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Global surgery and climate change: how global surgery can prioritise both the health of the planet and its people

Sophia Chen[1,2,3], Yvan Zolo[1*], Lumbani Ngulube[1], Moses Isiagi[1] and Salome Maswime[1]

Abstract

Climate change is an emerging global health crisis, disproportionately affecting low- and middle-income countries (LMICs) where health outcomes are increasingly compromised by environmental stressors such as pollution, natural disasters, and human migration. With a focus on promoting health equity, Global Surgery advocates for expanding access to surgical care and enhancing health outcomes, particularly in resource-limited and disaster-affected areas like LMICs. The healthcare industry—and more specifically, surgical care—significantly contributes to the global carbon footprint, primarily through resource-intensive settings, i.e. operating rooms that generate greenhouse gases and substantial medical waste. Therefore, Global Surgery efforts aimed at improving surgical access through an increase in surgical volumes may inadvertently exacerbate health challenges for vulnerable populations by further contributing to environmental degradation. This predicament is particularly pronounced in LMICs, who already suffer from a disproportionate share of the global burden of disease, and where the demand for surgery is rising without corresponding resilient infrastructure. LMICs face a double jeopardy of health inequity coupled with climate vulnerability. As a movement positioned to improve health around the world, Global Surgery has an increasingly significant role in envisioning and ensuring a sustainable future. Global Surgery initiatives must prioritise sustainable infrastructure in both high-income countries (HICs) and LMICs, all while accounting for the unequal polluting contributions between HICs and LMICs and, consequently, moral responsibilities moving forward. Moreover, through targeting upstream causes of poor health at urban and perioperative levels, Global Surgery's interventions may help to reduce the global burden of disease—avoiding preventable surgeries and their carbon footprints from the outset. Altogether, Global Surgery and climate change are two matters of social justice whose solutions must synergistically centralise the health of both the planet and its most vulnerable people.

Keywords Climate change, Global surgery, Global health, Surgery carbon footprint, LMIC, Sustainable healthcare, Sustainability

*Correspondence:
Yvan Zolo
yvanzolovie@gmail.com; andre.zoloossou@uct.ac.za
[1]Global Surgery Division, Department of Surgery, Faculty of Health Sciences, University of Cape Town, Cape Town, South Africa
[2]Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA, USA
[3]Department of Architecture, Massachusetts Institute of Technology, Cambridge, MA, USA

Introduction

In 2021, over half of the world's population lacked access to essential health services [1]. The severe inequality in healthcare access is especially prevalent when considering surgical services. According to the Lancet Commission on Global Surgery, only 6% of the 313 million surgical procedures worldwide each year occur in the poorest countries—despite being home to over a third of the world's population [2].

Emerging from the urgent pressure of systemic poverty and inequity, Global Surgery is an interdisciplinary field that aims to improve health outcomes and achieve health equity for all people who need surgical, obstetric and anaesthesia care [3]. Global Surgery focuses on underserved, marginalised, and vulnerable populations, demanding engagement with and empowerment of communities in need. Broadly, Global Surgery seeks to develop and improve health systems, including surgical care. Efforts revolve around five targets: (1) to increase the number of surgeons, (2) increase the number of surgeries, (3) improve surgical outcomes, (4) decrease the need for surgery, and (5) increase the cost-effectiveness of surgery.

However, an increase in surgical access means a consequent increase in anaesthetic gas usage, energy consumption, and surgical waste. These carbon emissions and waste deposits only worsen health outcomes, contributing to existing environmental concerns such as air pollution, rising temperatures, extreme climate events, water and food insecurity, and the spread of vector-borne diseases [4]. In already vulnerable populations, this creates a vicious cycle and paradox: the pursuit of increased and improved surgical care is at the expense of planetary and public health [5]. In other words, interventions for better, more accessible surgical care may only result in more disease for the same people it seeks to help.

Yet increasing access to surgery does not have to be at the expense of the environment. Fundamentally, Global Surgery seeks to improve health for all—meaning that it is, by principle, a key stakeholder in tackling climate change's effects on health. It is clear that Global Surgery can exert a large influence on re-defining the volume and quality of surgical access, as well as the sustainability of surgery altogether.

This paper aims to present the current state of surgical access, surgery-related carbon emissions, and climate-induced crises drawing from published data from multiple hospitals and countries across the world, yet focusing on low- and middle-income countries (LMICs). We conclude by suggesting possible solutions, emphasising the need for adopting sustainable practices to ensure universal healthcare goals can be achieved whilst addressing the climate crisis.

Background

The need for global surgery

According to the Lancet Commission report in 2015, there is a critically unmet need for surgery: 5 billion people do not have access to safe, affordable surgical and anaesthesia care when needed, despite surgical cases accounting for 28–32% of the overall burden of disease globally [2, 6]. In LMICs alone, 98% of people with surgical conditions do not receive safe, timely and affordable surgical and anaesthesia care; 143 million more surgeries are needed in LMICs each year to save lives and prevent disability [2, 6].

Although Global Surgery aims to increase access to surgical care, the operating room has a significant contribution to healthcare's carbon footprint as a resource-intensive setting. Without sustainable frameworks in place, an increase in operations will only result in more harm to the environment, which has severe health impacts—especially for already vulnerable populations. In the fundamental pursuit of health care for all, Global Surgery must also be at the forefront of climate activism.

Surgery's carbon footprint

It is estimated that the health-care sector is responsible for 4–5% of global greenhouse gas emissions [7]. Although an estimate for surgery's precise contribution to this footprint could not be identified, studies have found that operating theatres account for at least 21–33% of total hospital waste, and are often 3 to 6 times more energy-intensive than the rest of the hospital [8]. An individual procedure may emit anywhere between 4 and 814 kgCO2e, depending on the type and length of intervention, hospital setting, and geographic location [8, 9]. This carbon footprint comes in the form of energy use, greenhouse gas emissions and equivalents, personal travel emissions, consumable throughput, and waste production and disposal. Respective contributions from each of these categories vary between procedures.

Energy consumption is one of the most significant producers of hospital greenhouse gas emissions. A resource-intensive setting, operating theatres contribute greatly to these emissions; energy use can come in the form of heating, ventilation, air conditioning, lighting, as well as other electricity-consuming services (e.g. electronic equipment). In three studies across different surgical operations, electricity was found to produce 63–78% of the carbon footprint of each respective procedure [10–12].

Beyond the emissions associated with electricity, there are the emissions released on-site in the form of anaesthetic gases, inhaled medicine propellants, and other medical and surgical gases. According to a limited estimate by Health Care Without Harm in 2019, 0.6% of health care's global climate footprint or over two million

Table 1 A comparison across countries of healthcare sector carbon emissions and GDP

Countries' healthcare sector carbon emissions and GDP								
	India	**Mexico**	**China**	**England**	**Japan**	**Canada**	**Australia**	**USA**
kg CO_2e per capita in given year	54 (2014)	118 (2014)	181 (2014)	540 (2019)	566 (2015)	899 (2015)	1,495 (2015)	1,889 (2013)
Nominal gross domestic product (GDP) per capita in USD in given year	1.56K (2014)	11.5K (2014)	7.64K (2014)	42.7K (2019)	35K (2015)	43.6K (2015)	56.8K (2015)	53.3K (2013)

metric tons of health care emissions come from the sector's use of anaesthetic gases [13].

Travel emissions must also be accounted for, i.e. that of staff, patients, and visitors, especially for those commuting from rural areas into cities. Some studies that accounted for travel have found that it was responsible for 10–37% of the carbon footprint of surgery [10, 14].

Furthermore, and perhaps most significant, are the emissions produced by the supply chain associated with pharmaceuticals, equipment, and services. Multiple studies across different surgical operations identified procurement to be the largest contributor to the carbon footprint of each procedure, with single-use items alone responsible for up to 78% of emissions [14–17].

The global disparity in surgery-related carbon footprints

The global carbon footprint of surgical operations is disproportionately created by HICs, yet the debilitating impact of climate change is most acutely faced by LMICs. Table 1 compares the carbon emissions of healthcare sectors across multiple countries, alongside their gross domestic products (GDPs), which serve as an indicator for the size of each countries' economies.

Emissions data is from Tennison et al. (2021), Pichler et al. (2019), and Wu (2019). [7, 18, 19]*Gross domestic product (GDP) data is from the IMF Datamapper tool.* [20]

GDP of each country is reported to match the year of the data in the kg CO_2e row, which was more limited. The healthcare footprint in 2014 was the most recent available year across which most countries could be compared. Note that the kg CO_2e estimates are highly variable based on the method used to calculate.

Countries with larger GDPs tend to have more healthcare sector carbon emissions, with HICs producing more than LMICs. However, there is very limited data on healthcare-related carbon emissions from LMICs, as no systematic reviews were found by the authors. New studies must be conducted to provide more recent, updated measurements, especially for countries such as China whose economies have rapidly changed over the past decade.

Due to limited data, African countries lack representation within this comparative dataset. Regardless, many assert that the carbon footprints of healthcare sectors in African countries are negligible in comparison to many high-income countries [21, 22]. In a report by Health Care Without Harm (2019), all African countries combined account for far less than a quarter of the global healthcare footprint [13]. More specifically, the United States accounted for 27%, China for 17%, the European Union for 12%, and Australia, Canada, South Korea, India, Brazil, Russia, and Japan as 19% combined; all other nations were the remaining 25% [13]. North America emits 1.65 tCO_2e/capita of healthcare emissions while South Asia, for instance, emits only 0.03 tCO_2e/capita [13].

Although comprehensive studies that contrast hospital settings between LMICs and HICs from a sustainability perspective could not be identified, it can be inferred that hospitals in LMICs generally have lower healthcare emissions due to (1) lower patient volumes as a result of access inequalities and infrastructure, as well as (2) their low-resource and/or sustainable environments (e.g. the lack of electricity, air conditioning, or medical materials). For instance, over 30% of hospitals in LMICs report that they do not have access to continuous electricity; therefore, despite being a pronounced sustainability issue in HICs, carbon emissions from electricity consumption may not be as significant of a concern in many LMIC hospitals [23].

The disproportionate impacts of climate change on LMICs

Climate change is the most significant threat to human health in the 21st century [3]. As global temperatures continue to rise, there is a severe increase in heat-related deaths across the world; the WHO estimates that between 2030 and 2050, climate change will cause an additional 250,000 deaths per year, most of which will occur in LMICs [24, 25]. Climate change results in a host

of catastrophes with a grave impact on human and planetary health, including air and water pollution, food and water insecurity, crop failure, extreme weather events, loss of land and livelihood, the spread of disease, and economic losses. These natural disasters not only result in a loss of life, but also lead to the destruction of healthcare facilities and dysfunctional health systems, hence affecting the delivery of surgical care, medications, and human resources. Moreover, warmer climates and climate-induced human migration have been associated with the spread of disease, including the increased prevalence of HIV, tuberculosis, hepatitis, cholera, and malaria, amongst others [26–28]. Warmer climates due to global warming are anticipated to cause delayed wound healing and greater rates of surgical site infections [29].

The debilitating impact of climate change is already being faced in LMICs to a much greater extent than in HICs. There are significantly more deaths in LMICs attributed to climate change than in HICs [21]. According to the World Meteorological Organisation (WMO), 110 million people on the African continent were affected by climate or weather related changes in 2022; this led to economic losses amounting to around $8.5 billion USD, and 5000 deaths of which 48% were attributed to drought and 43% to floods [30]. There is a growing body of research showing how LMICs, such as those in the tropical and subtropical regions of Africa, are facing increased risk of vector-borne diseases due to rising temperatures [31]. Increasing frequency and severity of natural disasters, heat waves, floods, and droughts in LMICs due to climate change is well documented, as well as corresponding impact on food, water, and housing insecurity [32, 33]. Especially for women in LMICs, poverty, health inequity, gender inequality, and systemic barriers make it difficult for them to recover from climate impacts, deepening their vulnerability [34].

In LMICs, this climate vulnerability is compounded with already weaker health infrastructures and an existing, acute burden of disease. According to the WHO, there are 0.8 hospital beds per 1000 people in LICs, 2.3 in MICs, and 5.3 in HICs [35]. Further, 90% of LICs have less than 10 medical doctors per 10,000 people, as compared to HICs with only 5% [35]. LMICs carry a disproportionate amount of the global burden of disease [36]. It is clear that LMICs face a double jeopardy between climate change impacts and healthcare inequality.

Discussion & recommendations

Simultaneously improving surgical access while addressing climate change will require solutions that depend on hospital setting and available resources. These solutions range from macro-level system change to micro-level behaviour change, and are intrinsically different between HICs and LMICs.

Macro- and micro-level change

The carbon footprint of surgery can be greatly decreased through how energy and material resources are used. To reduce energy consumption, hospitals can change to more sustainable energy alternatives, improve insulation and building envelopes, upgrade control systems that reduce air flow turnover or energy usage, and install more efficient appliances. This would require additional funding and extensive leadership to restructure hospital utilities, although small steps can be taken to adopt more energy-efficient products such as LEDs. Within the operating room itself, providers can rethink how they conduct procedures, with a focus on inhalational agents and single-use consumables. For instance, using inhalational agents with low global warming potential, reducing fresh gas flows, using gas scavenging/capturing systems, implementing destruction technologies i.e. for nitrous oxide, and preferencing regional or total intravenous anaesthesia can all significantly reduce the climate impact of surgical procedures. A study by Thiel et al. on decarbonizing hysterectomies asserted that through the education of anesthesiologists and appropriate staff on environmentally-friendly anaesthetic practices, the ozone depletion potential (ODP) and greenhouse gas emissions of hysterectomies can be reduced 65–95% for abdominal and vaginal hysterectomies; switching to propofol or other IV or regional anaesthesia techniques could reduce ODP by 3% in laparoscopic and 28% in robotic hysterectomies [15]. Although unique to hysterectomies, this study demonstrates how changes to the conduct of procedures has the potential to greatly reduce carbon emissions.

As the supply chain itself is a main driver of carbon emissions, surgical operations can reduce the use of single-use consumables and increase reuse protocols for products that are currently considered single-use, such as fibre-based materials. However, more research is needed to determine how reduced energy usage and more sustainable equipment use may impact operating room safety and patient outcomes. Studies, for example, could compare how reusable versus disposable drapes affect postoperative healing, to help inform future adoption. Regardless, health professionals should carefully choose products that are less carbon-intensive, such as purchasing from local suppliers or partnering with low CO_2 companies. Additionally, engineers and designers must begin accounting for sanitation and reusability for medical tools and equipment, to lower rates of product waste.

Governance, management, and behaviour change are also critical solution spaces. It is important to note that doctors operate within a broader system of protocols, policies, and legal frameworks. Appropriate legislation and incentive structures must be developed, supporting sustainable practices such as reduced usage of single-use consumables or informed choice in anaesthetics.

Sustainable choices must not only be promoted, but desirable and preferable from a practical standpoint. Likewise, although requiring larger systems-level and infrastructure change, hospitals should promote public transit and adopt electric vehicles and ambulances if possible. Telehealth and virtual appointments could also reduce transit demands.

An LMIC-perspective

Given that HICs make the most significant contributions to healthcare-related carbon emissions due to their higher surgical volumes and more resource-intensive practices, HICs should be held primarily responsible for urgently adopting sustainable systems. Many of these recommendations are not applicable or realistic for LMICs. However, as LMICs scale up surgical services to meet growing healthcare demands and address unmet surgical needs, there is an opportunity to implement sustainable practices from the outset, preventing the replication of environmentally harmful models seen in HICs [37]. Moreover, LMICs are often more vulnerable to the impacts of climate change, including extreme weather events and health crises; building climate-resilient, low-carbon healthcare systems is therefore an imperative [38].

LMICs have the potential to lead innovation in sustainable healthcare by adopting context-specific solutions. For instance, many LMICs already rely on decentralised, renewable energy systems, such as solar power, to address unreliable energy supply in hospitals. By focusing on sustainable surgical infrastructure, LMICs can create scalable models for resource-efficient healthcare that align with their developmental goals and contribute to global climate action. This proactive approach can not only help LMICs meet their surgical care needs but also position them as leaders in environmentally conscious healthcare delivery.

Some hospitals in countries like Rwanda, Uganda, and Brazil have made strides in reducing reliance on carbon-intensive energy sources. Rwanda's Butaro District Hospital has adopted solar panels to power its surgical units, reducing the use of diesel generators that are typically relied upon during power outages [39, 40]. Similarly, a hospital in Entebbe, Uganda, integrated solar energy to support surgical services, showcasing the potential of renewable energy to mitigate carbon emissions in healthcare settings [41]. In Brazil, the Santa Izabel Hospital found a 2% reduction in total greenhouse gas emissions between 2018 and 2019 due to improvements in lighting, heating, ventilation, and air conditioning [13]. These efforts highlight the opportunities to address the energy-related environmental impacts of surgeries in LMICs through sustainable energy solutions.

In addition to energy usage, surgical waste and anaesthetic gases contribute significantly to the carbon footprint in LMICs. In India, hospitals have taken steps to manage anaesthetic gases, such as desflurane, which have high global warming potential [42–44]. While challenges remain in resource-constrained environments, efforts to reduce anaesthetic gas waste demonstrate that climate-conscious surgical practices can be implemented even in LMICs. Expanding such practices and studying how different surgical procedures, particularly high-volume surgeries in these regions, contribute to emissions would provide a more comprehensive understanding of how to reduce the environmental burden of surgical care.

A critical need for research

A major limitation of this paper is a lack of available research reflecting carbon emissions and current sustainability practices in LMICs. It is clear that more research is needed in these countries to draw robust international comparisons of carbon footprints in the healthcare sector; even the existing data in HICs is largely outdated. In future studies, more standardisation for measuring carbon emissions is essential, given that different studies use variable methodologies, which hinders the ability to make such comparisons. LMICs may also have limited access to carbon footprinting tools; bridging this gap will help LMICs develop sustainable frameworks [45]. This will allow for evidence-informed policy and infrastructure change. In fact, the WHO found that 46% of countries in a global survey indicated that a lack of research evidence was a barrier to implementing national health and climate change plans [46].

The lower healthcare-related carbon emissions seen in LMICs can be attributed to a variety of factors, i.e. lower patient volumes due to lower rates of healthcare access, as well as operating in already resource-limited settings where CO_2e-intensive practices such as single-use consumables are a luxury. More research is needed to formalise an understanding of what drives these significantly lower emissions, such as case studies across various hospitals or regions in LMICs. In fact, by looking at surgical conduct in low-resource operations in LMICs, HICs may be able to reduce their consumption and healthcare waste, challenging possibly excessive or unnecessary protocols currently considered the norm in HICs. Inversely, an open area of research is whether or not certain unsustainable practices observed in HICs are truly necessary. For instance, future studies could compare how reductions in energy usage (e.g. reduced climate control in the operating room), changes in anaesthetic usage (e.g. prefencing regional or total intravenous anaesthesia), or more frequent reuse of equipment may impact patient outcomes. Data-informed changes in clinical conduct

will allow for sustainable practices without compromising healthcare quality.

The future of global surgery

The healthcare sector's carbon footprint is largely driven by the significant global burden of disease. Global Surgery not only aims to provide increased access to surgical care, but also fundamentally advocates for the reduced need for surgery—achieved through preventive medicine and safe, healthy cities. In HICs and LMICs alike, public health campaigns such as community awareness, health promotion, and disease prevention programs can result in better patient outcomes and an overall lower demand for healthcare and surgery. In other words, intervening before conditions deteriorate to the point of resource-intensive surgical operation will lower the rates of diseases altogether, and therefore reduce the carbon footprint of the healthcare sector. Particularly in LMICs, increasing the capacity and reach of healthcare systems to provide more patients with quality care is essential to preventing otherwise avoidable illness and lowering the burden of disease, thereby circumventing the admission of patients into hospitals and mitigating the need for surgery.

Lowering the global burden of disease requires a variety of solutions, including more healthcare facilities, greater funding, improved infrastructures, more providers and resources, and better training. Moreover, engagement with communities to foster greater understanding of health and disease will prevent conditions from occurring or progressing. It is necessary that communities can trust healthcare systems and that individuals have the competency and social support to pursue help when they need it. Altogether, shifting away from hospital-centric care towards community-oriented and preventive care will improve patient health in the long-term [45]. Global Surgery provides the critical advocacy work needed to engage communities and pressure governments to increase investment in population health.

Conclusion

A global crisis, climate change poses the most critical risk to LMICs, who experience climate-induced catastrophes at a higher incidence, and who have weaker health infrastructures and financial resources. The healthcare industry and the operating room are significant contributors to the global carbon footprint, with HIC systems generating the majority of these emissions. HICs have a moral imperative to take responsibility for their carbon contribution, and urgently need to adopt sustainable practices in the healthcare setting, including efficient energy use and lower waste production. LMICs must also develop sustainable frameworks as they build necessary climate-resilient infrastructure. Already, countries like India and Rwanda have made strides in integrating solar energy into healthcare, demonstrating that resource-limited settings can successfully implement environmentally responsible solutions. In fact, LMICs can serve as leaders in sustainable healthcare infrastructure, from which HICs can learn. Through climate conscious development and interdisciplinary collaboration, Global Surgery can simultaneously address climate change whilst pursuing health for all. In envisioning an equitable future, planetary health and human health are fundamentally inseparable.

Abbreviations

LMIC Low- and middle-income country
HIC High income country

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Author contributions

S.C., Y.Z., and L.N. conceptualized the study and developed the initial framework. S.C. conducted the literature review and drafted the main sections of the manuscript. S.C., Y.Z., L.N., and M.I. contributed to writing the discussion and ensured the integration of global surgery perspectives. S.C., L.N., and M.I. assisted with data acquisition, analysis, and interpretation, particularly in the context of low- and middle-income countries. S.M. provided critical revisions and insights into the aspects of sustainable infrastructure. All authors reviewed and edited the manuscript. S.C. prepared all the figures.All authors approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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