Greening Healthcare: An Approach to Assess the Environmental Impact of Medical Procedures

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Abstract: There is an increasing awareness of how human activities, such as waste generation, resource consumption, and greenhouse gas emissions, affect the environment. Among these activities, healthcare facilities stand out as significant consumers of resources and generators of waste, leading to growing attention. However, transitioning to more sustainable practices necessitates a detailed comprehension of the factors influencing resource consumption and waste generation to facilitate the creation of effective, enduring solutions. The medical care process can be complex and multifaceted. Starting from an initial diagnosis, a patient may go through various phases, such as surgical interventions and recovery periods, each involving specific consumption and impacts. This study proposes a model for schematizing the care process that highlights the interconnections between the various phases of care. This model serves not only to visualise the real journey of the patient but also to investigate the impact of procedures, assessing both environmental effects and effects on patient well-being. In this context, the patient is not just a passive recipient of care but plays an active role in the healing process. Adopting a holistic approach thus allows for the integration of considerations on resource consumption with the effectiveness of treatments and patient outcomes, creating a comprehensive view that embraces both environmental and social sustainability. Exploring these themes underscores the urgency of healthcare policies that holistically promote sustainability, addressing environmental challenges without neglecting the human and clinical aspects of the healthcare system. Through the promotion of sustainable practices, it is possible not only to reduce the environmental impact of healthcare facilities but also to improve the quality and efficacy of the care provided. Healthcare providers can establish a healing environment that promotes the well-being of both the planet and individuals by incorporating sustainability into their daily operations.

Keywords: Healthcare Sustainability; Care Process Mapping; Environmental Impact; Patient Well-Being.

1. Introduction

The healthcare sector is an essential component of the general public's well-being. Nonetheless, it is at the core of a convoluted paradox: maintaining health comes at a significant environmental cost. Hospitals are held accountable for their substantial ecological footprint, second only to the hotel industry in terms of energy and resource consumption (Karliner et al., 2019). They are in a unique position because of their continuous and vital operations: they must be ready to protect people's health at all times, but they also urgently need to reevaluate their methods in light of sustainability. One of the biggest optimisation challenges the sector faces is the choice to maintain medical devices in a state of stand-by, which results in significant energy expenditure (Benmamoun et al., 2023). This choice is made to achieve maximum operational efficiency. The inevitable and unquestionable need to adhere to hygienic standards also results in significant use of chemicals and disposable materials (Campion et al., 2015; Snigdha et al., 2023). Although necessary for infection control, these become special/hazardous waste, accounting for most of the sector's waste production. This phenomenon is especially noticeable in operating rooms, which account for roughly 20% to 30% of all hospital waste (MacNeill et al., 2017). Research on how medical care affects the environment primarily concentrates on pinpointing the areas or systems that use the greatest amounts of energy and materials to identify hotspots and offer suggestions for improvement (Keller et al., 2021). In particular, the patient is thought of as a passive beneficiary of care when evaluating the ecological effects of medical procedures. Sustainability is primarily evaluated from an environmental standpoint, which is also intimately related to the healthcare facility's finances: cutting back on resource consumption will almost certainly have a positive financial effect. Indeed, multiple studies demonstrate that the adoption of environmental sustainability strategies not only has positive effects on the environment but also leads to cost reduction (McAleese et al., 2023; Thiel et al., 2019). However, it is restrictive and reductive to conduct sustainability analyses in the healthcare industry, whose main goal is to protect people's health, without considering how medical procedures affect

patients' quality of life. Evaluating optimisation strategies on factors that impact both human well-being and the environment is made possible by taking a holistic approach to the care process. This study suggests using an innovative model to assess medical procedures, incorporating them into the patient's care process, and trying to represent the pathway to recovery in a clear, sequential manner. With the help of this method, it is possible to comprehend that each interaction with the patient, from the initial diagnostic appointments until their complete recovery, represents not just a time for medical intervention but also a crucial stage in a longer process of transformation. Every medical procedure affects the patient's health and well-being in addition to the environment. Careful examination of the various stages of the care process can show how sustainable practices can be successfully incorporated, helping to significantly reduce the ecological footprint without compromising the standard of care. The existing literature on this subject is extremely limited, and to the best of our knowledge, no current study adopts the comprehensive approach that is critically needed in the health sector. This study aims to address this significant gap by proposing a perspective that encompasses both an analysis focused on maximizing patient well-being and an analysis dedicated to minimizing environmental impacts. Adopting a holistic approach is essential because the goals of innovation in the medical field often neglect other vital factors, such as the reduction of resource consumption and the mitigation of harmful emissions. By integrating these considerations, our approach ensures that advancements in medical procedures not only enhance patient outcomes but also promote environmental sustainability. The article begins by outlining a standardized care process, divided into several distinct phases, each emphasizing crucial medical activities. It then explores the significant social and environmental impacts of these medical procedures, stressing the importance of incorporating patient quality of life into assessments of environmental sustainability.

2. Methodology

The methodology is divided into two stages. First, an analysis of the existing literature was conducted to establish a foundation for scientific advancement. This phase highlighted that multiple studies investigate the issue of environmental sustainability in the healthcare industry, with a specific focus on resource consumption. These studies highlight the operating theatre as the area with the highest level of wasteful resource consumption (MacNeill et al., 2017).

Furthermore, in many cases is crucial to determine which technique is the most sustainable due to the possibility of accomplishing the same operation using different techniques that require different surgical time and a different number of resources, such as endoscopic surgery or robot-assisted surgery (Campion et al., 2012; Thiel et al., 2018; Zhang et al., 2023). It is important to note that carrying out a surgical procedure entails a set of pre- and post-operative activities that vary depending on the specific type of operation and impact the utilisation of resources. Also, the type of anaesthesia given to the patient has a significant impact on the overall environmental impact of a surgical procedure. Recent research indicates that the choice of anaesthetic gas has a significant impact on total GHG emissions into the atmosphere: desflurane, which is still widely used in medicine, is 20 times more pollutant than sevoflurane and isoflurane (Sherman et al., 2012). To accurately compare various surgical procedures, it is

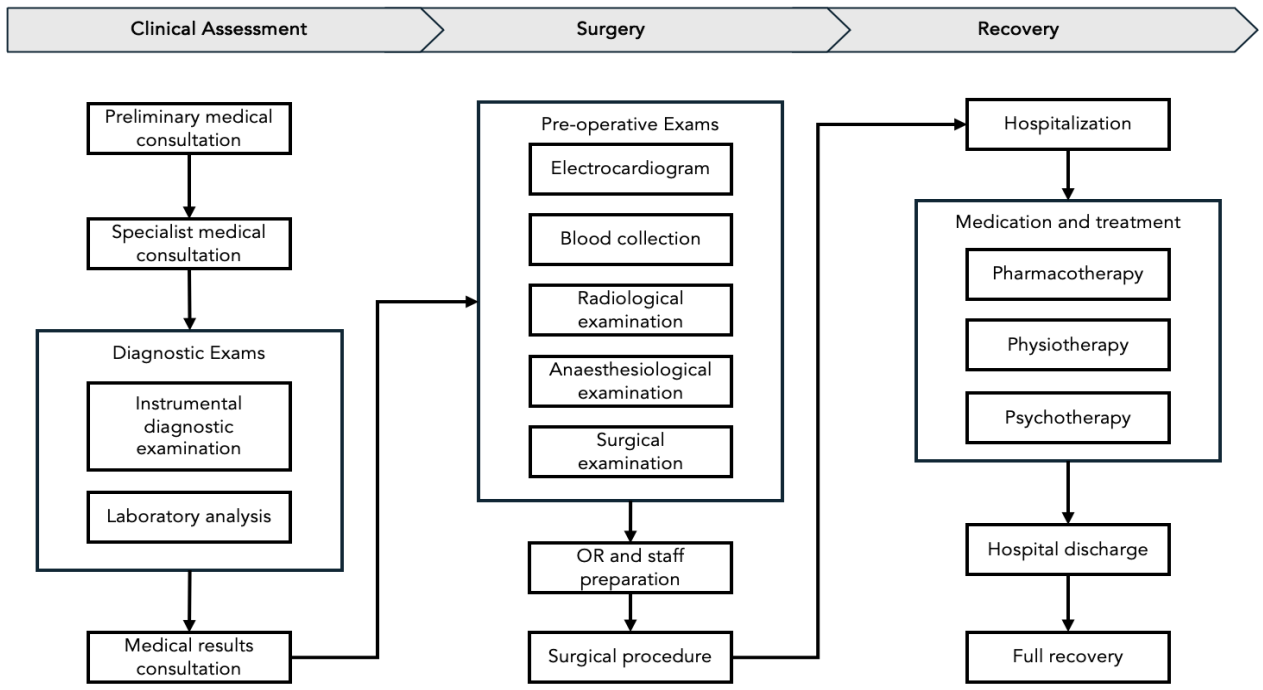

Figure 1: Generic Care Process Map

essential to employ a methodology that considers the complete care process faced by the patient.

Secondly, the study proposes a method for identifying the activities that comprise the care process for a patient undergoing surgery, with an emphasis on the sequential identification of the stages involved in achieving well-being. Three fundamental temporal phases were identified: clinical assessment, surgery, and recovery. Each of them is associated with several activities. By extending the research boundaries to all activities before and after surgery, it is possible to evaluate, in parallel with the environmental analysis, a series of factors affecting the patient's state of well-being, considering both the approach to surgery and the rehabilitation process. In this way, it is possible to place not only the environmental but also the social impact at the centre of the debate. Both impacts are part of the concept of sustainability, which complements the primary aim of healthcare: to improve people's health, effectively and efficiently.

3. Care Process Mapping

The different phases of the care process were subdivided and summarised using a logical map of activities, as shown in Figure 1.

The diagram illustrates the activities sequentially, simplifying the patient's journey to recovery to the greatest extent possible. The mapping should function as a reference for identifying the specific pathway experienced by the patient.

3.1 Clinical Assessment

During this phase, the hospital carries out activities aimed at providing the patient with an accurate diagnosis. This involves determining the location and nature of the health problem by assessing symptoms and the patient's physical condition. The primary activities include:

- Medical consultations: involve patients going to a healthcare facility to consult medical specialists to determine the cause of their symptoms or to undergo routine checkups.
- Diagnostic examinations: following the medical instructions, the patient may need to undergo a range of diagnostic instrumental examinations (such as radiology, nuclear medicine, echography, electrocardiogram, etc.) and laboratory tests to confirm the patient's condition and identify the location of the illness.

3.2 Surgery

Surgery activities are categorised into two separate stages:

- Pre-operative exams: further diagnostic examinations are conducted to assess the patient's eligibility for the surgery. After confirming the patient's condition, the medical team arranges the operating room, and the hospital staff gets ready for the surgical procedure.
- Surgical procedure: it includes the precise duration of the surgery, starting from the moment the patient enters the operating room until the patient's departure. The instruments, equipment, supplies, duration, and operators vary significantly based on the specific surgery being conducted.

3.3 Recovery

During this phase, the activities are focused on returning the patient to a condition of optimal physical and mental health. The patient who has received surgical intervention will subsequently experience a period of hospitalisation of varying duration and will be required to undergo specific treatments, including physical, pharmacological, and psychotherapeutic interventions. After being released from the hospital, he will go through a period to reach a full recovery either at home or in specialised clinics.

4. Discussion

The purpose of schematizing the patient care process flow is to expand the application of analysing the environmental impact associated with medical procedures. Every stage of the care process involves the proper utilisation of resources, leading to the release of pollutants and the generation of waste. These processes can be associated with related greenhouse gas emissions, which can be categorised according to the activity carried out. According to the Greenhouse Gas Protocol (GHGP), the three categories into which to classify emissions according to their origin are: Scope 1 for "Direct GHG emissions"; Scope 2 for "Electricity indirect GHG emissions"; and Scope 3 for "Other indirect GHG emissions" (Ranganathan et al, 2004). This subdivision helps to understand the nature of the environmental impact of hospital activities, and which of them form part of the patient care pathway. In particular, the processes with the greatest environmental impact associated with hospital activities all fall under Scope 2 (Health Care Without Harm, 2019). Dividing the care process into time phases (clinical assessment, surgery, and recovery) helps identify the interconnected and essential activities involved in a patient's rehabilitation.

Clinical assessment includes diagnostic activities, of which diagnostic imaging covers a large part of the health care activities that a patient receives in his or her medical care. The energy consumption of imaging equipment has a significant impact on the environmental footprint of healthcare facilities. Equipment such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI), and Positron Emission Tomography (PET) account for approximately 10% of a hospital's energy consumption. (Picano et al, 2022). In addition, diagnostic imaging activities also result in the use of a considerable amount of consumable material, which increases the amount of waste produced by the hospital (McAlister et al, 2022). A careful analysis of this essential phase in the patient care process therefore appears necessary, considering all the phases that, within a structured model, prove to be interconnected with the other phases of the patient care pathway.

The surgical procedure is considered the focal point of the treatment process, as the literature examining the

environmental consequences of these procedures raises inquiries about what should be the beginning and conclusion points for assessments. Various disparities exist in the studies that conduct these types of assessments, in which research boundaries depend on distinct objectives and the feasibility of data collection. The article presents an innovative perspective in which the patient's care can be seen as a transformative procedure that not only aids healing but also actively engages the patient. Undoubtedly, he is not simply a passive recipient of treatment, but an active participant in his process of care. By adopting this analytical perspective, it is possible not only to improve current practices but also to innovate responsibly in the medical field, considering the environmental impact and the overall well-being of the patient. Within the assessment of environmental impact in medical practices, it is crucial to also extend the investigation to factors that influence the overall physical and mental condition of the patient. This approach aligns with the concept of social sustainability, which recognises the patient not only as a beneficiary of medical care, but also as an integral part of a broader system that includes his or her quality of life. Consider endoscopic surgery as an example: minimally invasive surgery, by definition, provides multiple benefits compared to conventional surgical methods.

Furthermore, the utilisation of advanced imaging systems not only enhances the accuracy of the procedure but also minimises blood loss during the operation. The advantages of endoscopic surgery primarily manifest on the patient's side, as it entails smaller incisions that minimise tissue trauma and the likelihood of infection. Consequently, there is a reduced requirement for pain-relieving medications and the resulting scars are less noticeable. Patients typically undergo a more rapid recovery, enabling faster restoration of daily activities and a reduced duration of hospitalisation, resulting in decreased financial and resource costs for the hospital. Nevertheless, when examining consumption during operation, the utilisation of endoscopic techniques leads to a more significant ecological footprint compared to conventional techniques (Campion et al., 2012; Zhang et al., 2023). The primary reason for this is the employment of sophisticated instruments and machinery, as well as the requirement for additional time to execute the procedure.

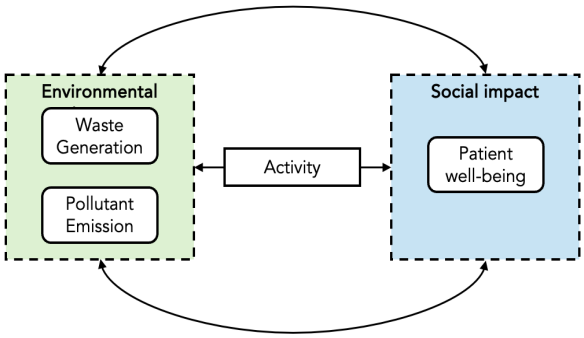

Figure 2: Environmental and Social Impact of Medical Activity

Therefore, simply evaluating the environmental consequences of a specific surgical procedure will not result in comprehensive conclusions that help determine the most efficient technique to use. To ensure proper consideration, it is crucial to give equal importance to the effect of each activity on both the environment and the well-being of the patient (Fig.2).

Key determinants that can influence the patient's overall well-being during the care process include:

- Length of hospital stay: prolonged periods of hospitalisation can negatively affect the patient's mental health and increase the risk of infection.
- Total recovery time: the length of recovery affects the patient's daily life and ability to return to normal activities. A faster and more effective recovery has a positive impact on the patient's perception of the quality of care received.
- Pharmacological treatments: the side effects of drugs can impair the patient's quality of life. The choice of treatments with fewer adverse effects or the use of innovative therapies can significantly improve the patient's well-being.
- Effectiveness of treatment: effective treatment not only cures the disease but also improves the patient's mood and boosts his or her confidence.

In addition to these, other factors such as emotional support during treatment, the accessibility and quality of information provided to the patient, and the patient's involvement in treatment decisions play a key role in his or her recovery and overall well-being. It is essential that, when analysing the sustainability of treatment processes, not only the environmental effects but also the impacts on the patient's well-being are disclosed. This means transparently reporting the results of treatment effectiveness, side effects, recovery times, and any other factors that may affect the patient's quality of life. This not only assists patients in making well-informed decisions but also motivates healthcare institutions to consistently enhance care protocols to achieve a balance between treatment effectiveness and reducing inconvenience to the patient's life. Incorporating these measurements into the concept of social sustainability within the healthcare sector not only enriches the understanding of the overall impact of medical care but also promotes a holistic approach that evaluates treatment success not only in terms of medical outcomes but also in terms of improved quality of life and patient well-being.

5. Conclusions

The proposed innovative method of analysis that emerges from this study emphasises the need to evaluate each phase of the patient care pathway under the lens of sustainability. Such a model proposes to examine the interactions and mutual influence between the various phases, intending to identify points of inefficiency and outline opportunities for improvement. This method would not only facilitate the identification of strategies to minimise environmental impact but also provide the tools to assess the operational

efficiency of healthcare facilities and the overall well-being of the patient. It is essential to promote medical practice that is oriented towards sustainability, not only in ecological terms but also in human/social terms, recognising that the health of the patient and that of the environment are intrinsically linked.

6. Study Limitations

The model proposed in the study provides a streamlined visualization of the essential steps in a patient's recovery pathway. However, it is important to note that not every factor influencing the patient during the care process is examined by this model. In practice, each activity within the care cycle may repeat multiple times until the desired medical outcome is achieved. The generic care process can be optimized by analyzing the probability of each activity occurring, allowing for a revision and improvement of the process's logical map. This cyclical nature of medical interventions reflects the complexities and iterative adjustments often required in personalized care plans. Moreover, while the study emphasizes the importance of integrating each assessment with social considerations, particularly concerning the patient's well-being, it stops short of delving into the various methods available for assessing environmental impacts in healthcare settings. A comprehensive approach would benefit from including a broader range of environmental assessment techniques, such as Life Cycle Assessment (LCA), which can systematically and carefully examine multiple impacts associated with all stages of a product's life from cradle to grave.

References

Benmamoun, Z., Fethallah, W., Bouazza, S., Abdo, A. A., Serrou, D., & Benchekroun, H. (2023). A framework for sustainability evaluation and improvement of radiology service. *Journal of Cleaner Production*, *401*.

Campion, N., Thiel, C. L., DeBlois, J., Woods, N. C., Landis, A. E., & Bilec, M. M. (2012). Life cycle assessment perspectives on delivering an infant in the US. *Science of the Total Environment*, *425*, 191–198.

Campion, N., Thiel, C. L., Woods, N. C., Swanzy, L., Landis, A. E., & Bilec, M. M. (2015). Sustainable healthcare and environmental life-cycle impacts of disposable supplies: A focus on disposable custom packs. *Journal of Cleaner Production*, *94*, 46–55.

Health Care Without Harm (2019) Health care's climate footprint - How the Health Sector Contributes to the Global Climate Crisis and Opportunities for Action

Karliner, J., Slotterback, S., Boyd, R., Ashby, B., & Steele, K. (2019). *Healthcare's climate footprint: How the health sector contributes to the global climate crisis and opportunities for action*.

Keller, R. L., Muir, K., Roth, F., Jattke, M., & Stucki, M. (2021). From bandages to buildings: Identifying the environmental hotspots of hospitals. *Journal of Cleaner Production*, *319*.

McAleese, T., Jagiella-Lodise, O., Roopnarinesingh, R., Cleary, M., & Rowan, F. (2023). Sustainable orthopaedic surgery: Initiatives to improve our environmental, social and economic impact. In *Surgeon*. Elsevier Ltd.

McAlister S, McGain F, Petersen M, et al (2022) The carbon footprint of hospital diagnostic imaging in Australia. Lancet Reg Health West Pac 24:100459.

MacNeill, A. J., Lillywhite, R., & Brown, C. J. (2017). The impact of surgery on global climate: a carbon footprinting study of operating theatres in three health systems. *The Lancet Planetary Health*, *1*(9), e360–e367.

Picano E, Mangia C, D'Andrea A (2022) Climate Change, Carbon Dioxide Emissions, and Medical Imaging Contribution. J Clin Med 12:215.

Sherman, J., Le, C., Lamers, V., & Eckelman, M. (2012). Life cycle greenhouse gas emissions of anesthetic drugs. *Anesthesia and Analgesia*, *114*(5), 1086–1090.

Snigdha, Hiloidhari, M., & Bandyopadhyay, S. (2023). Environmental footprints of disposable and reusable personal protective equipment – a product life cycle approach for body coveralls. *Journal of Cleaner Production*, *394*.

Thiel, C. L., Woods, N. C., & Bilec, M. M. (2018). Strategies to Reduce Greenhouse Gas Emissions from Laparoscopic Surgery. *American Journal of Public Health*, *108*, S158–S164.

Zhang, D., Dyer, G. S. M., Blazar, P., & Earp, B. E. (2023). The Environmental Impact of Open Versus Endoscopic Carpal Tunnel Release. *Journal of Hand Surgery*, *48*(1), 46–52.

Ranganathan J, Corbier L, Bhatia P, et al (2004) The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard. WBCSD/WRI 2004; World Resources Institute.