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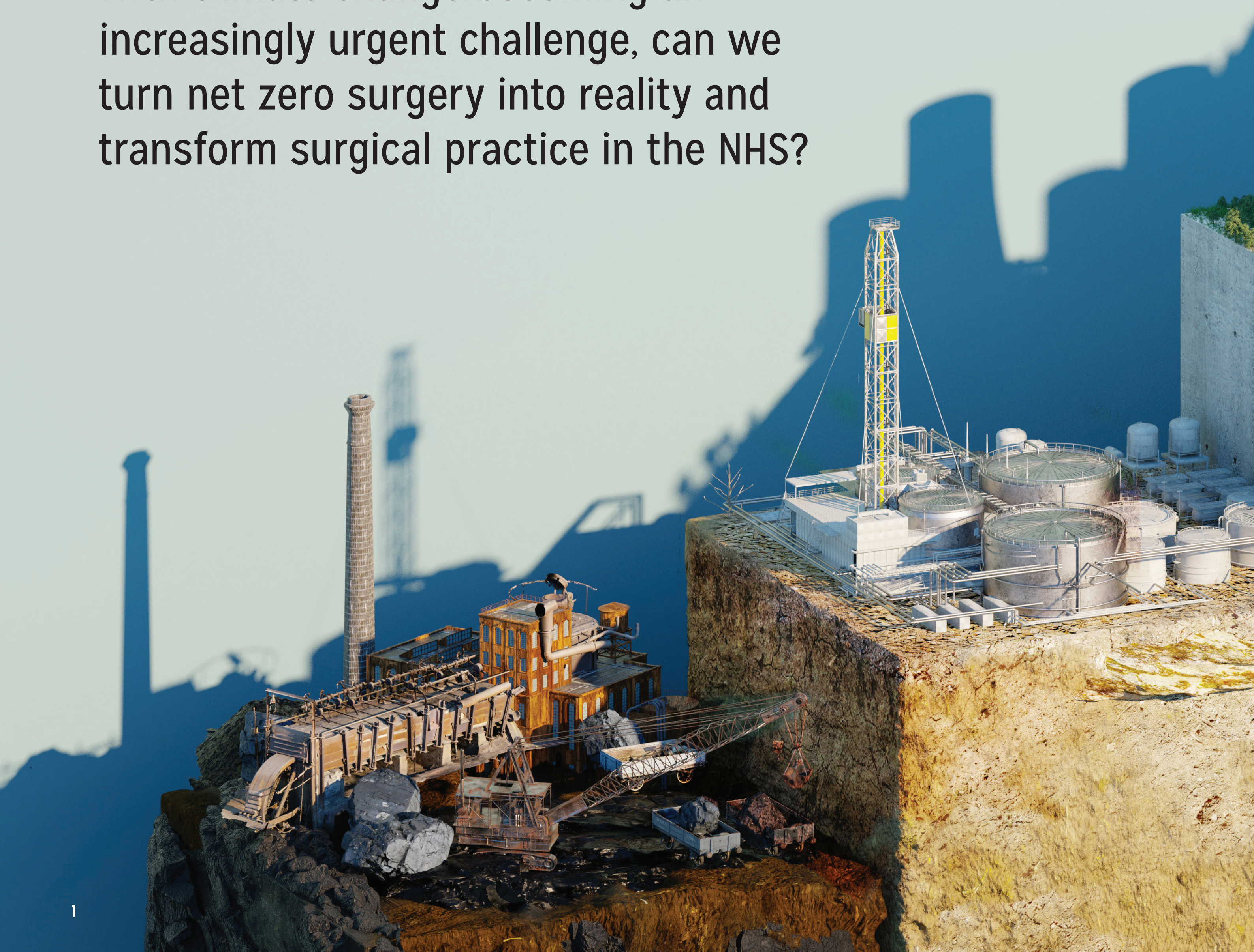
Net zero surgery: proof of concept and uncertainties

With climate change becoming an increasingly urgent challenge, can we turn net zero surgery into reality and transform surgical practice in the NHS?



Surgical teams around the world continue to strive for more environmentally sustainable operating theatres. Although pockets of enthusiasm exist, the expert teams required to develop better evidence and then scale proven strategies are lacking. Single interventions will not have a whole system impact and one method of change is not better than another. Multiple interventions and different strategies are needed to tackle a complex area, leading to change that can be embedded over time. In this article, we describe our experience in selecting simple measures, bringing them together into a package, and the barriers to ongoing change. By doing so, we highlight the uncertainties in the field and why new collaborations are needed. We also discuss the importance of how a research strategy should be considered an essential component to change.

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RATIONALE

Climate change is emerging as one of the greatest threats to public health globally over the next 50 years.[1] In response, governments around the world are committing to reducing carbon outputs.

Since healthcare is responsible for 4.6% of the world's greenhouse gas emissions,[2] even small reductions in carbon will likely have a significant impact on national carbon outputs.

In hospitals, operating theatres account for 25% of the total carbon output as they are highly resource intensive.[3] Carbon reduced surgical environments are an excellent early target for decarbonisation of hospitals. They are a relatively contained setting and focused on treatment of a single patient at a time. Early initiatives are easier to deliver and quantify, and are more likely to succeed in a controlled operating theatre than on a hospital-wide basis.[4] Subsequent expansion to more complex settings (including critical care and wards) can then be based on the lessons learnt in the operating theatre.

While there is a focus on carbon reduction, there might be also other benefits of these strategies. For example, although recycling of plastics results in negligible carbon impact,[3] the potential for plastic waste contamination of the ground, rivers and oceans is high. This may have an even greater impact in the Global South, where plastic waste in drainage systems and on beaches is high.

The COVIDSurg Collaboration projects include research to boost the delivery of elective surgery.[5–7] As health systems upscale surgical provision to address long waiting lists, sustainable systems to reduce carbon emissions should be developed in parallel. As a network of frontline clinical teams, we sought information on proven strategies that are implementable by frontline surgical teams, without complex resource requirements.

THE CASE FOR RESEARCH

Our aim was to map out how a research project could address this knowledge gap given that national strategies without guidance on implementation often achieve nothing. The well conducted EPOCH (Enhanced Peri-Operative Care for High-risk patients) trial showed that implementing change around emergency laparotomy did not change mortality[8] since teams had limited time and resources to effect changes. For this reason, launching national strategies for carbon reduced surgery without well conducted implementation research is at risk of early failure. Other types of research are complementary and essential. These include lifecycle assessments, analysis of supply chains and evaluation of local procurement/sterilisation processes. The collaborations that accompany such projects are also crucial.[1] However, understanding how to implement strategies is just as important as identifying innovations that work.

SCOPING REVIEWS

We set out to design our research according to the IDEAL (Idea, Development, Exploration, Assessment and Long-term follow-up) framework principles. In order to test a pilot package, a longlist of key interventions was developed through a scoping review of published and grey literature, undertaken in January 2022. The aim was to identify broad domains listing interventions to reduce carbon emissions. This included evidence from existing systematic reviews and data from original papers (eg lifecycle assessments and carbon hotspots).[9–11] The evidence supporting the longlisted interventions was ranked by impact on carbon output and then rated by quality, which was found to be moderate at best. Taking these data, a global voting process was conducted to elucidate the most feasible interventions to be delivered by frontline teams. Key interventions were defined as having enough evidence to be effective and being simple enough to be implementable by a frontline team (Table 1).

METHODS

An implementation package was built around these domains, using the COM-B (Capability, Opportunity and Motivation – Behaviour) framework.[12] During a three-month engagement process, key stakeholders were identified and the components needed to effect change were discussed (Table 1). A patient due to undergo a laparoscopic bowel cancer resection was consented to take part. We explained that no adverse events were anticipated but that we would be well prepared to deal with any potential problems (eg anaesthetic or surgical site infection complications).

The operation was conducted at Solihull Hospital on 25 April 2022. Relevant permissions were obtained from the NHS trust executive board. The procedure took 5.5 hours and there were no reported intraoperative complications. The patient was discharged on postoperative day 6 days and after a follow-up period of up to 30 days, no postoperative complications were detected.

> *Our aim is to transform the net zero case described here into standard operating procedures and promote the adoption of carbon reduced surgery in the NHS*

CARBON OUTPUT

Our scoping review found no holistic approach or whole theatre calculator to determine the impact of these measures compared with baseline practice. Baseline practice will vary and will include a 'worst case' scenario (eg most carbon heavy practices) or a 'better case' scenario (where some carbon reduced practices are in place). In order to support this pilot, we used the

Table 1 Evidence-based components of a net zero operation from a scoping review

Carbon source	Typical operation	Net zero operation	Implementation strategy (COM-B behavioural target)[12]
Anaesthetic and surgical gases	• Volatile gas use, including desflurane as worst case scenario • Other volatile gas use • Higher oxygen concentrations • Carbon dioxide insufflation for laparoscopy	• Total intravenous anaesthesia using propofol • Lower oxygen concentrations	• Identification of anaesthetist trained in total intravenous anaesthesia • Ensuring correct and working monitoring equipment available
Energy use	• Theatre lights and heating switched on 24 hours per day	• Theatre lights off when theatre not in use • Heating reduced by 50% overnight and at weekends	• Agreement with director of estates and joint action ahead of date of surgery
Consumables	• Single-use surgical gowns, drapes and scrub caps • Single-use surgical equipment (eg staplers, energy devices)	• Reusable surgical gowns and drapes • Reusable scrub caps • Recycle surgical equipment	• Purchase reusable gowns/drapes • Purchase reusable scrub caps • Agreement with director of procurement to allow an industry partner to remove and repurpose energy device
Waste	• No recycling • Some non-contaminated waste disposed of in clinical waste bin	• All clean materials that are recyclable are recycled • All non-contaminated, non-recyclable waste disposed of in household waste	• Agreement with director of facilities for recycling and waste management plan • Training of theatre staff
Other	• Theatre team commute to hospital by car • Materials wasted owing to having been opened even when they are not needed	• Theatre team commute to hospital by active transport (walk, run, cycle) • Materials only opened when required by surgeon	• Theatre team encouraged to use active transport in meeting on day before procedure • Training of surgeons and theatre staff around opening equipment

Table 2 Carbon output in a typical operation versus the net zero operation we delivered

Carbon source	Carbon output (kg CO_2)*		Reduction in net zero operation
	Typical operation	Net zero operation	
Anaesthetic and surgical gases	1,270.1	0.9	99.9%
Electricity use	521.7	274.6	47%
Waste production	149.9	140.3	6%
Gowns and drapes	6.0	1.8	70%
Total	**1,947.7**	**417.6**	**79%**
Carbon offsetting	–	-417.6	100%

*The carbon output refers to a 5.5-hour operation. These calculations are based on our estimations following a scoping review of published literature and will differ from the calculations of others so caution is required when interpreting these figures. Different estimates of carbon loads will create different outputs and reduction effects. Our calculations do not consider carbon outputs from supply chains or instrument sterilisation processes.

data from our scoping review to calculate the likely carbon reductions associated with these measures as well as those for a worse case baseline. We accept that caution is required when interpreting these figures as many baseline practices will include some carbon reduction measures; however, we judged this to be acceptable within an IDEAL stage 1 pilot.[13]

With all adopted strategies, we estimate that the carbon footprint for the operation was reduced from 1,948kg CO^2 (worst case estimate) to 418kg CO2. This represents a 79% reduction using the best available evidence, although this calculation does not consider carbon outputs from supply chains or instrument sterilisation processes (Tables 2 and 3). In order to make the operation completely carbon neutral, we planted three trees on the hospital's green campus, which, over 30 years, will offset the remaining carbon. Although offsetting is not part of the NHS strategy (or realistic at scale), we succeeded in proving the principle and contextualising the remaining carbon. During this procedure, two other patients underwent their operation as scheduled, meaning there was no reduction in surgical capacity.

DISCUSSION

This IDEAL stage 1 study has demonstrated that conducting a single carbon reduced operation is safe and feasible with no compromise to patient safety. However, the transition to and implementation of 'net zero' operations across surgical services globally will be complex.[12] Our aim is to transform the net zero case described here into standard operating procedures and promote the adoption of carbon reduced surgery in the NHS.

Table 3 Carbon output modelling

Anaesthetic and surgical gases
This includes the use of anaesthetic gases to maintain anaesthesia, carbon dioxide (CO_2) for insufflation during laparoscopy and supplemental oxygen. Anaesthetic gases are potent greenhouse gases. For example, desflurane has a global warming potential of 2,540, meaning it is 2,540 times more potent than CO_2. Anaesthetic gases are not altered by the human body and are breathed out by the patient, meaning that large amounts of these potent gases are released during surgery. An alternative form of anaesthesia is total intravenous anaesthesia, which works by infusing propofol into the patient's vein throughout the surgery. Propofol is broken down by the human body so there are no direct emissions related to using propofol. For the purpose of insufflation, approximately 1kg of CO_2 is required per hour. The emissions related to the use of supplemental oxygen are very low.
Energy consumption
The greatest use of energy in theatre is for the heating/ventilation system and theatre lights.
Waste production
Theatre waste broadly breaks down into three categories: non-contaminated waste that can be recycled, non-contaminated waste that cannot be recycled and is disposed of in domestic waste (which goes to landfill), and contaminated clinical waste that must be incinerated. The calculation of carbon output relating to waste also captures the impact of manufacture of the consumables. We have considered the use of personal protective equipment separately.
Personal protective equipment
The key personal protective equipment used in the operating theatre is theatre gowns. These can be either single-use, with the gowns disposed of after the surgery (often in clinical waste), or reusable (gowns sterilised prior to reuse). The same principles apply to the surgical drapes.
Other
There are additional potential sources of carbon output during surgery, such as the use of drugs, sterilisation of instruments and water use. However, these make relatively minor contributions to the overall carbon footprint of surgery so these are not included in our calculations.

Table 4 Areas of ongoing uncertainty in developing a net zero operation

Carbon source	Typical operation
Anaesthetic	
Increasing total	Environment: Although this reduces volatile gas use, its impact on the environment is less well established Clinical: Unclear clinical benefit to patients at present Implementation: Challenging behavioural change among anaesthetists due to training needs
Reducing desflurane use	Environment: Clear benefit of use Clinical: Variation in use among anaesthetists and clinical benefit Implementation: Partially implemented owing to differences in individual opinions on environment and clinical benefit
Surgical	
Reusing surgical devices and repurposing medical devices	Environment: Incomplete and inaccurate lifecycle assessments, often performed by manufacturer Clinical: Lack of evidence of clinical harm to patients Implementation: Lack of implementation across hospitals despite proposed environmental benefit
Recycling and segregating waste	Environment: The non-carbon environmental benefits are potentially ignored in pursuit of carbon reduction; recycling pathways across cities need to be negotiated with concerns around contamination Clinical: No clear impact in this category on patients Implementation: Lack of implementation across hospitals despite proposed environmental benefit
Methodological	
Lifecycle assessments	Issue: No clear, standardised and systematic approach in lifecycle assessments Solution: 'Lighter touch' models are needed for wider applicability
Whole theatre carbon outputs	Issue: Carbon output calculations are low fidelity and not related to the whole operating theatre Solution: Improving development needs to take into account different baseline practices and better hotspot analysis
Engaging management for organisational change (eg sterilisation or recycling contracts)	Issue: Difficulty with high level engagement with hospital Solution: Health economic strategies to be presented at business meetings
Changing behaviours	Issue: Difficulty with changing current practice among surgeons and anaesthetists Solution: Co-developing behavioural change techniques
Effecting change in lower resource hospitals	Issue: Implementing changes might be costly or challenging in these settings Solution: 'Lighter touch' carbon reduction targets

Implementing changes in existing healthcare systems is challenging. There are substantial barriers that limit wide uptake of these interventions across the UK and globally. A key limiting factor is the complexity related to behavioural change among clinicians, as demonstrated by the EPOCH and ASOS-2 (African Surgical OutcomeS-2) trials.[8,14] Both of these cluster randomised trials focused on reducing postoperative mortality through behavioural changes; they found that offering a wide choice of interventions can be time consuming and can result in decision fatigue. This leads to a high level of friction, preventing translation into practice. Only easy and implementable changes will enable translation into sustained, ubiquitous adaptations in practice.

Additionally, quantification of the health

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system's impact with more homogeneous and generalisable criteria is essential to fully acknowledge and compare carbon reducing interventions. Only with this would it be possible to identify those target areas that are more likely to produce results. Further work is required to refine carbon hotspots, identify national routes to offsetting, engage industry, address supply chains and reusable devices, and engage wider health systems to include the whole patient pathway (Table 4).[1]

CONCLUSIONS

Behavioural change is complex and can result in harm even for seemingly innocuous interventions. National interventions are costly and thorough evidence is warranted before mandating change. The surgical community needs to develop better expertise and national leadership in this area. The many hundreds of operating theatres around the country mean that more than a handful of experts are required and, as we have demonstrated through research on surgical site infection and COVID-safe surgery,[5,15] collaboration is vital. There are currently more unknown factors than known factors and high quality, scalable initiatives are needed to ensure correct resource allocation.

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