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Green Endoscopy and Sustainable Practices: A Scoping Review

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Abstract

Objectives The emergence of "green endoscopy" arises from the increasing global need to reform environmental sustainability due to climate change. Our review aimed to provide current evidence surrounding green endoscopy on sustainable issues including environmental impact, innovations, guidelines, policies, future directions, and recommendations.

Materials and Methods A scoping review was conducted following the Preferred Reporting Items for Systematic Review and Meta-Analysis extension for scoping reviews guidelines. Full-text English articles from established databases were screened for eligibility criteria and analyzed.

Results Out of 7,892 identified articles, 28 met all the eligibility criteria. Key findings include (1) the significant environmental impact of single-use items in current endoscopic practices; (2) there are emerging green innovations in endoscopy, such as reusable instruments, eco-friendly sterilization methods, and energy-efficient technologies; (3) guidelines and green policies are increasingly available to provide clinical guidance and framework for health care facilities; (4) model institutions can provide case studies and examples of implementing green endoscopy; and (5) unified efforts from all stakeholders are needed to address challenges, including cost-effectiveness.

Conclusion A paradigm shift toward green endoscopy is clearly in place and should be driven by the need to reduce environmental impact, be cost-effective, and not sacrifice patient safety.

Keywords
- green endoscopy
- sustainable practices
- environmental impact
- gastroenterology

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Introduction

Climate change poses a significant global challenge, influencing the environment, human health, and societal structures. The health care sector, a considerable contributor to environmental degradation, is responsible for substantial emissions of greenhouse gases and generates extensive medical waste. As the urgency to address climate change intensifies, the medical community is exploring sustainable practices across all specialties, including gastroenterology, where endoscopy is a fundamental diagnostic and therapeutic tool.[1]

Endoscopy involves using specialized equipment to visualize the gastrointestinal tract for diagnostic and therapeutic purposes. Traditional endoscopic practices, however, are resource-intensive, involving significant use of disposable instruments and materials, energy consumption, and chemical use for sterilization processes.[2] The concept of "green endoscopy" has emerged as a response to the need for more sustainable medical practices. This approach seeks to minimize the environmental impact of endoscopic procedures by optimizing resource use, reducing waste, and implementing more sustainable technologies.[3]

Endoscopy is a natural result of the development of advanced surgical techniques. It allows for the minimally invasive diagnosis and treatment of surgical diseases and the surveillance of gastrointestinal and respiratory disorders.[1,4] Upper endoscopy or esophagogastroduodenoscopy, colonoscopy, and bronchoscopy are now regular medical diagnostic tools, helping doctors in diagnosis and disease management for a wide range of medical problems.[2] However, it is evident that the increasing utilization of endoscopy may pose significant environmental waste.[5]

In response to environmental hazards, health institutions and various stakeholders have investigated alternative ways to greener endoscopy, including green policies.[3] Implementing green endoscopy policies is crucial for not just addressing environmental concerns but also economic concerns.[4] Establishing quality assurance procedures, sustainable strategies for endoscopy services, and standardized rules that health care facilities must adhere to are all part of green endoscopy policies.[5,6]

Through this review, we aimed to provide evidence on green endoscopy, especially in the context of climate change/environmental impact, innovations, policies and guidelines, and future directions and recommendations. The objectives of our review are summarized in ►**Table 1**.

Materials and Methods

Research Design

The study design was a scoping review of articles published on green endoscopy in the context of sustainable medical practices utilizing the Preferred Reporting Items for Systematic Review and Meta-Analysis extension for scoping reviews (PRISMA-ScR) 2018 guidelines. After screening the literature, all authors filtered the papers that met the preidentified eligibility criteria.

Eligibility Criteria

Eligible articles included noninterventional and interventional studies based on the following criteria: (1) "The article must consider green endoscopy practices or innovations"; (2) "study involved all settings regardless of the type of health care facility or geographical location"; (3) "the study reported at least one outcome related to the environmental impact, resource use, or cost implications of green endoscopy"; and (4) "the study was published in English and related to human health care." In addition, if the studies were not categorized in the health care sector, unrelated to endoscopy, or published before 2013, they were excluded. Any studies categorized as conference abstracts, posters, oral communications, or textbooks were excluded during the screening phase. Furthermore, studies from secondary research (i.e.,

Table 1 Specific objectives of the study on green endoscopy practices

Objectives	Description
Assessing environmental footprint	The first target is to reflect on the magnitude of the environmental influence of routine endoscopy, encompassing factors like water and energy utilization and measuring waste quantities at endoscopic procedures.[7,14] The aim is to provide a detailed examination of the lifecycle of endoscopic equipment and supplies for a holistic understanding of environmental implications[15]
Evaluating alternative approaches	The second objective explores alternative approaches to endoscopic procedures and the latest generation of endoscopic technology.[2] This includes promoting reusable equipment and accessories over disposable ones, aiming to define quality practices and identify potential issues while transitioning to eco-friendly endoscopy methods[6,23]
Analyzing economic implications	This objective involves a cost–benefit analysis to identify the financial feasibility of green endoscopy in accepting institutions.[16] It focuses on estimating initial investment costs, operational costs, and potential savings from using sustainable practices[26]
Examining regulatory guidelines	The fourth objective reviews regulations and practices promoted by health institutions and synthesizes information from peer-reviewed scientific literature, governmental documents, and professional organization recommendations.[7,12] It aims to produce science-based suggestions for green endoscopy programs, focusing on regulatory compliance and policy changes to facilitate sustainable health care practices[5,6]

literature reviews, comments, letters, and editorials), irrelevant articles, and duplicates were also excluded.

Search Strategy and Selection Process

The literature search was conducted across five databases: PubMed, Science Direct, Scopus, ProQuest, and Web of Science. A search strategy was designed to identify articles published from 2013 to the present. The keywords and Booleans used in the literature search were ("green endoscopy" OR "sustainable endoscopy" OR "environmental impact of endoscopy") AND ("gastroenterology" OR "medical practice" OR "healthcare"). To limit the occurrence of undesirable articles, these keywords and Medical Subject Headings terms were searched in the "Title/Abstract" category. Having collected the studies from the database, the authors exported them into Excel software (Microsoft Corp, United States) for duplication removal and screening. The two independent review authors (T.H.K. and V.T.) first screened the titles and abstracts of articles before scrutinizing the full texts. Any disagreements between the two review authors were resolved by discussion with a senior reviewer (Y.Y.L.) until a consensus was reached. Excluded studies were described in the PRISMA flow diagram alongside the reasons why they were excluded (►**Fig. 1**).

Data Extraction and Collection

Two authors (T.H.K. and V.T.) extracted relevant data using structured and standardized forms. The extracted data included (1) study characteristics (author, year of publication, country of origin, and study design), (2) intervention characteristics (types

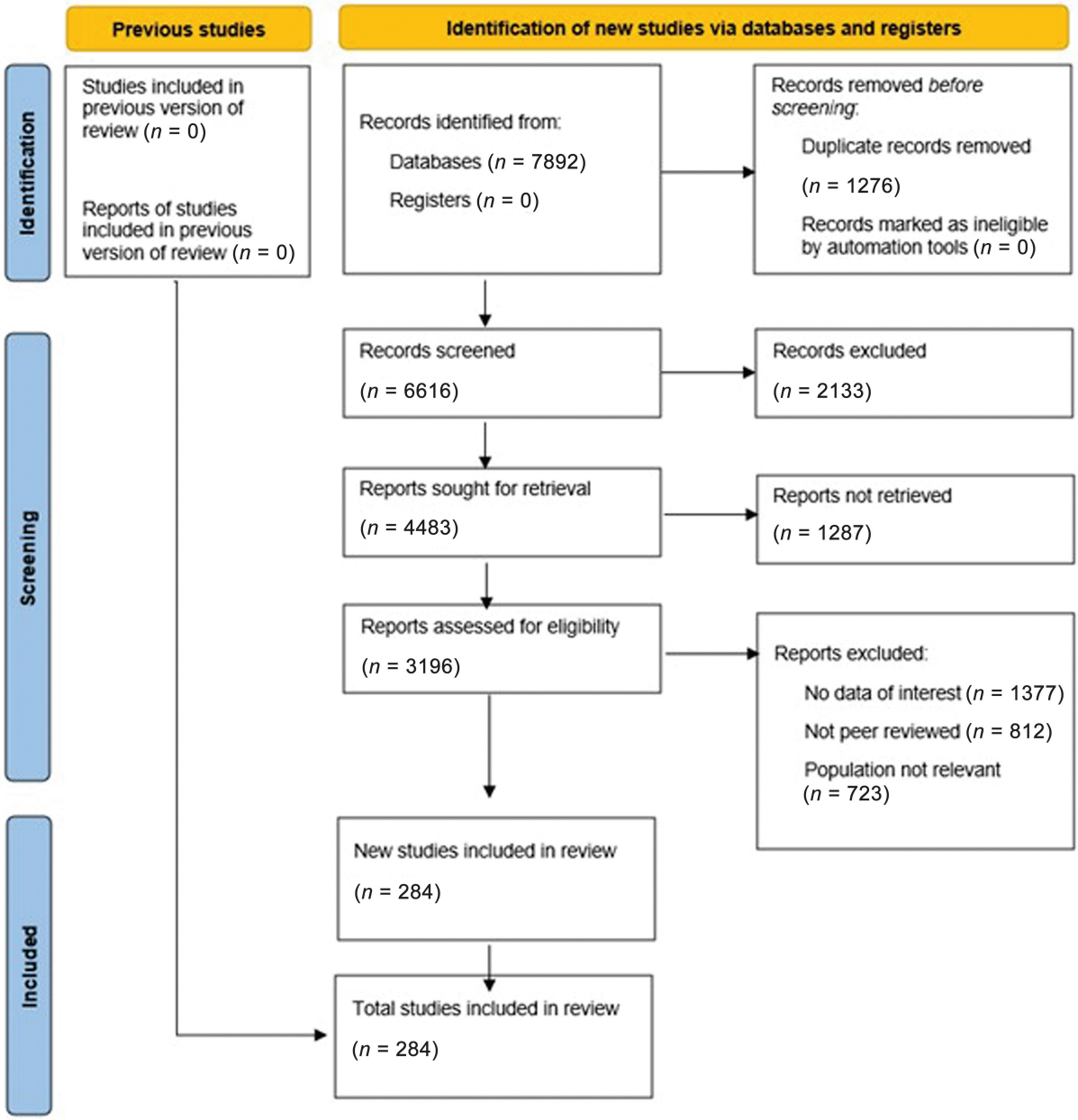

Fig. 1 Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) flow diagram of study methodology.

of green endoscopy practices or technologies used), and (3) outcome data (environmental impact, resource use, cost implications, and patient outcomes).

Results

Study Selection

The keyword "green endoscopy" yielded 8,452 results, the combination of "green endoscopy" and "sustainable practices" produced 1,769 results, the combination of "green endoscopy," "environmental impact," and "gastroenterology" generated 587 results, and the combination of "green endoscopy" and "cost implications" resulted in 324 hits. A total of 7,892 papers were identified, and 1,276 duplicate titles were excluded. A further 2,133 articles were eliminated; eventually, 4,483 articles met all eligibility criteria. Of these, 1,287 articles were excluded due to lack of full-text articles, and 3,196 full articles were reviewed. Upon review, articles with no data of interest ($n = 1,377$), not peer-reviewed ($n = 812$), and population not relevant ($n = 723$) were excluded, and 284 articles were included at this point. After reviewing the selected articles, only 28 were deemed relevant and included in the final writings. The PRISMA flow diagram is shown in ►**Fig. 1**.

Environmental Impact of Traditional Endoscopic Practices

The modern approach to traditional endoscopy practices relies heavily on single-use instruments and devices primarily made of plastics and other nonbiodegradable materials.[7,8] The environmental impact of endoscopy involves all stages of the procedure.[3] It begins with the manufacturing and shipping of disposable units and later the disposal of plastic waste.[9] The production, use, and disposal of these materials contribute significantly to the carbon footprint of medical procedures.[6] According to Namburar et al,[10] single-use endoscopes are responsible for up to 25% of waste generated in gastroenterology departments.

Accessories like biopsy forceps, suction catheters, and irrigation syringes are indispensable components of endoscopic procedures but are usually one-time-use items.[4] Throw-away items provide convenience and patient safety; however, their disposal aggravates environmental wastes and depletion of resources, especially if they are not able to be recycled.[6,9] Plastic wastes pose a potential danger for terrestrial and aquatic ecosystems but also pose safety concerns for human health. Our research group has published that microplastics are ubiquitous in the human colon, and studies are ongoing on the impact of these microplastics on disease, especially cancer.[11]

Research also reported excessive consumption of resources, such as energy and water, during endoscope reprocessing.[7] Furthermore, chemical disinfectants necessary for patient safety pose additional environmental hazards during reprocessing, with effluents often containing harmful bioaccumulative toxins and bacteria detrimental to aquatic and terrestrial ecosystems. Studies have shown the significant environmental impact of these chemical processes; for example, Homyer and Mehendale[12] and Miley et al[13] have conducted state-of-the-art analyses of water and energy consumption throughout the lifecycle of an endoscope.

In addition, Ribeiro et al[14] have reported a consistent and significant rise in the overall plastic imprint of endoscopic interventions. Addressing the above requires efforts to research viable alternatives to sustainable endoscopic practices without compromising clinical safety and efficacy.

Innovations in Green Endoscopy

A multinational commentary led by Leddin et al[15] has suggested methods for reducing nonrecyclable wastes, including the readoption of reusable instruments and eco-friendly sterilization methods. Additionally, initiatives like those detailed on the Healthcare Plastics Recycling Council's (HPRC) Web site have demonstrated successful recycling case studies in health care settings.[3,9]

More importantly, recent advancements in endoscopic technology by the industry have included efforts to reduce the environmental burden of these procedures. Recent technological advancements have centered around developing reusable endoscopic instruments that, when properly maintained and sterilized, significantly mitigate waste and reduce operational costs without increasing the risk of infection, as was shown by Kumar.[16] Researching durable materials that may be reused to minimize junk production is ongoing and such materials also help reduce expensive replacement costs. Studies also demonstrated that reusing reusable endoscopic devices was achievable and feasible, providing another reason to embrace them.[17,18]

In the context of evaluating the cost-effectiveness of green endoscopy, it is crucial to consider the economic implications of using reusable equipment and accessories versus disposable equipment. Studies indicate that while the initial investment in reusable endoscopic instruments and eco-friendly sterilization technologies may be higher, long-term savings are significant.[7] Reusable instruments reduce the need for the continuous procurement of single-use items, thereby lowering operational costs over time.[16] Furthermore, reusable equipment, when properly maintained and sterilized, has been shown to mitigate waste and reduce the carbon footprint associated with endoscopic procedures, aligning with sustainable health care goals.[10] Conversely, single-use items, despite their convenience and perceived safety, contribute extensively to medical waste and environmental pollution.[14] Therefore, the shift toward reusable alternatives not only supports environmental sustainability but also proves economically advantageous, fostering both ecological and fiscal responsibility in health care practices.[6]

Moreover, the recent introduction of energy-efficient systems featuring light-emitting diode lighting and digital imaging and the global adoption of water-based cleaning agents in place of traditional solvents further exemplify the progress made in innovative green approaches. Researchers have observed that hospitals adopting these water-based solutions could reduce hazardous waste production by 40%.[15]

Table 2 Summary of guidelines and best practices for implementing sustainable green endoscopy

Aspect	Guideline description	Recommended actions
Instrument reuse	Encourages the use of reusable endoscopic instruments[19]	Implement rigorous cleaning and sterilization protocols[7,10]
Waste reduction	Focuses on reducing medical waste from endoscopy procedures[1,26]	Segregate waste and increase recycling efforts[3,15]
Energy consumption	Promotes the use of energy-efficient endoscopic equipment[2,13]	Upgrade to LED lighting and energy-efficient devices[4,23]
Chemical use	Advises on reducing harmful chemical use in sterilization[6,27]	Transition to water-based or eco-friendly cleaning agents[3]

Abbreviation: LED, light-emitting diode.

There is a parallel effort in exploring alternative approaches to endoscopy that prioritize sustainability without compromising patient care. For example, Cunha and Pellino[6] have highlighted innovative research into the resource consumption involved in reprocessing endoscopic devices, emphasizing the potential of disposable endoscopic devices and recycling durable materials. Such initiatives underscore the possibility of reducing environmental impacts through thoughtful redesign and materials sciences, ensuring safety and operational efficiency.

The economic implications of integrating innovative sustainable practices in endoscopy are increasingly recognized. Ilias et al[7] argued that through cost–benefit analysis, durable and reusable materials have been proven feasible and economically advantageous for health care facilities. In addition, studies have shown the economic benefits of anesthetic green practices during endoscopy.[8,19,20] For example, adopting low-flow anesthesia systems during procedures could reduce the consumption of anesthetic gases and subsequently environmental impact of anesthetic gases that are known to have high global warming potential.[21,22]

The shift toward sustainability provides substantial long-term savings by reducing procurement costs, minimizing waste, and decreasing reliance on disposable instruments.

Guidelines and Best Practices for Sustainable Endoscopy

The integration of sustainable practices in endoscopy into clinical practice has been hampered partly by the absence of standardized guidelines. According to Leddin et al,[15] there is a pressing need for a unified global approach to enhance sustainability in gastroenterology, including creating and adhering to guidelines that promote reusable and recyclable materials in endoscopic procedures.

Nonetheless, recent initiatives by professional organizations are addressing this gap. For example, in 2022, the European Society for Gastrointestinal Endoscopy published comprehensive guidelines that championed reusable instruments, advocated for proper waste segregation, and promoted environmentally friendly cleaning agents.[23] Besides clinical practice, guidelines help provide a framework for health care facilities to meet stringent environmental regulations. The guidelines also stressed training and education for medical staff on sustainable practices and underlining the roles of human resources in implementing successful green initiatives.

There are various generic recommendations and frameworks across multiple reports and official documents, which cover essential aspects such as regulatory compliance, policies for sustainable growth, quality assurance, and strategic factors, and these documents may be relevant for endoscopy services. ►**Table 2** provides a summary of these recommendations and frameworks.

Case Studies and Real-World Implementations

Several hospitals and health care systems have begun implementing green endoscopy initiatives with promising results. For instance, the Green Endoscopy Initiative at Boston Medical Center, implemented in 2020, focused on reducing the use of disposable instruments, optimizing the recycling of noncontaminated waste, and using more energy-efficient endoscopic equipment.[24] The initiative reported a 30% reduction in wastes generated by endoscopic procedures within the first year of implementation.[24] Other successful case studies include institutions like the Ohio State University Wexner Medical Center, as mentioned on the HPRC Web site, which has demonstrated successful efforts to achieve significant waste diversion through innovative recycling programs.[25] Another example is the St. Mark's Hospital in London, where a comprehensive program to reduce energy consumption in endoscopy units was established.[26] This program included the installation of solar panels and energy-efficient endoscopic equipment, which resulted in a 25% reduction in energy usage. These real-world examples provide a template for other medical centers to model their green initiatives. Furthermore, these cases illustrate and provide examples of the challenges and successes of implementing sustainable practices in a clinical setting.

Challenges and Future Directions

►**Table 3** shows the significance of green endoscopy practices. While substantial progress in sustainability practices has been made in recent years, challenges such as the high costs associated with transitioning to greener technologies and the operational challenges of maintaining stringent sterilization protocols remain. Cost–benefit analyses have shown that green projects provided enormous fiscal benefits in terms of reduced purchasing expenses, disposal of garbage,

Table 3 Significances of green endoscopy practices

Significances	Description
Environmental impact reduction	Green endoscopy practices contribute directly to reducing health care's environmental footprint.[7,14] By switching to sustainable methods, health care institutions can significantly lower carbon emissions, minimize waste production, and conserve scarce natural resources.[5] This also supports broader strategies for climate change mitigation, biodiversity conservation, and ecosystem resilience[23]
Public health and well-being	Green endoscopy improves public health by reducing exposure to hazardous chemicals and pollutants inherent in traditional endoscopy practices.[22] This leads to enhanced safety and health for patients, staff, and the community, reducing cross-contamination and health care-associated infections, thereby improving health care and patient safety[4,26]
Cost savings and operational efficiency	Sustainable endoscopic practices lead to substantial cost savings and enhanced operational efficiency.[2,8] By investing in reusable tools and equipment, health care facilities can reduce expenses related to procurement, maintain low disposable costs, and maximize the use of resources.[10] This approach streamlines workflows, boosts productivity, mitigates operational risks, and improves the financial bottom line[28]
Corporate social responsibility and ethical imperatives	Adopting green endoscopy practices embodies the principles of corporate social responsibility (CSR) and ethical standards within the health care sector.[12] This enhances the institution's brand and trust among stakeholders, promoting a culture of efficiency, accountability, and transparency.[27] Embracing green initiatives aligns with health care providers' professional duty to preserve the environment and promote social equity through ecologically sound practices[5]
Leadership and innovation in health care	Green endoscopy positions medical institutions as leaders and innovators in the health sustainability landscape.[15] By introducing innovative endoscopic techniques and leveraging advanced technology, health care providers can lead cultural shifts toward sustainable practices.[19] This fosters the dissemination of efficient approaches, shared knowledge, and successful experiences, spreading innovation and fostering collective efforts toward a greener future[26]

and fewer consumables.[27] Furthermore, sustainable infrastructure and practices can lead to cost-efficiency in the long run for health care institutions.

Further research is essential for developing more cost-effective and environmentally friendly endoscopic accessories. Continued advocacy and policymaking are crucial in promoting sustainable health care technologies and practices, as emphasized by the global call for action in the gastroenterology community outlined by Leddin et al.[15] Also, as Ali et al[28] noted, the path forward will require a concerted effort from manufacturers, health care providers, and regulatory bodies to foster an environment where sustainable practices are the norm rather than the exception.

Current Recommendations for Sustainable Endoscopy Practices

To address the environmental impact of traditional endoscopic procedures, several key recommendations and action steps have been identified to promote sustainability. These include implementing reusable endoscopic instruments, reducing medical waste, adopting energy-efficient technologies, and minimizing harmful chemical usage. Effective resource management, enhanced recycling efforts, the development of clear sustainability policies, comprehensive staff training, and the integration of new eco-friendly technologies are also crucial. Conducting cost–benefit analyses to evaluate the financial feasibility of these initiatives further supports the long-term economic and environmental benefits of green endoscopy. ►**Table 4** provides a detailed summary of these current recommendations and action steps.

Conclusion

The convergence of evidence presented throughout this review underscores the necessity for a paradigm shift toward green endoscopy, which should be driven by the need to reduce environmental impact and cost-effectiveness without sacrificing patient safety. Emerging innovative solutions include reusable instruments, energy-efficient technologies, and eco-friendly sterilization methods. Initiatives like those undertaken by Boston Medical Center and St. Mark's Hospital exemplify clinical benefits and feasibility, providing blueprints for other institutions. Despite these promising developments, there are challenges, such as the high initial costs of greener technologies and the operational complexities of maintaining stringent sterilization protocols for reusable instruments. More availability of clinical guidelines on sustainable practices would help execution and compliance in complex health care settings. In addition, a broader dialog and collaboration among health care practitioners, policymakers, and professional organizations are crucial. The path to ecologically sustainable endoscopy practices requires unified efforts across the complex broader health care system with the ultimate goal of sustainability benefitting both individuals and the planet.

Table 4 Current recommendations for sustainable endoscopy practices

Aspect	Recommendation	Action steps
Instrument reuse	Implement reusable endoscopic instruments	- Develop rigorous cleaning and sterilization protocols - Invest in high-quality reusable tools
Waste reduction	Reduce medical waste	- Segregate waste for proper recycling - Utilize reusable accessories over disposable ones
Energy consumption	Adopt energy-efficient technologies	- Upgrade to LED lighting and energy-efficient endoscopic devices - Implement energy-saving protocols in endoscopic suites
Chemical use	Minimize harmful chemical usage	- Transition to eco-friendly, water-based cleaning agents - Regularly audit chemical usage and waste
Resource management	Optimize resource utilization	- Implement water conservation techniques during endoscope reprocessing - Monitor and manage energy and water usage effectively
Recycling initiatives	Enhance recycling efforts	- Set up comprehensive recycling programs for noncontaminated materials - Educate staff on proper recycling practices
Policy and guidelines	Develop and adhere to green endoscopy policies	- Establish clear sustainability guidelines for endoscopy practices - Ensure compliance with environmental regulations
Staff training	Educate and train health care professionals	- Conduct regular training on sustainable practices - Promote awareness about environmental impacts and green endoscopy methods
Innovation adoption	Integrate new eco-friendly technologies	- Explore and adopt advanced sustainable endoscopic technologies - Encourage research and development in green endoscopy
Financial strategies	Conduct cost–benefit analyses	- Evaluate the financial feasibility of green endoscopy initiatives - Promote long-term cost savings through sustainable practices

Abbreviation: LED, light-emitting diode.

Details of Earlier Presentation
None.

Authors' Contributions
Conceptualization, T.H.K. and Y.Y.L.; methodology, T.H.K. and V.T.; validation, T.H.K., Y.Y.L., and V.T.; formal analysis, T.H.K.; investigation, T.H.K., N.S.R., and Y.S.I.; resources, T.H.K., N.S.R., and Y.S.I.; data curation, T.H.K. and V.T.; writing—original draft preparation, T.H.K.; writing—review and editing, T.H.K., Y.Y.L., V.T., N.S.R., and Y.S.I.; visualization, T.H.K.; supervision, Y.Y.L.; project administration, T.H.K.. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest
None declared.

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