Advancing Sustainability in Healthcare: Recycling and Reuse of Single-Use Metal Instruments at UVA Health

(Technical Paper)

Balancing Safety and Sustainability: Ethical Implications of Reducing Medical Waste in Healthcare

(STS Paper)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

The healthcare industry in the United States is among the largest contributors to waste and greenhouse gas emissions, producing over 6 million tons of waste annually and accounting for 8.5% of total U.S. emissions. Operating rooms alone generate approximately 30% of a hospital's solid waste, including single-use instruments made of high-quality metals such as stainless steel and titanium. Despite their value, these instruments are typically incinerated or landfilled due to the lack of recycling protocols, contributing to harmful emissions like dioxins and squandering resources that could be reclaimed and reused (Lee et al., 2023; Rizan et al., 2020).

Single-use instruments were adopted widely in the 1980s and 1990s as a response to heightened concerns about cross-contamination and infection risks. Advances in manufacturing made single-use tools affordable, and hospitals prioritized sterility and convenience over environmental considerations (Repertoire Magazine). However, recent innovations in sterilization technologies and recycling infrastructure challenge the necessity of these practices. For example, modern autoclaves achieve higher levels of sterilization efficiency, enabling safe reuse of instruments with proper protocols (Chowdhury et al., 2022). Similarly, recycling processes for stainless steel and other metals have become more efficient and economically viable.

This prospectus explores a two-fold approach to addressing the waste burden of single-use metal instruments: (1) implementing a recycling protocol for single-use tools, and (2) transitioning to reusable instruments where feasible. The project focuses on piloting these changes at UVA Health, aiming to develop scalable frameworks that reduce waste, improve cost efficiency, and align hospital operations with broader sustainability goals.

Technical Topic: Reducing Waste Through Instrument Recycling and Reuse

The environmental toll of single-use medical instruments is significant. Stainless steel, the primary material in most surgical tools, is energy-intensive to produce, requiring large amounts of mined ore and energy for processing. Once discarded, these instruments often end up in landfills, where they contribute to long-term environmental degradation. Studies have shown that approximately 85% of surgical instruments are unnecessarily discarded after a single use, even though they could be safely recycled or reused with proper sterilization protocols (Williams et al., 2021).

The first objective of this project is to implement a recycling protocol for single-use metal instruments. Hospitals such as Kaiser Permanente have piloted recycling programs for specific medical products, demonstrating reductions in both waste volume and costs (Rizan et al., 2020). However, recycling single-use instruments poses unique challenges, including contamination risks, logistical hurdles, and lack of infrastructure for handling sterilized medical waste. To address these barriers, a map of the lifecycle of single-use instruments at UVA Health has been created, identifying points where recycling can be seamlessly integrated. Partnerships with local metal recycling facilities, such as Gerdau Metals Recycling, will also be made to create a streamlined collection and processing system. Furthermore, educational programs for hospital

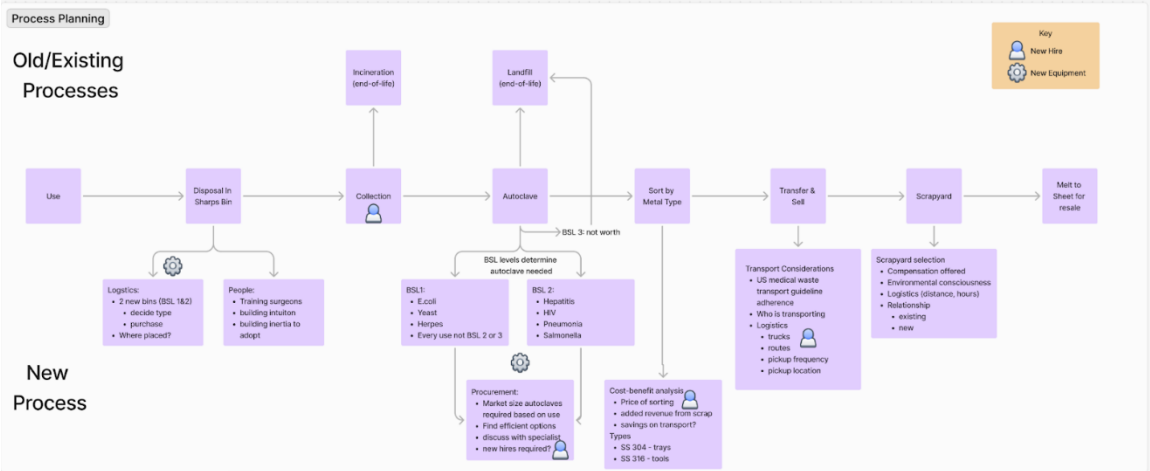

Figure 1. Single-Use Metal Instrument Process Map. Created by the Author.

staff will be developed to ensure proper segregation of recyclable instruments and minimize contamination risks (Jameton & Pierce, 2001).

The second objective is to transition to reusable instruments in select departments, such as the Emergency Department (ED), where high turnover of patients generates substantial instrument waste. Reusable instruments are sterilized through autoclaving, a process that uses pressurized steam to eliminate pathogens. Advances in autoclaving technology now allow for more energy-efficient and reliable sterilization, addressing previous concerns about operational feasibility (Johnson & Lu, 2020).

To facilitate this transition, the project will evaluate the cost-benefit analysis on the benefits of switching to reusable metal instruments performed by a previous capstone team. (McComb et al., 2024) Sterilization tests will check the performance of autoclaves at UVA Health to ensure compliance with infection control standards. The additional workload for hospital staff will also be assessed, and automation strategies to streamline sterilization processes will be developed and proposed (Zhang et al., 2019).

A pilot program will be conducted in the ED to implement the recycling program for single-use tools. Sharps bins to collect used single-use metals will be placed in operating rooms. The bins will then be collected and the metal autoclaved. The metal will then be sorted and sold to a scrapyard. This pilot program will reveal any issues with the program that need fixing. Metrics such as waste reduction, cost savings, and staff satisfaction using surveys will be tracked to evaluate the program's success and scalability.

STS Topic: Ethical and Societal Implications of Healthcare Waste

The shift toward more sustainable practices raises critical ethical questions about balancing patient safety, environmental stewardship, and operational feasibility. From a patient safety perspective, single-use instruments provide peace of mind by eliminating cross-contamination risks. However, this assurance comes at a high environmental cost, disproportionately affecting vulnerable populations. For instance, the production and disposal of single-use instruments

contribute to air and water pollution, which disproportionately impacts low-income communities and countries where medical waste is often exported (Smith et al., 2023).

Through an STS lens, this project examines the ethical tensions between three key stakeholders: healthcare providers, patients, and society at large. Healthcare providers must navigate conflicting priorities—minimizing costs, ensuring patient safety, and reducing environmental impact. Patients, on the other hand, often remain unaware of the environmental consequences of single-use practices, focusing primarily on their immediate health outcomes. Finally, society bears the long-term costs of healthcare waste in the form of climate change, resource depletion, and public health risks.

To analyze these dynamics, the project employs the framework of environmental justice, which emphasizes the equitable distribution of environmental benefits and burdens (Jameton & Pierce, 2001). The case study at UVA Health will compare two scenarios. The first scenario is the current practice of relying exclusively on single-use instruments, including its financial and environmental costs. The second is an intervention scenario that incorporates recycling protocols and reusable instruments, evaluating its feasibility and broader implications. By applying this framework, the project aims to highlight the societal implications of medical waste reduction and propose equitable strategies for implementation.

Research Questions and Methods

The central research question for this project is: *How can hospitals reduce the environmental and financial impact of single-use metal instruments while maintaining safety and operational efficiency?*

To answer this question, the project will employ a mixed-methods approach. First, a comprehensive review of existing studies on medical waste management, sterilization technologies, and recycling protocols will be conducted. Key sources include studies on the environmental impacts of single-use instruments (Lee et al., 2023; Williams et al., 2021) and the efficacy of autoclaving technologies (Chowdhury et al., 2022). Data on the lifecycle of single-use instruments at UVA Health, including procurement, usage, and disposal will be collected and documented through interviews. Waste and cost data will also be collected to quantify the environmental and financial impact of current practices. Interviews and surveys with key stakeholders, including hospital staff, autoclave specialists, and recycling vendors will be held. These discussions will identify barriers to adoption and inform the design of the pilot program.

The project will also launch a pilot recycling program in the Emergency Department at UVA Health, installing dedicated bins for single-use instruments and coordinating their sterilization and transport to a recycling facility. Waste reduction and cost savings during the pilot will be monitored and documented (Jameton & Pierce, 2001). Lastly, the project aims to develop a sustainability dashboard using Discrete Event Simulation (DES) to compare the financial and environmental impacts of different scenarios. The dashboard will incorporate data from the pilot program, historical procurement trends, and previous studies (Zhang et al., 2019).

Conclusion

This project addresses a critical gap in hospital waste management by proposing a dual approach to reduce the environmental footprint of single-use metal instruments. By implementing recycling protocols and transitioning to reusable alternatives, UVA Health can serve as a model for other institutions seeking to balance sustainability with operational efficiency. Beyond waste reduction, the project aims to foster a cultural shift within the healthcare industry, emphasizing the role of hospitals as stewards of both public health and environmental responsibility.

Through its technical innovations and ethical analysis, this project demonstrates the feasibility and necessity of integrating sustainability into healthcare operations, providing a scalable framework for hospitals nationwide.

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