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Exploring the feasibility of home-delivered capsule endoscopy with 5G support: innovations and carbon footprint insights

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ABSTRACT

Introduction Colorectal cancer (CRC) poses a significant global health threat, necessitating early detection. Traditional diagnostic tools like optical colonoscopy have limitations prompting our '5G-SUCCEEDS' initiative to explore a novel approach involving remote colon capsule endoscopy (CCE).

Methods This prospective feasibility study was conducted at a single hospital in England. Between December 2022 and September 2023, we introduced a remote CCE service within the 5G-SUCCEEDS framework. We undertook a feasibility study of CCE in patients with low-risk/moderate-risk CRC stratified by faecal haemoglobin. Outcomes included carbon footprint analysis (outlined through three potential clinical pathways) and patient-reported outcomes through structured questionnaires and interviews.

Results Among 25 participants, 88% expressed satisfaction with remote CCE. 82% were willing to have remote CCE if clinically indicated in future. CCE findings included adenomatous polyps (58%), normal results (17%) and diverticulosis (21%), with no cancers identified in this pilot. Notably, we found that the carbon footprint associated with delivery of CCE at home (pathway 3) was lower compared with CCE delivered in a clinical setting (pathway 2). A fully optimised, automated scaled-up pathway would combine the delivery and collection of CCE equipment within a local area to reduce the carbon footprint of the travel element by 75%. Moreover, the conversion rate into a colonoscopy pathway is not static and clinicians acknowledge that this could be as low as 28%. Carbon footprint is more favourable for home-delivered CCE in the optimised scenario, while less so when considering the need for additional procedures (colonoscopy conversion).

Conclusion The 5G-SUCCEEDS initiative highlights the feasibility and advantages of home-based diagnostics using CCE.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Early detection of colorectal cancer (CRC) is critical for improved patient outcomes.
⇒ Traditional colonoscopy, while effective, poses logistical challenges and a high carbon footprint, especially in hospital-based settings.
⇒ Remote colon capsule endoscopy (CCE) has emerged as an alternative, offering the potential for home-based screening but requires further evaluation in terms of patient satisfaction, feasibility and environmental impact.

WHAT THIS STUDY ADDS

⇒ This study demonstrates that home-delivered CCE is a feasible and acceptable alternative to traditional hospital-based screening methods.
⇒ Patients reported high levels of satisfaction with the home-delivered CCE service, indicating its potential for wider adoption.
⇒ The study provides comparative data on the carbon footprint of home-delivered CCE versus hospital-based CCE and traditional colonoscopy.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings support the integration of home-delivered CCE into CRC screening programmes, potentially increasing screening uptake and accessibility.
⇒ Policymakers might consider promoting home-delivered CCE as a standard option, particularly in the context of reducing healthcare's carbon footprint.
⇒ Future research could focus on optimising the logistics of home-delivered CCE to enhance its efficiency and further reduce its environmental impact.

INTRODUCTION

Colorectal cancer (CRC) represents a significant global health challenge. WHO takes a proactive role in combatting CRC's global burden through a comprehensive strategy. This approach includes raising public awareness, cancer prevention and control, early detection and screening. These collective efforts are aimed at reducing CRC's impact, promoting prevention, ensuring equitable access to quality care and improving global cancer control.[1] CRC often begins as small polyps/polypoidal adenomas in the colon,[2 3] and early intervention can be lifesaving.[4] Unfortunately, current CRC screening methods, particularly colonoscopy, present various challenges, including discomfort, resource-intensive investigations, complications and poor uptake within certain communities.[5]

The COVID-19 pandemic, declared a global health crisis in March 2020,[6] has placed immense pressure on healthcare systems worldwide.[7] In response, specialty organisations have issued guidelines to adapt clinical practices.[8] Elective endoscopy procedures were suspended, raising concerns about CRC survival rates due to delays in colonoscopy investigations.[9–11] To tackle these issues, and address unmet clinical needs, innovative approaches to CRC screening, diagnosis and healthcare delivery are needed.

Traditional CRC screening methods, such as colonoscopy, are effective but come with inherent limitations. They demand meticulous preparation, occasional anaesthesia and carry some risks.[12] Even with skilled medical practitioners, small polyps may evade detection.[13] Thus, there is a pressing need for a test that is easy, safe, effective and accessible to a broader population. An example is faecal immunochemical testing (FIT)[14–16] and colon capsule endoscopy (CCE). FIT, which detects occult blood, is a simple and widely implemented screening modality. However, false positives and the need for subsequent colonoscopy present challenges.[14] CCE introduces a revolutionary approach by using a small camera enclosed in a pill. Recommendations by the National Health Service England (largest global experience of CCE) highlight the potential of CCE, especially for low-risk to intermediate-risk patients, in screening and diagnosing colonic conditions.[17]

The 5G-SUCCEEDS (Setting Up CCE Home Delivery System) is a pilot study focused on developing a 5G-connected CCE home delivery system.

There are two substudies within the 5G-SUCCEEDS initiative:

Carbon mapping: this substudy focuses on evaluating the environmental impact of the 5G-enabled home delivery system by mapping its carbon footprint. It aims to provide insights into how this new delivery model can contribute to sustainability goals within healthcare.

Assessment of patient satisfaction: this substudy assesses patient satisfaction with the 5G-enabled CCE home delivery service. It aims to gather detailed feedback from patients regarding their experiences, which will help refine and improve the service model. The feasibility study presented here builds on previous research[18] and tests a novel delivery approach that brings CCE directly to people's homes, using technology to enhance simplicity and safety. Home delivery of CCE requires cutting-edge technology including super-fast 5G internet[19] and the greater adoption and acceptance of telehealth following the COVID-19 pandemic.[20] We acknowledge that while the concept of at-home CCE is not entirely new, our study seeks to further optimise this approach.

METHODS

This prospective feasibility study of 25 patients was designed to test the feasibility, patient acceptability and carbon impact of delivering CCE to patients in their home and was conducted at a single hospital in England. Eligible patients were referred to the hospital from primary care with lower gastrointestinal (GI) symptoms. The study specifically targeted those at low or intermediate risk for CRC according to NHS England guidelines[21] and it included individuals in the postpolypectomy surveillance group as recommended by the British Society of Gastroenterology and the Association of Coloproctology of Great Britain and Ireland.[22]

Participant selection and recruitment

Participants were provided with the InteliGI Smartbox (figure 1) to facilitate the CCE procedure at home. The Smartbox contains the colon capsule itself, a recorder belt that captures data as the capsule passes through the GI tract, bowel preparation solutions and communication technology to allow remote monitoring and troubleshooting. To support participants throughout the CCE process, the Smartbox was equipped with a tablet that enabled video consultations. By switching on the tablet, participants could connect with clinician and nurse for

Figure 1 InteliGI Smartbox.

real-time video consultations. This feature allowed for remote monitoring, troubleshooting and guidance, ensuring that participants could receive immediate assistance and support during the entire procedure.

Eligibility criteria for the study included patients aged 18–65 years who were recommended by their clinician for CCE according to NHS England guidelines. Essential criteria included adequate hand and finger dexterity for interacting with the Smartbox and basic IT literacy to use the digital components of the procedure. IT skills were assessed by verifying the participants' ability to use a smartphone effectively, while dexterity was evaluated by inquiring about any joint problems or history of arthritis and ensuring that participants could open and close the Smartbox without difficulty and wear the recorder and CCE belt at home (online supplemental table 1).

Exclusion criteria included individuals unable or unwilling to provide informed consent, pregnant individuals and those with conditions, consistent with standard CCE exclusion guidelines. This approach ensured participant safety and adherence to established medical protocols.

Following screening, eligible patients were invited to participate in the CCE at home study and, if they consented, were put on the CCE home delivery pathway. Study participants received InteliGI Smartbox (figure 1) to their home containing the colon capsule and recorder belt, bowel preparation solutions and communication technology. Patient experience data were gathered via a paper questionnaire, included within the Smartbox, and through semi-structured interviews. The paper questionnaire was selected as the preferred method for data collection due to its ease of access within the box containing the CCE equipment, ensuring a secure means of return and completion. The questionnaire featured a mix of structured, closed-ended questions, including Likert scale items to assess satisfaction and ease of use, and open-ended questions that allowed participants to provide more detailed feedback. This questionnaire delved into four pivotal dimensions: equipment/technical issues, communication and rapport, clinical assessment and overall evaluation of the remote programme. In addition to the questionnaire, semi-structured interviews were conducted with a selected subset of participants to gain deeper insights into their experiences. These interviews followed a flexible guide, which allowed interviewers to explore participants' responses to the questionnaire in more detail, ask follow-up questions about their experience with the Smartbox and CCE process and understand any concerns or challenges they encountered during the procedure. We acknowledge several potential pitfalls in delivering expensive items, such as the Smartbox for remote CCE. These include logistical challenges, storage issues, insurance concerns and the need for patient education. To address these, we collaborated with CitySprint, a medical courier service, to streamline delivery processes. We established secure storage within the endoscopy department and ensured comprehensive insurance coverage so that that patients could easily follow the procedure. Additionally, a detailed video guide was created by the study group and made accessible through the tablet provided inside the Smartbox.

The 5G-SUCCEEDS initiative was implemented to address logistical challenges, improve security and provide patient-centred education and support. These measures were designed to facilitate the efficient and reliable home delivery of high-value medical items, such as the Smartbox.

Carbon footprint methods

Carbon footprint assessment measures greenhouse gas emissions resulting from a chain of activities, such as manufacturing a product or carrying out a procedure, using resources like energy and water.[23] The carbon dioxide equivalent (CO_2e) unit used in this study is typically used to measure carbon footprint and represents, for any quantity or type of greenhouse gas, the amount of CO_2e which would have the equivalent global warming impact. A comparative analysis of the CO_2e emissions was made for three distinct endoscopy pathways. The carbon impacts associated with three endoscopy pathways were grouped into three categories: patient travel, clinical procedures and pharmaceutical products. Assumptions made for each pathway are summarised below.

1. Conventional colonoscopy delivered within the hospital's endoscopy unit.
2. CCE procedure delivered at a clinical facility. The colon capsule is ingested at a clinical facility, followed by discharge, and subsequent patient travel to return equipment.
3. Home delivery of CCE (this study): the necessary equipment for a colon capsule is dispatched to the patient's home, where they communicate with their clinician via an electronic tablet over 5G for guidance on ingestion and positioning of equipment. The equipment is then collected afterwards.

Travel

Bowel preparation laxatives must be taken before the procedure, which can be collected either from a local community pharmacy or, in an estimated 50% of cases, by the patient attending the hospital to pick up these medications. The analysis of journeys to local community pharmacies is based on estimates of the average distance travelled to community pharmacies.[24] The distances from patients' homes in this study cohort to the endoscopy clinic at the University Hospital Coventry and Warwickshire (UHCW) have been used to estimate the CO_2e by applying the appropriate conversion factor as set out by the Department for Energy Security and Net Zero.[25] Unless otherwise stated, travel is assumed to be in a standard car or using patient transport. Staff travel to clinics has not been included in the models presented here as it is considered a fixed element of the service irrespective of patient pathway. However, we recognise that in this

Table 1 Base and optimised estimates for carbon footprint per patient by category for each pathway ($kgCO_2e$)

Scenario	Type	Pathway 1	Pathway 2	Pathway 3
Base case—using most conservative assumptions	Travel	6.62	17.09	12.67
	Procedure	5.46	3.87	3.87
	Pharma	0.02	0.01	0.01
	Total	12.10	20.98	16.56
Optimised case	Travel	2.52	7.99	1.36
	Procedure	3.06	1.56	1.56
	Pharma	0.02	0.01	0.01
	Total	5.60	9.57	2.94

CO_2e, carbon dioxide equivalent.

pilot, majority of CCE patients required subsequent flexible sigmoidoscopy or colonoscopy, limiting the extent to which clinic-based procedures were avoided. Therefore, while CCE may reduce the number of initial clinic-based colonoscopies, the need for follow-up procedures should be factored into future assessments of cost and logistics.

This may, however, be a significant factor in a larger reconfiguration of services where significant numbers of clinic-based colonoscopies were avoided. Based on these assumptions, several scenarios were modelled, the most conservative and optimistic of these are presented in table 1. The most conservative assumption is that all travel is conducted in an average-sized car using either diesel or petrol fuel (which are equivalent for an average-sized car), with a conversion factor of 0.27 $kgCO_2e$ per mile. All equipment deliveries in scenario 3 (scaled-up/milk-round approach to equipment delivery using logistic scheduling techniques) are assumed to be single deliveries requiring travel between hospital site and the patient's address.

Procedure

The carbon footprint of a standard endoscopy has been reported previously.[26–30] For all pathways, letters/information leaflets are sent by royal mail post. While the impact of this has been reviewed, it has not been included as part of the model as it is expected to be negligible in comparison with other factors. The environmental impact of the 5G hardware and Smartbox manufacture, as well as home delivery, has not been included in our calculations. Although the existing 5G network is used by the service, emissions associated with this network, along with the manufacturing of the 5G hardware and Smartbox, have not been accounted for in our analysis.

Pharmaceutical elements and medical devices

These elements were associated with lower carbon footprints. Laxatives used for bowel preparation were a part of all three pathways and were therefore excluded.

Patient acceptability and satisfaction with the home delivery of CCE services

We introduced a questionnaire designed to capture comprehensive participant feedback. Furthermore, participants engaged in quantitative interviews alongside the satisfaction questionnaire, enabling us to explore their perspectives on the CCE home delivery service in greater depth. The 5G-SUCCEEDS patient experience interview aimed to achieve several key objectives including levels of confidence, satisfaction, convenience and overall experience with the service. Assess patient acceptability and preferences regarding the 5G-SUCCEEDS study. Gather emerging learning points that can inform future service roll-out and improvements. Identify and consolidate key considerations for future roll-out of the service. The study focused on a subset of participants from the 5G-SUCCEEDS study. Eligible participants for this substudy were required to have been part of the 5G-SUCCEEDS study, to have already undergone their CCE procedure and to express their willingness to participate in an interview led by an evaluator specialised in conducting quantitative interviews. Recruitment was conducted by UHCW clinicians, who approached potential participants based on convenience, taking into consideration available time and resources. Interviews were conducted and recorded using either telephone calls or Microsoft Teams, depending on each patient's preference. The interviews took place between 1 and 7 months after the CCE procedure. Interview recordings were transcribed and processed using qualitative data management and analysis software, NVivo V.14 by Lumivero. The thematic coding strategy followed closely to that of Bond *et al*,[31] using the Non-adoption, Abandonment, Scale-up, Spread and Sustainability framework as a basis for organising and coding the data. This framework encompassed multiple domains, including condition or illness, technology, value proposition, adopter system (comprising professional staff, patients and lay caregivers), organisation, wider institutional and societal context and interaction and mutual adaptation between these domains over time.

Table 2 Baseline characteristics

Median age (SD)		53 (9.8)
Gender	Female	8 (32 %)
	Male	17 (68 %)
Ethnicity	White	24 (96 %)
	Black	1 (4 %)
Mean Hb (g/L) (SD); n		145 (14.8); 25
Mean creatinine (µmol/L) (SD)		81 (11.9)
Mean BMI (SD)		25 (3.3)
FIT (µg Hb/g)	>7	4 (16%)
	<7	12 (48%)
	N/A	9 (36%)
Reason for referral	Postpolypectomy surveillance	9 (36%)
	CIBH	10 (40%)
	FIT positive	1 (4%)
	CIBH, abdominal pain	1 (4%)
	CIBH, per rectal bleed	3 (12%)
	Black stool, normal gastroscopy	1 (4%)

Values are n (%) unless otherwise stated.
BMI, body mass index; CIBH, change in bowel habit; FIT, faecal immunochemical test; Hb, haemoglobin; N/A, not available.

RESULTS

Feasibility

From December 2022 to September 2023, 32 eligible patients were referred for bowel/colon investigations. Of these, 26 patients consented to participate in the study, while 6 patients did not consent. One patient withdrew due to an inability to complete the bowel prep, leaving a total of 25 participants. Baseline patient characteristics and reasons for referral are shown in table 2. Out of 25 participants, 8 (32%) were female and 17 (68%) were male with a mean age of 51 years. 24 (96%) participants identified as white and 1 (4%) identified as black.

Out of the 25 participants, 9 (36%) were recruited from the postpolypectomy surveillance group (did not require FIT test, see 'Methods' section) and 16 (64%) were from the symptomatic group (experiencing lower GI symptoms, see 'Methods' section). Of those who completed the FIT, 4 (25%) had FIT results >7 and 12 (75%) had results <7 µg Hb/g.

Our study evaluated three endoscopy pathways: hospital-based colonoscopy (pathway 1), clinical facility-based CCE (pathway 2) and home-delivered CCE (pathway 3). We conducted a comparative analysis of the CO_2e emissions for these distinct endoscopy pathways. In this study, we specifically examined pathway 3, which involved home delivery of the InteliGI Smartbox.

The Smartbox contained all the components needed for bowel preparation, the colon capsule, a recorder belt to capture images from the colon capsule and an electronic tablet for video consultation with clinicians (figure 1).

Out of 26 patients, 25 successfully completed the procedure, as one could not complete the bowel preparation. Evaluation of bowel cleaning using the Colon Capsule Cleansing Assessment and Report grading scale revealed that 60% achieved good cleansing, while 32% had inadequate cleansing.

No major complications occurred in this cohort of patients. Following CCE, 18 out of 25 participants underwent further testing, while 7 participants (28%) did not require additional examinations. Among those who underwent further testing, 8 participants (44%) did so due to an incomplete exam, while 10 participants (56%) underwent additional tests based on the discovery of polyps. Completeness of the CCE examination was defined as achieving a comprehensive video recording of the colon and rectum with adequate cleansing (figure 2).

Colonoscopy was the most common further procedure performed in 89% of the 18 participants that required further investigation, followed by flexible sigmoidoscopy in 11%. In participants who underwent further investigations, 56% had polyps, 17% had normal findings and 22% had other non-clinically significant findings, such as diverticulosis. One participant (5%) declined further investigation after the initial capsule endoscopy (figure 2). Similar to the initial colonoscopy findings, the majority of polyps detected during further investigations were small. No cases of CRC were identified among the participants.

Participant experiences and satisfaction

A paper patient satisfaction questionnaire was provided and collected from each participant with the Smartbox.

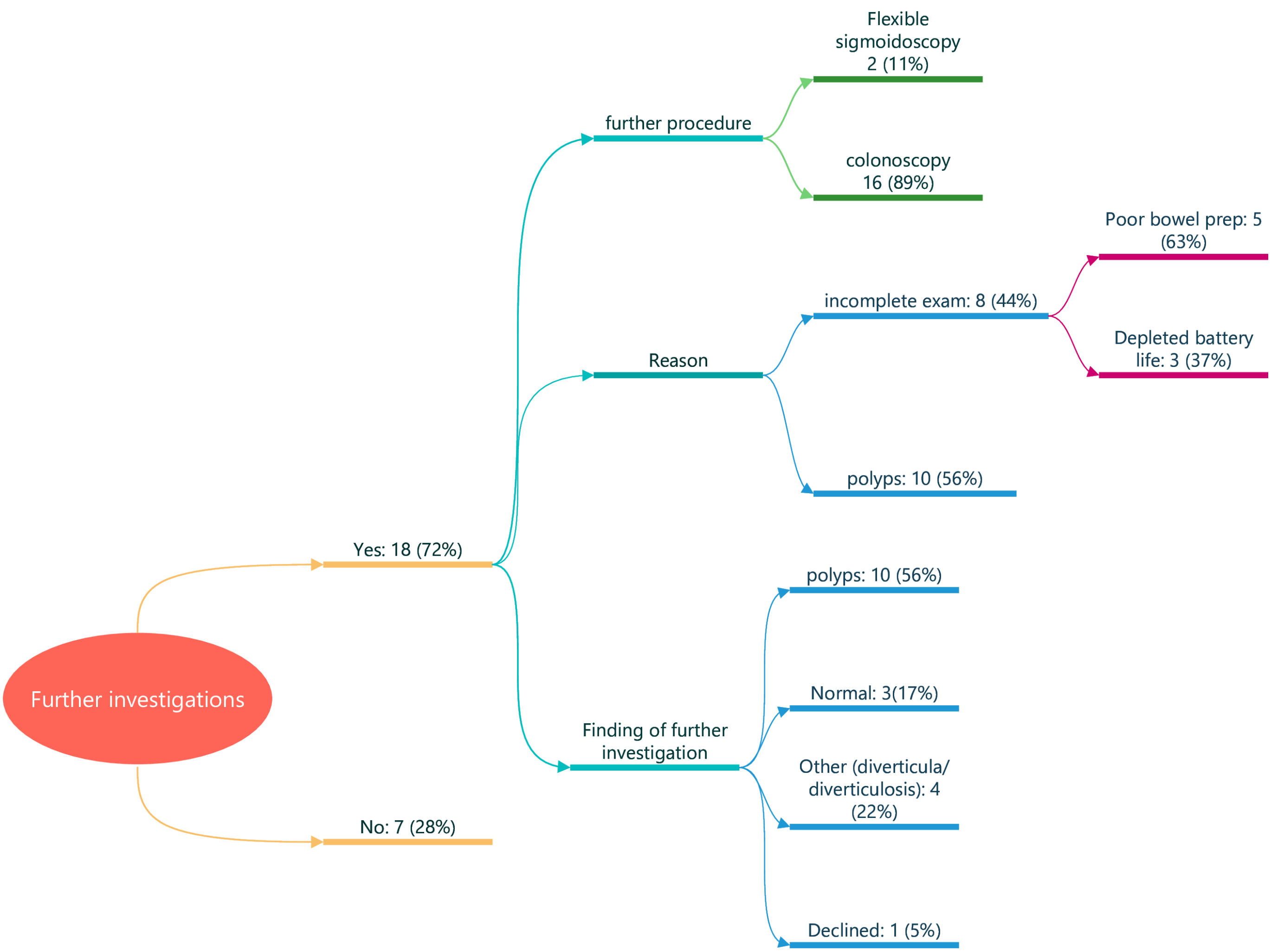

Figure 2 Flow diagram: completion rate and findings of CCE, findings of further investigations and pathology detected in both CCE and subsequent endoscopy. CCE, colon capsule endoscopy.

22 (88%) participants completed the questionnaire. A subset of participants (n=8, 32%) also participated in semi-structured interviews with an independent interviewer to capture their experiences and learning points for future roll-out and scale-up.

Participants expressed high satisfaction with the procedure, with 68% being 'very satisfied' and 32% 'satisfied' (figure 3). Patients who were interviewed reported finding the at-home CCE a convenient and comfortable alternative to hospital-based colonoscopy. Almost all interviewees took time off work for the entire duration of the procedure, citing a desire to remain near toilet facilities as the main reason for wanting to be at home. Within the home, the procedure did not significantly disrupt their daily activities.

In interviews, participants universally reported the bowel cleansing process to be the most challenging aspect of the procedure. They described the bowel preparation solutions as having an unpleasant taste and some struggled with the volume of liquid to be consumed. However, 77% of survey respondents reported the bowel preparation as being either 'easy' or 'very easy' to use.

Most (86%) of survey respondents scored the equipment as being easy to use (figure 3). Participants described the video consultation with clinicians as essential during the setup of the equipment and the swallowing of the capsule. The video consultation allowed clinicians to guide patients through setting up the belt and holster, providing reassurance for swallowing the capsule, which some found larger than expected. All patients successfully swallowed the capsule without issues. The support needed at home varied among patients. While one patient had no physical support but had the option to call a nurse if needed, others had friends or family members who assisted with different aspects of the procedure.

All but one of the patients interviewed who had experienced both CCE and colonoscopy (n=5) stated they would choose to have a CCE again if it meant avoiding a colonoscopy. Participants cited the lack of sedation and the freedom to perform the procedure at home as key reasons for their preference. Additionally, 82% of survey respondents (n=22) reported being very likely or likely to have remote CCE if clinically indicated in the future.

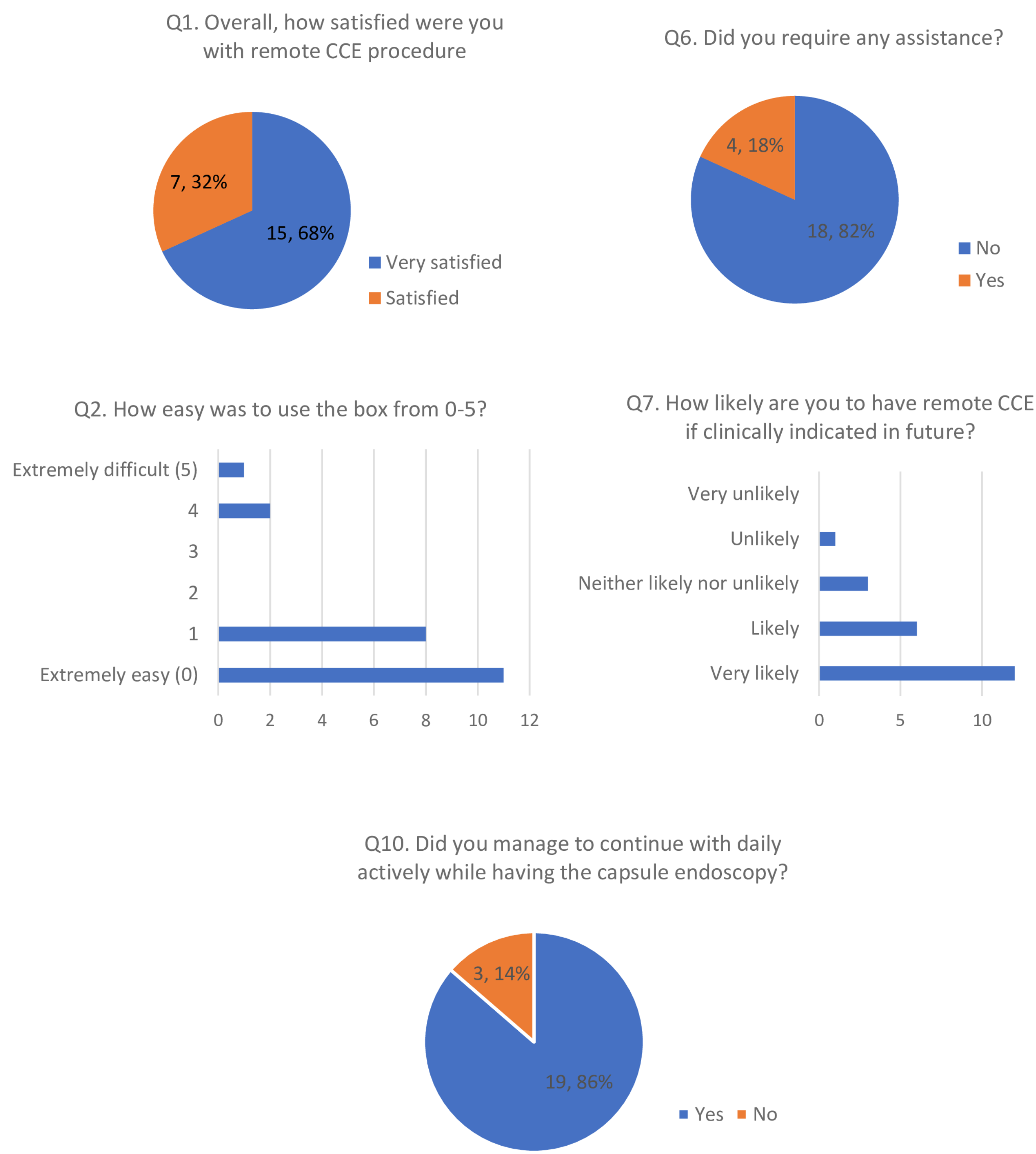

Figure 3 Patient experience. CCE, colon capsule endoscopy.

Carbon mapping

Clinical procedures generate carbon emissions through a variety of means, the mapping of which has come into sharp focus over the last decade.[26] Gastroenterology is recognised as a resource-intensive clinical area, contributing substantially to greenhouse gas emissions and waste generation.[27]

Pathway 1—colonoscopy

The contribution of patient travel to the carbon footprint was considered. Bowel preparation laxatives need to be taken before the procedure and can be collected from a local community pharmacy. In an estimated 50% of cases, patients are required to attend the hospital to pick up these medications. Patients also need to travel to the hospital site for the procedure itself. Given that they are required to take bowel preparation before the procedure and are likely to be sedated, travel is assumed to occur in a standard car or via patient transport.

The carbon footprint of a standard endoscopy procedure has been reported as 4.8 $kgCO_2e$ based on energy usage and waste disposal.[28 29] Additionally, it is estimated that in 78% cases[30] polyps will be removed during the colonoscopy procedure. Previous estimates of greenhouse emissions of GI biopsies in a surgical pathology laboratory[32] have been applied to estimate the carbon footprint of polyp removal based on a UK study[33] as 0.47 kgCO_2e. These figures have been used to estimate the carbon impact of the procedure for pathway 1—colonoscopy (a small element has also been included for emissions associated with running an office to provide prescription services). It is noted in this study that there is potential to reduce the carbon footprint by, for example, varying the number of sample pots used in the procedure. The figures for the base case are taken from this study prior to any optimisation.

All pathways involve the use of laxatives for bowel preparation, but their carbon footprint is not well reported[34] and is excluded from the study. The pharmaceutical products in pathway 1 are sedation and analgesia medicines used in most colonoscopy procedures, the most common sedation medicines being fentanyl and midazolam. Here, the carbon footprint of intramuscular morphine has been used as a proxy.[35]

Pathways 2 and 3—CCE pathways

For pathway 2, the patient travels to the colonoscopy unit to collect the initial bowel preparation, swallow the colon capsule and to return the belt as this is reusable equipment. Some of these journeys may involve public transport when the patient has not yet taken the bowel preparation medication.

For pathway 3, patient travel is eliminated and only occurs in exceptional cases—specifically, if a patient is referred for an X-ray (which was 1.5% of cases reported previously and none required in this study) or directed into pathway 1 for a colonoscopy. Instead, the carbon footprint of a courier service delivering and collecting the Smartbox from the patient's home using a standard car is considered.

Pathways 2 and 3 follow the same procedure using the Medtronic colonoscopy capsule, although the delivery methods differ. The carbon footprint of the Medtronic colonoscopy capsules is not reported; however, it is recognised that they contribute to emissions arising from the manufacturing supply chain. In line with Department for Environment, Food, and Rural Affairs (DEFRA) guidance,[25] as these emissions take place outside of the UK, they are excluded from this analysis.

The base case reflects the carbon emissions associated with the current pathways and procedures used at UHCW the time of this study (pathway 3). In a small-scale study involving 25 patients in a conservative scenario, pathway 3 (delivery at home) has a lower carbon footprint compared with pathway 2 (CCE delivered in a clinic), but it remains higher than pathway 1 (colonoscopy).

The carbon footprint of each pathway was also calculated under the assumption of optimisation, based on possible improvements that could be made to the pathways.

In the optimised case (table 1), travel is assumed to occur via electric vehicles, with public transport used where appropriate. For pathway 3, a milk-round style of courier deliveries reflects what the pathway could look like if delivered at scale. Additionally, emissions from colonoscopy procedures were assumed to be 50% greener, which is achievable through the implementation of green initiatives and the use of renewable energy sources.[31] The lowest conversion rate of CCE to colonoscopy was also used, reflecting the efficiency of CCE in reducing the need for follow-up colonoscopies.

DISCUSSION

The primary objective of this study was to assess the feasibility of providing a home-delivered CCE service. Feasibility was evaluated based on several key factors: whether patients could follow the instructions, successfully take the bowel preparation, swallow the capsule without difficulty and complete the CCE examination. We found that logistically and technically, it was feasible to run a clinical, remote CCE service and that patients found this service to be acceptable and, generally, preferable to a clinic-managed CCE service or undergoing traditional colonoscopy, citing undertaking the procedure within a familiar, comfortable environment as the main benefit. It is important to note that during the consenting process, patients were informed of the possibility of needing a subsequent endoscopy if the CCE detected a pathology or if the test was incomplete. No instances of severe discomfort or complications were reported during the trial.

A substantial portion of eligible participants enthusiastically embraced the concept of home-livered CCE services and effectively used the provided Smartbox device. The integration of a virtual assistant proved highly advantageous, with participants expressing notable satisfaction, particularly concerning the convenience of conducting the procedure at home. CCE delivered at home offers significant opportunities to reduce carbon impacts if using a scaled-up model. Transport impacts of the delivery and collection of the Smartbox is controlled by the health provider. There are opportunities to use a 'milk-round' scheduling approach with electric vehicles. This could be both for pathway 3 and for any patient transport provided. This aligns with the NHS net zero travel and transport strategy, which states 'By 2035, all vehicles owned and leased by the NHS will be zero-emission vehicles (excluding ambulances), and all non-emergency patient transport services will be undertaken in zero-emission vehicles'.[36] In a scaled-up model, the Smartboxes can be stored in community locations, and imaging analysis may also be conducted in satellite locations to further reduce travel distances. There is the potential also to minimize the travel required by staff.

Reducing the carbon impact of pathway 1 affects the overall carbon impact of pathways 2 and 3, given the conversion rate for patients recommended for a follow-up colonoscopy appointment. The need for a second test has been factored into the carbon footprint calculations for these pathways. While some of these changes cannot be implemented in the short term, they are possible with the scaling up of pathways and the reconfiguration of diagnostic centres. We acknowledge certain limitations. Our sample size was relatively small, and the study duration was limited. Long-term studies with larger cohorts are needed to further evaluate effectiveness in this regard. Additionally, socioeconomic status and educational qualifications were not specifically assessed in this pilot study, which may affect our understanding of how these factors impact patient acceptability and the potential for widespread adoption. Future studies should incorporate these variables to better assess their influence on the feasibility and acceptance of home delivery of medical devices.

Targeting the right cohort is crucial, as high-risk patients for polyps or poor preparation may not benefit as intended. Much larger and comparative studies are needed to fully understand the benefits and drawbacks of this technology. Efforts should be made to make remote CCE accessible to underserved and remote populations. Telemedicine networks and mobile clinics equipped with this technology could bring advanced healthcare services to areas with limited access to specialised medical facilities. However, as telehealth becomes more widespread, it is critical to consider its potential to exacerbate disparities in care. Challenges such as accessing technology and digital literacy disproportionately impact older patients and those living in poverty.[37] Addressing these digital disparities is essential to ensure that remote CCE and other telemedicine innovations do not inadvertently deepen existing health inequities but rather help bridge these gaps in care.

In conclusion, our study demonstrates the feasibility and patient acceptability of remote capsule endoscopy as a non-invasive alternative for CRC screening, particularly in terms of patient satisfaction and engagement. The study highlights the potential of CCE to enhance the patient experience and address health inequalities by providing a more accessible screening option. However, challenges such as the need for additional tests, along with their impact on overall costs and carbon footprint, must be addressed through improved selection of participants for CCE or colonoscopy.

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Contributors GJN: conceptualisation, methodology, data curation, writing—original draft preparation. CC, FW, SD: investigation, writing—review and editing. LS, BBL, BL, JC, HW, CS, SE: review. RA: supervision, writing—review and editing. GJN is the guarantor of this work and, as such, had full access to all the data in the study.

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Competing interests None declared.

Patient consent for publication Not applicable.

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