Uncertainties and opportunities in delivering environmentally sustainable surgery

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DOI:
10.1111/anae.16195

Anaesthesia 2024 doi:10.1111/anae.16195

Review Article

Uncertainties and opportunities in delivering environmentally sustainable surgery: the surgeons' view

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Summary

Surgery is a carbon-heavy activity and creates a high volume of waste. Surgical teams around the world want to deliver more environmentally sustainable surgery but are unsure what to do and how to create change. There are many interventions available, but resources and time are limited. Capital investment into healthcare and engagement of senior management are challenging. However, frontline teams can change behaviours and drive wider change. Patients have a voice here too, as they would like to ensure their surgery does not harm their local community but are concerned about the effects on them when changes are made. Environmentally sustainable surgery is at the start of its journey. Surgeons need to rapidly upskill their generic knowledge base, identify which measures they can implement locally and take part in national research programmes. Surgical teams in the NHS have the chance to create a world-leading programme that can bring change to hospitals around the world. This article provides an overview of how surgeons see the surgical team being involved in environmentally sustainable surgery.

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Accepted: 8 November 2023
Keywords: anaesthesia; environment; surgery; sustainability
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Introduction

Surgery is a carbon-heavy activity and surgical teams around the world are worried about their impact on the environment [1]. Surgery conducted in high-income countries has become fraught with single-use devices, complex supply chains and a high plastic waste burden that is often sent for incineration which worsens the carbon impact [2]. Here, we describe a surgical viewpoint on sustainable operating theatres.

Trying to change a whole hospital at once is complex and likely to fail, so we have focused on operating theatres [3]. These contribute 25% of a hospital's total carbon output, using a high volume of consumables and energy [3]. Operating theatres represent the intersection of numerous healthcare professionals (e.g. anaesthetists, radiologists, nurses and porters) [4] and evidence-based change here can result in learning that can then be shared across other hospital areas. Beyond this, the solution to creating more

environmentally sustainable surgery lies not only in the operating theatre but also across the whole patient journey.

The current literature describes events in single operating theatres, with a lack of evidence of scaling to the rest of the hospital or across multiple sites [5–7]. There is very little evidence proving that any changes (e.g. sorting waste) will last over time. Evidence from single-centre experiences often does not incorporate behavioural change strategies and lacks data on clinical safety and sustainability over time. Furthermore, there is a paucity of published data considering the environmental impact of surgery in low- and middle-income countries, where it is likely that single-use equipment is utilised less frequently and the problem-solution cycle is different.

In order to lead change in both the operating theatre and across the wider patient pathway, surgeons, anaesthetists and the teams around them must upskill. We discuss environmentally sustainable surgery from the frontline surgeon's viewpoint, including which skills are needed to create change, and how to select interventions. We also discuss the importance of behavioural change training and basic carbon literacy skills for surgical teams, to ensure we create environmentally sustainable operating theatres of the future.

Changing team behaviours

Changing behaviours in operating theatres is the cornerstone of sustainable surgery [8]. Behaviour change is required to increase the uptake of carbon-efficient processes, apply evidence-based practice and avoid the carbon burden associated with postoperative complications. However, concepts in behaviour change theory are not taught routinely to theatre teams, and resources are not widely available outside of specialist training courses [8]. The COM-B model considers capability (C), opportunity (O) and motivation (M) as three key factors that can result in changes in behaviour (B). This is an attractive intervention to apply to the peri-operative setting as it is simple, comprehensive, reproducible and can be used throughout research cycles including in process evaluation [9]. There are many complex behaviours underpinning goals such as improving waste management; introducing reusable drapes and gowns; or changing anaesthetic approaches. These extend beyond readily apparent actions like recycling and reuse [10]. Behaviour change techniques described to date include: providing verbal, digital and written materials to surgical teams (COM-B: psychological capability); restructuring operating theatre layouts (COM-B: physical opportunity); infection control procedures and direct patient communication (COM-B: social opportunity); and monitoring (COM-B: reflexive motivation) [10–15].

Changing behaviour among surgical teams can be challenging and counterintuitive. Often, behaviour change interventions in operating theatres appear predicated on the assumption that behaviours are rational, and therefore that more information, education and training (COM-B: psychological capability) alone will influence reflective cognitive processes that subsequently shape behaviour [16]. Evidence from other domains, like patient behaviour, shows that information-only interventions have limited efficacy because behaviours are linked to complex systems that can be difficult to shift [17, 18]. Approaches to behavioural intervention in surgery should therefore be diversified [9]. Examples of relevant behaviour change interventions that go beyond information include automated technologies to control energy use such as occupancy sensors; key card systems; and green workplace champions [17, 19, 20]. Such interventions target automatic and social influences rather than solely reflective motivation influences [17, 19, 20].

Even when clear evidence exists and meaningful change occurs during a research study, changes in practice do not always follow [21]. Surgeons are invested in their training and behaviours in theatre, and often worry about the collateral impact of practices on patient safety. Studies suggest that it may take 17 years for practice to change following evidence, with only half of actionable trial findings having an influence on practice, although recent evidence suggests the implementation gap is closing [22]. Implementation considerations need to be built into behaviour change interventions in surgery, with a high-quality evaluation of safety and patient outcomes to ensure that changes are sustainable and adopted widely [11].

Practical environmental literacy for surgeons

Traditional carbon literacy brings an understanding of technical components and terminology, such as life-cycle assessments. While important, surgeons need a broader knowledge to select interventions, especially when being presented with conflicting information, complex data and information from commercial suppliers [23]. We are proposing that this is beyond carbon literacy alone and encompasses wider environmental and ethical impacts. Such training does not yet exist but should include the key points shown in Box 1. Introducing practical carbon literacy training within operating theatre teams can lead to an impact outside the hospital setting, informing policy makers

Box 1 Key points in practical carbon literacy for the surgical team

- An understanding of lifecycle assessments and carbon estimates
- An understanding of environmental impact, from carbon to waste
- Awareness of supply chains, including country of production and supply chain awareness of raw materials
- The ethical standing of supply chain mapping, including child labour and safe working conditions
- Evidence around implementation and scalability, especially if working in a team with average resources
- The need for organisational change and tools provided to support this (e.g. business models or successful cases in other Trusts)
- The need for capital investment and whether that is realistic in current healthcare climates, especially within the NHS

and industry members, and reaching the community (Fig. 1).

Selecting interventions

Choosing which interventions to implement is currently the greatest challenge. All surgical teams have limited time, funding and personal energy. Two key randomised trials help inform how many interventions teams should be addressing. The EPOCH (15,873 patients, 93 NHS hospitals) [24] and ASOS-2 (13,275 patients, 172 African hospitals) [25] randomised trials evaluated interventions to reduce complications after surgery; however, neither showed benefit, as too many complex interventions were attempted at once. Addressing numerous new interventions at the same time runs the risk that none can be successfully implemented.

To identify feasible, safe and immediately actionable interventions in sustainable surgery, we have undertaken a scoping Delphi consensus to understand the priorities of surgical teams [11]. Following a systematic review, a longlist of candidate interventions was subjected to clinician and patient prioritisation: 15 interventions were shortlisted and ranked in terms of feasibility and safety by 5218 peri-operative professionals. Key areas for implementation of sustainable interventions were identified that included: anaesthesia; energy; supply chain of peri-operative equipment; drapes and gowns; and waste management [11]. Whilst it is recognised that a multidisciplinary approach is key to implementing sustainable interventions effectively in operating theatres, some of the interventions were identified as being more immediately actionable by the frontline surgical team than others (Box 2).

What current initiatives are underway?

The Green Checklist published by the Royal College of Surgeons attempts to introduce practical environmentally sustainable interventions on a large scale [26]. This evidence-based list of 16 action-points, approved by Surgical Colleges in the UK and Ireland, follows the structure of the widely disseminated World Health Organization (WHO) surgical safety checklist [27]. Interventions are grouped according to peri-operative phases (anaesthesia; pre-operative; operative; and postoperative). While some are practical measures that can be implemented by frontline teams, many consist of longer-term initiatives that require financial investment, infrastructure changes and engagement of a wider range of stakeholders (Table 1) [26]. How this is used alongside the surgical safety checklists, and whether teams will meaningfully engage over time, is worthy of further research.

We are aware of pockets of excellence where enthusiasts can drive good practice, and where motivated managers have driven change. However, for the average resourced site, and when the enthusiast is not present, routine change needs a different approach. A National Institute for Health and Care Research (NIHR) programme grant on environmentally sustainable surgery launches in late 2024 and aims to use the following principles. First, to address measures for the average surgical team in the average hospital, it will focus on a maximum of three interventions. Second, it will provide evidence of the clinical, cost and carbon impact of interventions. Third, it will incorporate the patient voice, which so far has identified the need to prove safety as important. Within this context, it will learn how this body of evidence can be communicated to local communities. Following a Delphi process and community engagement, the research programme will deliver three research pillars (Box 3).

As with all interventions, there will be trade-offs in terms of risks and benefits. With different practices and processes in every hospital, there will also be a range of carbon and environmental benefits. Surgeons and patients remain interested in anaesthetic practices, and in how to deliver environmentally friendly surgery. For example, patients are concerned about infection risk with reusable devices, and there is awareness regarding changes in anaesthetic practice [11]. Although much of this may be overcome by developing communication toolkits, good scientific

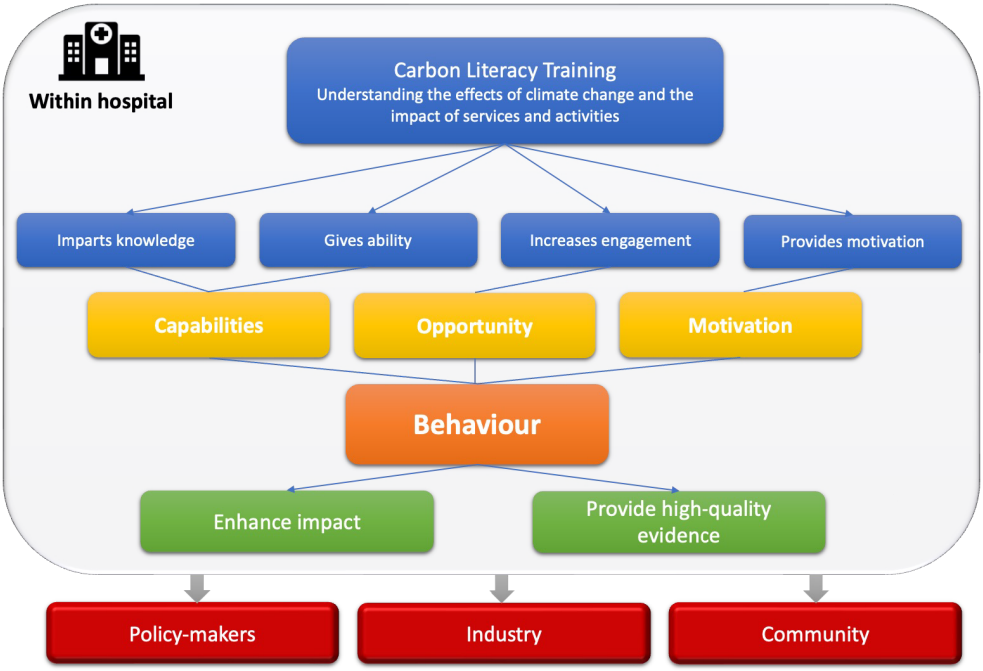

Figure 1 Theory of change model linking practical carbon literacy to policy impact via a series of behavioural mediators.

Box 2 Five interventions immediately actionable by frontline surgical teams

- Reduce consumables used
- Reduce energy and water use
- Make more use of lightly packaged consumables
- Increase the use of consumables that can be easily recycled
- Introduce surgical devices that can be re-used

evidence should underpin such communication. The following sections describe four examples of interventions, each discussing the clinical, carbon, and cost trade-offs. Table 1 shows a more expansive list, based on the Green Surgery Checklist [26].

Reusable drapes and gowns

The WHO makes no recommendations on the use of disposable or reusable drapes and gowns due to a lack of evidence on their effects on surgical site infection [28]. Outside of the UK (where International Organization for Standardization (ISO) standards of sterilisation exist), processes are likely to vary and not be quality assured. Lifecycle assessments show that reusable textiles are likely to have a lower carbon burden [29, 30]. We are planning an NHS-wide budget impact model to drive national-level change. Sterilisation depends on having access to facilities, which may be absent, and this may force the use of disposables. Engagement with management is needed to ensure capacity in sterilisation contracts.

Optimisation of waste management

Appropriate waste segregation could reduce the carbon impact of the operating theatre considerably. Inappropriate segregation means that large volumes of waste are incorrectly disposed of, and then processed through higher-emission waste streams [31]. Education and training, as well as appropriate logistics with clear differentiation of waste bins, could represent solutions to reduce the carbon footprint of surgical waste [32]. Hard plastic is often disposed of in operating theatres. While recycling has been shown to have a small impact on reducing carbon emissions from waste, new technologies could prove blister packs to be a valuable resource [6]. Implementing change in waste management practices does not have an impact on patients and clinical safety. However, it is important that hazardous waste is disposed of safely to prevent injury and infection to hospital and waste facilities staff [33]. Change in waste management processes strongly relies on the engagement of a wider range of stakeholders and contracts with external waste management companies. This represents a challenge, as there is wide variation in the management of waste among

Table 1 Interventions recommended by the Green Surgery Checklist, classified according to ease of implementation in the clinical setting [26].

Areas addressed	Interventions recommended		Details of wider stakeholder requirements
	Interventions easily implemented by frontline teams	**Interventions requiring a wider range of stakeholders**	
Anaesthesia	Local/regional anaesthesia TIVA use	Switch to reusable equipment*	Introduction of reusable equipment requires set up of new sterilisation facilities and pathways with infrastructure changes and management involvement
	Limit nitrous oxide use Minimise drug waste	Follow inhalational anaesthesia guidance	Inhalational anaesthesia guidance (volatile capture technology, low-flow target-controlled anaesthesia machines, removing desflurane from formulary) requires the involvement of management and procurement
Preparing for surgery	Avoid clinically unnecessary interventions		
	Reduce water and energy consumption, i.e. `rub do not scrub´	Reduce water and energy consumption, e.g. via automatic or pedal-controlled taps	Installation of taps requires engagement with management, estates and changes in infrastructure
Intra-operative equipment	Do not open or use unnecessary equipment	Switch to reusable textiles* Switch to reusable equipment*	Set up of new sterilisation equipment and pathways for reusable textiles requires infrastructure changes and management involvement
	Revise and rationalise instrument trays	Switch to low-carbon alternatives	Switch to low-carbon alternatives requires involvement of procurement
After surgery	Use lowest carbon-appropriate waste streams	Ensure damaged reusable equipment is repaired, encourage active maintenance	Efficient surgical instrument repair system requirement
	Power off theatre lights, ventilation, temperature control and equipment when theatres are empty		

TIVA, total intravenous anaesthesia.
*If reusable equipment or textiles not currently in use within the hospital.

different NHS Trusts in the UK. While policies should be tailored to the needs of individual Trusts, sharing results and identifying effective interventions is necessary to deliver more environmentally sustainable healthcare.

Instrument trays

Instrument trays contain a broad range of components. There seems to be no significant clinical difference in using a tray with a wider variation of instruments or not,

Box 3 Environmentally Sustainable Surgery Programme research pillars

- A major randomised trial testing reusable compared with single-use drapes and gowns including 26,000 patients from 126 hospitals in eight countries that includes low- and middle-income countries (this trial is currently undergoing ethics approval).
- A collaboration with anaesthetists to create national change in an area prioritised by anaesthetists (to be determined).
- An improvement in waste management, including better sorting of waste, recycling of hard blister packs and working with industry to reduce waste upstream.

because this can be overcome by opening smaller trays if specific instruments are needed. Finding the right number and variety of instruments tailored to the requirement of different surgical specialties is key to reducing the carbon footprint from sterilisation of instruments that are not usually needed or used during surgery [34]. Life-cycle assessments of steamed sterilisation have concluded that, independent of the number of times a tray is used, the fact that not all instruments were needed and yet were sterilised produces a significant environmental impact. Furthermore, it seems to be cost-neutral or even cost-saving to rationalise trays [35]. Overall, optimisation of instrument trays may be the ideal first step towards achieving sustainable change, as the team required for implementation is concentrated within the operating theatre and this is not dependent on external companies. A multidisciplinary approach including surgeons, operating theatre managers and nurses and sterilisation managers is crucial to finding the right balance [34].

Reducing energy use

This is a complex topic with change needed at organisational and frontline levels. At an organisational level, external energy supply from a reusable supplier has a large effect [1]. In operating theatres, installing lights and heating on sensors is sensible, but requires moderate capital investment. Turning off air conditioning overnight is possible but, in some systems, requires organisation-wide change, through managers that surgeons rarely encounter [26]. A theatre shutdown protocol (including anaesthetic machines) that can be actioned by staff at the end of day is probably the most immediately feasible and impactful intervention [36].

Selecting devices and supply chains

Surgeons retain a high degree of autonomy over their individual practice and often have strong attachments to their preferred surgical devices, especially those held in their hands or implanted into patients. However, surgeons need to be carbon literate and understand the supply chain complexities to better select devices. As opinion is swayed towards sustainability, this could drive a change from 100% disposable to reusable or remanufactured devices (e.g. staplers and energy devices), that will, in turn, reduce the impact of the supply chain. It is this supply chain that is the major problem, rather than theatre energy use or waste disposal, both of which are tiny in comparison. Concerns over contamination and infection are likely to be overcome rapidly, although new evidence to support their safety is warranted [11]. The NHS spends £10 billion ($12 billion, €11.5 billion) per year on medical devices, with a staggering 600,000 different medical devices available in the UK [37, 38]. By 2028, regulations will be introduced that require carbon footprinting for all individual products supplied to the NHS [39]. Life-cycle assessments of each device will take decades, are costly and will be quickly out of date. A universal tool is required that is medical device specific, accounts for the reusability element of many medical devices and should identify the carbon and environmental impact per use. Furthermore, it needs to offer intra-device comparisons, be low burden and low cost, and enable regular and easy updating.

Sustainable surgery in low- and middle-income countries

Much of the current literature on life-cycle assessments and implementation of sustainable practices in operating theatres is from high-income countries. It is likely that environmental impact, its communication to patients and the public, and behavioural mediators of green interventions will differ substantially between contexts. This represents a high-priority knowledge gap in health systems research and global health for the next 10 years. Research efforts must begin by better understanding and describing the contexts in which surgery and anaesthesia are provided, then developing accessible and pragmatic tools for carbon modelling, before applying these to interventions to reduce the environmental impact of surgery and measuring change. It is more important than ever to deliver contextually relevant and important research with partners

in the `Global South´ for three reasons [40]. First, patients and populations in these contexts are likely to be at the highest risk of extreme weather events, human migration, natural disasters, epidemics and other systemic `shocks´ that increase in likelihood with global temperature rises [41]. Second, a higher proportion of patients suffer adverse effects of surgery in low- and middle-income countries, many of which are likely to have a high environmental impact [42]. Third, for many topics, e.g. reuse, opening instruments and packaging, there is a strong potential for south–south and south–north learning, since high-income practice is now dominated by single-use equipment. Reuse has been driven initially by necessity due to supply chain challenges, cost, and availability of disposable equipment, but if applied safely, could present opportunities for cost and carbon savings across better-resourced hospitals.

Environmentally sustainable surgery is at the start of its journey, with far more uncertainties than certainties. Surgeons need to rapidly upskill their generic knowledge base, identify which measures they can implement locally and take part in national research programmes. Surgical teams in the NHS have the opportunity to create a world-leading programme that can bring change to all hospitals around the world.

Acknowledgements

This study/project is funded by the NIHR (NIHR204403: Developing environmentally sustainable operating theatres). The views expressed are those of the authors and not necessarily those of the NIHR or the Department of Health and Social Care. Data sharing not applicable as no datasets were generated and/or analysed in this study. No competing interests declared.

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