgery. Austral J Dermatol. 2021;62:e170–7.
49. Salas RN, Maibach E, Pencheon D, et al. A pathway to net zero emissions for healthcare. BMJ. 2020;371:m3785.
50. Rizan C, Steinbach I, Nicholson R, et al. The carbon footprint of surgical operations: a systematic review. Ann Surg. 2020;272:986–95.
51. Esmaeili A, McGuire C, Overcash M, et al. Environmental impact reduction as a new dimension for quality measurement of healthcare services: the case of magnetic resonance imaging. Int J Health Care Qual Assur. 2018;31:910–22.
52. Lenzen M, Malik A, Li M, et al. The environmental footprint of health care: a global assessment. Lancet Planet Health. 2020;4:e271–9.
53. England N. Carbon emissions: carbon foot printing study. Sustainable Development Commission; 2008.
54. HM Government. Net zero strategy: build back greener. Controller of Her Majesty's Stationery Office. 2023 (cited 2025 Jan 9). Available from: https://assets.publishing.service.gov.uk/media/6194dfa4d3bf7f0555071b1b/net-zero-strategy-beis.pdf
55. Plötz P, Wachsmuth J, Gnann T, et al. Net-zero-carbon transport in Europe until 2050—targets, technologies and policies for a long-term EU strategy. Fraunhofer Institute for Systems and Innovation Research ISI; 2021 (cited 2025 Jan 9). Available from: https://www.isi.fraunhofer.de/en.html
56. Wilkinson E. NHS in England on track to hit first-year carbon reduction target. BMJ. 2021;375:n2466.
57. Perry H, Reeves N, Ansell J, et al. Innovations towards achieving environmentally sustainable operating theatres: a systematic review. Surgeon. 2023;21:141–51.
58. Guetter CR, Williams BJ, Slama E, et al. Greening the operating room. Am J Surg. 2018;216:683–8.
59. Drew J, Christie SD, Tyedmers P, et al. Operating in a climate crisis: a state-of-the-science review of life cycle assessment within surgical and anesthetic care. Environ Health Perspect. 2021;129:076001.
60. Vergunst F, Berry HL, Rugkåsa J, et al. Applying the triple bottom line of sustainability to healthcare research—a feasibility study. Int J Qual Health Care. 2020;32:48–53.

61. Almukhtar A, Batcup C, Bowman M, et al. Barriers and facilitators to sustainable operating theatres: a systematic review using the Theoretical Domains Framework. Int J Surg. 2024;110:554–68.
62. French H. Blueprint for reducing, reusing, recycling. AORN J. 1994;60:94–8.
63. Hubbard RM, Hayanga JA, Quinlan JJ, et al. Optimizing anesthesia-related waste disposal in the operating room: a brief report. Anesth Analg. 2017;125:1289–91.
64. Lin J, Pai JY, Chen CC. Applied patent RFID systems for building reacting HEPA air ventilation system in hospital operation rooms. J Med Syst. 2012;36:3399–405.
65. McCarthy CJ, Gerstenmaier JF, O'Neill AC, et al. "EcoRadiology"—pulling the plug on wasted energy in the radiology department. Acad Radiol. 2014;21:1563–6.
66. Burrell R. Primum non nocere: greening anaesthesia. Anaesth Intensive Care. 2018;46:630–1.
67. Wormer BA, Augenstein VA, Carpenter CL, et al. The green operating room: simple changes to reduce cost and our carbon footprint. Am Surg. 2013;79:666–71.
68. McGain F, Story D, Lim T, et al. Financial and environmental costs of reusable and single-use anaesthetic equipment. Br J Anaesth. 2017;118:862–9.
69. MacNeill AJ, Lillywhite R, Brown CJ. The impact of surgery on global climate: a carbon footprinting study of operating theatres in three health systems. Lancet Planet Health. 2017;1:e381–8.
70. Azouz S, Boyll P, Swanson M, et al. Managing barriers to recycling in the operating room. Am J Surg. 2019;217:634–8.
71. Moya E, Bryant SA, Horneck N, et al. Advancing sustainability in healthcare: a scoping review of global recycling practices in operating rooms. Am J Surg. 2024;116178.
72. Amariglio A, et al. Waste management in an Italian hospital's operating theatres: an observational study. Am J Infect Control. 2021.
73. Wyssusek K, et al. The volume of recyclable polyethylene terephthalate plastic in operating rooms—a one-month prospective audit. Am J Surg. 2020.
74. Braschi C, et al. The impact of waste reduction in general surgery operating rooms. Am J Surg. 2025.