

Moving Toward a More Sustainable Diagnostic and Interventional Radiology Department

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Abstract

Radiology significantly impacts the environment, contributing to the healthcare sector's approximately 5% of global greenhouse gas emissions. This is largely due to high electricity consumption from advanced imaging technology and increasing demand for services. A single interventional procedure, for example, can generate 77-243 kg of CO₂ equivalent (CO₂e) emissions and around 8 kg of waste. Environmental burdens include excess energy usage, substantial medical product waste from single-use materials, hazardous substances, and wastewater pollution from contrast agents. A significant problem is the improper mixing of hazardous and nonhazardous waste, which not only exacerbates pollution but also dramatically increases disposal costs, as hazardous waste is ten times more expensive to manage. Studies show that up to 85% of operating theater waste may be incorrectly disposed of as biohazardous. Sustainability in radiology focuses on: 1). Materials optimization: Prioritizing reusable devices, seeking eco-friendly alternatives, implementing recycling programs, and converting to multi-dose contrast vials with weight-based dosing. 2). Waste segregation: Establishing clear protocols to ensure accurate classification of waste, disposing of only visibly blood-saturated items as hazardous, thereby reducing costs and environmental impact. 3). Energy efficiency: Employing as-low-as-reasonably-achievable (ALARA) principles, improving climate control management, powering off unused equipment (which can reduce energy use by up to 70% in standby mode), and collaborating with manufacturers for energy-efficient systems, including those with micro-cooling technology for MRI scanners. 4). Responsible care planning: Reassessing the appropriateness of imaging studies to avoid unnecessary scans, which annually contributed an estimated 3,550-129,200 metric tons of avoidable CO₂e emissions from 2017 to 2021 in the US Medicare Part B population. While artificial intelligence offers potential, its significant data and energy requirements for training models present a "double-edged sword." Radiology departments hold crucial potential to lead sustainable healthcare transitions by optimizing protocols, adopting low-dose technologies, and redesigning waste management in collaboration with industry.

Keywords: sustainability, radiology, waste

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There is no question that advances in radiology have led to remarkable improvements in diagnosis and treatment across a wide range of conditions and diseases. Yet, while these successes and contributions to health care should be celebrated, the impact of medical imaging

on the environment should also be considered and addressed.

Pollution greatly impacts population health by contributing to the development of cardiovascular and respiratory diseases^{1,2} and a host of other conditions related to the impacts of climate change.

Health care has a significant impact on climate change: worldwide, the health care sector is responsible for roughly 5% of total greenhouse gas emissions, which include carbon dioxide, methane, and ozone, among others; the percentage can vary with nation.^{3,4} Diagnostic and interventional radiology are among the highest contributors to health care greenhouse emissions, owing to high electricity consumption by the technology, coupled with increasing demand for services.⁵ For example, the estimated mean CO₂ equivalent (CO₂e) emissions for a single interventional procedure can be between 77 and 243 kg².

Artificial intelligence (AI) is gaining attention for its potential to improve sustainability in radiology in multiple ways, including accelerating imaging and optimizing scanners to improve patient workflows. However, tremendous data and storage requirements for AI and the energy to train models present another challenge as a double-edged sword.⁶

The Hidden Waste

All surgical suites share a common challenge with respect to reducing waste. A typical interventional radiology department places a significant burden on the environment in terms of excess energy usage, waste generation, and water pollution. There is tremendous energy utilization by imaging equipment, medical product waste created by single-use materials and hazardous substances, and wastewater pollution, particularly from iodinated and gadolinium-based contrast agents voided by patients. Researchers estimate that one neurointerventional procedure alone generates approximately 8 kg of waste.⁷⁻⁹

Different Wastes, Different Discard Ways

The improper mixing of hazardous and nonhazardous waste not only exacerbates environmental pollution but also leads to significantly increased disposal costs. When nonhazardous materials are mistakenly discarded as biohazardous waste, the cost of disposal escalates owing to the stringent handling and treatment processes required for hazardous waste. This misclassification not only places an undue financial burden on health care facilities but also underscores the need for better waste segregation protocols and staff training. By improving these practices, radiology departments can reduce their environmental footprint, lower operational costs, and contribute to a more sustainable health care system.

Waste Reduction Strategies

In recent years, the concept of sustainability and its potential to mitigate the impact of pollution and climate change have become more widely recognized in mainstream culture and business practices in the Western world.^{10,11} Waste reduction strategies are a common focus of sustainability initiatives. Increased awareness among frontline health care professionals and departmental, institutional, industry, and government leaders, as well as taking concrete steps to address these issues, can help to substantially reduce medical waste.¹⁰⁻¹² Beyond hospitals, politicians must be educated to help elevate their awareness of the importance and potential impact of proper waste management.

Materials Optimization

All diagnostic and interventional radiology clinicians can have a direct impact on waste reduction by carefully evaluating the materials they use. Prioritizing reusable devices over

disposables and seeking eco-friendly alternatives, for example, can minimize waste without compromising patient safety. Along these lines, comprehensive recycling programs can significantly reduce waste.¹³ Regarding contrast, several vendors offer consulting services to help radiology teams convert from single-dose to multi-dose contrast vials and to help implement weight-based contrast dosing.¹⁴

Waste Segregation

Disposing of hazardous waste costs ten times more than nonhazardous waste,¹⁵ and yet studies have shown that up to 85% of waste in operating theaters is incorrectly disposed of as biohazardous waste, leading to increased disposal costs and environmental impacts.^{7,8} Hazardous waste, including blood-soaked materials, requires specific handling owing to its biohazard risk. Such waste should be disposed of in designated clinical waste bins (typically yellow bags or containers) immediately after use to prevent contamination. Importantly, only items visibly saturated with blood require such treatment; lightly stained materials can often be discarded as nonhazardous waste, depending on local guidelines. Implementing clear waste segregation protocols and educating staff can significantly improve safety and sustainability, ensuring that only truly infectious waste enters the hazardous waste stream.

Energy Efficiency

Climate control systems represent the largest source of carbon emissions from hospitals. Energy expenditure can be reduced by employing as-low-as-reasonably-achievable (ALARA) principles with respect to radiation exposure. In addition, maintaining a consistent temperature in the operating room and managing in-room climate settings can help to reduce electricity consumption.^{2,10}

Energy consumption can also be reduced by powering off unused workstations and monitors, turning off lights in rooms not being used, and implementing energy-efficient equipment. In a recent paper, researchers analyzed the energy consumption and carbon footprint of interventional imaging systems in radiology, cardiology, and urology. They found that systems consume significant energy even in standby mode and that turning them off when not in use could cut energy use by up to 70%.^{2,16,17} Medical device manufacturers also play a crucial role in enhancing sustainability. Several radiology departments are working with vendors to help create more energy-efficient systems.¹⁸ MRI and CT scanners are available with standby modes to reduce energy consumption; some allow customization of scan duration for energy efficiency. Moreover, many newer MRI scanners employ efficient micro-cooling technology that reduces the amount of liquid helium required to cool their magnets.

Responsible Care Planning

Sustainability, optimizing energy use, and managing waste can also be aided through a critical reassessment of imaging appropriateness. A recent study published in the *Journal of the American College of Radiology* revealed that between 4% and 26% of imaging studies performed in the US Medicare Part B population between 2017 and 2021 were potentially inappropriate.¹⁹ These unnecessary exams contributed an estimated 3,550-129,200 metric tons of avoidable CO₂-equivalent emissions annually, primarily from CT and MRI. Such data underscore a dual responsibility of radiologists, to ensure diagnostic accuracy while actively reducing environmental harm. Limiting low-value or unnecessary imaging can make a measurable contribution to climate change mitigation—aligning

clinical excellence with planetary health. Although unnecessary procedures are fewer in interventional radiology than in some other specialties, restricting procedures only to those that are truly essential not only reduces patient radiation exposure but also lowers energy consumption and costs.^{19,20}

Conclusion

Sustainability is no longer just an ethical choice; it's a necessary component of mitigating the environmental consequences of our actions. In its diagnostic and interventional dimensions, radiology holds a unique and strategic position in this landscape. With their heavy reliance on advanced technologies, energy-intensive equipment, and single-use materials, radiology departments are among the highest contributors to hospital-related emissions and waste production. Yet, this also means that they hold untapped potential to lead the transition toward more sustainable health care. From optimizing imaging protocols to adopting low-dose technologies and rethinking waste management practices in interventional suites, every radiology department can make a difference. Interventional radiology, in particular, must actively engage in redesigning workflows and re-evaluating materials (also in cooperation with industry) to reduce environmental harm without compromising clinical efficacy.

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