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Green endoscopy: British Society of Gastroenterology (BSG), Joint Accreditation Group (JAG) and Centre for Sustainable Health (CSH) joint consensus on practical measures for environmental sustainability in endoscopy

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ABSTRACT
GI endoscopy is highly resource-intensive with a significant contribution to greenhouse gas (GHG) emissions and waste generation. Sustainable endoscopy in the context of climate change is now the focus of mainstream discussions between endoscopy providers, units and professional societies. In addition to broader global challenges, there are some specific measures relevant to endoscopy units and their practices, which could significantly reduce environmental impact. Awareness of these issues and guidance on practical interventions to mitigate the carbon footprint of GI endoscopy are lacking. In this consensus, we discuss practical measures to reduce the impact of endoscopy on the environment applicable to endoscopy units and practitioners. Adoption of these measures will facilitate and promote new practices and the evolution of a more sustainable specialty.

INTRODUCTION
The healthcare sector is responsible for 4.4% of total greenhouse gas (GHG) emissions worldwide.[1 2] As a high-throughput specialty, with typical national volumes reaching several million procedures annually,[3 4] endoscopy is held to be the third highest hazardous waste generating department in a hospital, per daily occupied bed (after anaesthetics and paediatrics/intensive care) and the second overall (average monthly) waste generator per clinical procedure after radiology.[5 6] In addition to patient volumes, routine endoscopic procedures incur frequent use of single-use items, resource-heavy decontamination, water consumption, significant demands on administration, patient and staff travel as well as high energy consumption in physical estates.

Based on operational energy usage and plastic waste from endoscopic procedures alone, the estimated carbon footprint of endoscopy in the USA stands at 85 768 metric tonnes of CO_2 emission annually, equivalent to >9 million gallons of gasoline consumed, 94 million pounds of coal burned and 212 million miles driven in an average non-electric car.[6 7]

In the context of reducing the environmental impact of healthcare, there is now considerable interest in the carbon footprint and GHG impact of gastroenterology, hepatology and GI endoscopy practice.[8–11]

There is a need for urgent change, without compromising the patient care, clinical standards or training needs. A high-quality evidence base of the actual carbon footprint of clinical activity and various elements of endoscopic procedures is presently lacking, and while more research needs to be done to generate this evidence, there is recognition that steps need to be taken now to protect our planet.

The National Health Service (NHS) in the UK is one of the first national healthcare systems that has made a policy direction towards net-zero, enshrined in legislation with a pledge to reach this target by 2040, and an 80% reduction by 2028–2032.[12] The recent Conference of Parties Health Programme[13] has recommended initiatives to build climate-resilient health systems and raising awareness through healthcare professionals to advocate change. The British Society of Gastroenterology (BSG), together with partner stakeholder organisations in endoscopic practice, Joint Advisory Group for GI Endoscopy (JAG) and the Centre for Sustainable Healthcare (CSH) recognised the need for a consensus document on pragmatic and practical measures that can be taken to minimise the environmental impact of endoscopy and this paper is the first attempt towards moving to a carbon neutral status for endoscopy practice.

METHODOLOGY

In line with accepted principles, these expert opinion consensus and practice position statements have been developed in an area where there is insufficient scientific evidence to produce formal guidelines. The process was compliant with the BSG guideline advice document.[14] Members of the BSG, JAG and the CSH were invited to participate based on their methodological expertise, publication record, accomplishments or experience in the field and commitment to the project. Invited members were divided into four working groups (WGs) focusing on key thematic and subthematic areas relevant to routine endoscopy practice requiring practical guidance. These areas were identified based on the previous work from the Green Endoscopy Group[15 16] and in line with BSG Strategy on Sustainability.[17] The topics of the WGs were: WG 1—functional organisation of a green endoscopy unit, WG 2—sustainable practice related to the endoscopy procedure, WG 3—sustainability practices related to endoscopy environment and WG 4—sustainable postprocedural practices.

The WG members performed a systematic literature search for each assigned topic with the appropriate keywords/Medical Subject Headings terms using Medline/PubMed, Cochrane database and conference abstracts. Outputs were then used to formulate draft practice position statements with the supporting text and references. The statements were further developed using a Delphi methodology[18] incorporating three successive rounds. The Delphi consensus group, in addition to the WGs, consisted of content and topic experts from members of the BSG Sustainability Committee, BSG Endoscopy Committee and The Clinical Standards and Service Committee.

The first round was web-based with anonymous voting using a custom built survey, using a 5-point scale for each statement, inviting feedback comments, exchange of available evidence and suggestions returned to the individual WGs to be included into the iterative development of the final statements. The second Delphi round was a dedicated web meeting involving all available participants on 21 April 2022, with discussion and revision of statements. A total of 25 current practice positions were accepted when ≥80% of participants agreed to the text of the statements. Statements and recommendations not reaching 80% consensus agreement following three rounds of voting were removed. The final manuscript was drafted for consistency by the three coordinators (SS, ADhar, B'HH) before a final review and approval by all WG participants. The document was then submitted for review to BSG, JAG and CSH for endorsement and approval.

The WGs identified a number of areas where evidence was insufficient to provide recommendations for practice and have incorporated areas where further research is desirable to support best practice guidelines.

Statements

Working group 1: functional organisation of a green endoscopy unit

Practice position statement 1:1

We recommend adherence to relevant professional guidelines to ensure clinical appropriateness for all endoscopic procedures.

Of the 'three Rs' (reduce, reuse, recycle) principles that govern attempts to reduce carbon footprint, reducing unnecessary endoscopy procedures is likely to have a significant impact. It is estimated that up to 56% of referrals for upper GI endoscopies and between 23% and 52% for colonoscopies may be inappropriate.[19 20] Of particular note is the low yield of endoscopic procedures in guiding management of some chronic scenarios such as endoscopy for simple dyspepsia and colonoscopy for constipation.[21] Furthermore, the value of screening and surveillance colonoscopy in average risk populations and in frail elderly or where the screening intervals exceed estimated life expectancy has been challenged.[22 23] Establishing guideline-supported referral pathways, enhanced departmental vetting procedures and regular educational activities to update emerging evidence for appropriate use of endoscopy are steps which endoscopy units can take to ensure the appropriateness of endoscopic procedures.[16 24] While recognising that endoscopy is a key component in the diagnosis and management of GI conditions, conventional diagnostic endoscopy can be replaced by alternative technologies in a number of clinical settings to minimise the number of procedures being carried out. An example of this approach is the practice of screening endoscopy for oesophagogastric varices in patients with cirrhosis and portal hypertension. The Baveno VII Consensus in Portal Hypertension suggests that liver stiffness measurement by transient elastography <15 kPa together with a platelet count of $>150\times10^9$/L rules out clinically significant portal hypertension in compensated advanced chronic liver disease.[25] These patients therefore do not need an endoscopy for assessment of varices. Similarly, non-selective beta-blockers (NSBB) are effective in reducing hepatic venous wedge pressure in patients with clinically significant portal hypertension and only those patients who are not candidates for NSBB may need endoscopic screening.[26] Similarly, it has been suggested that gastric ulcers which look benign macroscopically, have a low-risk score based on location and size and have six negative biopsies may not need endoscopic surveillance as currently recommended by most societies.[27] Coeliac disease can be diagnosed and monitored using serological testing, thereby limiting the need for endoscopic biopsy confirmation to a small number of selected patients.[28] Similarly non-invasive tests such as faecal calprotectin can be used to avoid unnecessary endoscopic procedures[29] with a low likelihood of significant pathology. Finally, up to 80% reduction in colonoscopy-based postpolypectomy surveillance can be achieved by discharging patients to stool testing-based[30] national screening programmes as per the British[31] and European[32] guidelines. Another important consideration is avoiding the need for re-do procedures by having a multidisciplinary team planning in complex cases (eg, large polyps, complex Endoscopic Retrograde Cholangio Pancreatography (ERCP)) to place patients in appropriate specialist lists. Overall, minimising unnecessary procedures can be achieved by innovating alternative options to endoscopy, and by implementing strict evidence-based referral and surveillance algorithms.

While this approach should be regarded as the foundation for a programme of sustainable practice change, it should be recognised that demand for endoscopy tends to increase year-on-year,[11] so other measures must be employed to ensure that those procedures still performed are as efficient as possible.

Practice position statement 1:2

We recommend that sustainable alternatives to conventional diagnostic endoscopy should be considered in all patients where clinically indicated. These might include Cytosponge for Barrett's oesophagus surveillance, CT colonography and colon capsule endoscopy for bowel cancer screening.

Diagnostic (non-therapeutic) upper and lower GI procedures are the bulk of any endoscopy practice, facilitating diagnosis and management of upper and lower GI conditions, excluding cancer in symptomatic patients and as part of a population screening programme (either primary or after stratification by faecal immunochemical test (FIT)).[11] Modalities like colon capsule endoscopy (CCE) and CT colonography (CTC)[33–36] could be more cost-effective and less environmentally impactful but should be evaluated for their cost-effectiveness and environmental impact compared with their equivalent endoscopic procedures. CCE can be performed in primary healthcare settings and may involve retrievable hardware, reducing patient travel as well as negating the carbon footprint of 'traditional' colonoscopy.[34] Incorporation of artificial intelligence in the detection and diagnosis of small polyps during CCE and cloud-based reporting could hasten the adoption of this technology.

There is suggestion in the literature of overutilisation of endoscopy for surveillance of Barrett's oesophagus,[37] while the novel Cytosponge has been shown to be effective in the diagnosis of dysplasia and cellular atypia in a number of studies in the UK (BEST 2, ISRCTN12730505 and BEST 3, ISRCTN68382401 clinical trials). A recent trial demonstrated the effectiveness of using a Cytosponge biomarker panel and clinical risk factors to prioritise endoscopic Barrett's oesophagus surveillance across multiple centres in the UK during COVID-19.[38] In this study, cellular biomarkers of atypia, p53 overexpression were combined with clinical risk factors of age, sex and length of Barrett's segment. Although the carbon footprint of this strategy has not been assessed, it is likely to be less than endoscopy. This strategy can also be implemented in primary healthcare settings and the cytological analysis automated using artificial intelligence.

System-wide service design across regions and integrated care systems may be required for the increased use, where possible, of non-endoscopy procedures such as colon capsules and Cytosponge. These may be provided in Rapid Cancer Diagnostic Centres and community endoscopy hubs, where travel will be less for patients.

Practice position statement 1:3

We recommend that evidence-based methods including simulation and online image libraries should play a role in sustainable endoscopy training.

Endoscopy training faced significant challenges even prior to the COVID-19 pandemic, with 50% of gastroenterologists in the UK, for instance, attaining Certification of Completion of Gastroenterology Training without full colonoscopy sign off.[39–41] If a move to more rational use of endoscopy with green endoscopy is successful, this could represent an additional challenge to training.

The use of simulation represents an evidence-based mitigation strategy to improve training. Demonstrable outcomes include faster overall time to sign-off, higher rates of duodenal (D2) intubation and completion, superior competency scores and aggregate measures of competency.[42–47] This may be of greatest utility in early training, however, with several studies showing a 'saturation effect' after a certain number of simulated procedures, where additional training with simulators does not appear to offer increased benefit.[48–52]

Simulation is likely to be most useful when combined with other evidence-based interventions to improve the overall quality of endoscopy training,[53] including hands-on courses, training for trainers and education on human factors.[54 55 56]

Lesion recognition has been shown to be possible using digital image libraries as well as video recordings of endoscopic procedures and there is good evidence to suggest that this can be achieved in neoplasia detection and characterisation in Barrett's oesophagus (Barrett's Oesophagus Related Neoplasia project).[57] The use of artificial intelligence in detection of neoplastic lesions is likely to further reduce the number of endoscopies needed to achieve competence among trainees.[58]

Practice position statement 1:4

We recommend providing digital patient information and communications to support a sustainable endoscopy unit; however, provision will be needed for patients/service users who require paper copies.

It is universally accepted that structured, comprehensive written information is beneficial for patients undergoing endoscopy.[59] As patients become increasingly engaged in their own healthcare, supported by the growth of information technology, access to patient information in a digital format can be transformative.[60 61]

Many, but not all, are familiar with using digital methods for obtaining information in most aspects of daily life and a recent study,[62] identified that 71% of patients had used quick response codes (QR codes) in the past; the study also demonstrated that this also has the added benefit of environment impact. In endoscopy, personalised digital support at each stage would optimise communication between the patient and healthcare providers.

While there is a literature on digital patient information, the main focus is on retention of information or outcomes rather than environmental consequences, but a number of examples exist.[63] Interactive text message-based systems used in scheduling appointments improve non-attendance rates,[64 65] while patient-facing digital technology can be used in scheduling communications and in pre-assessment.[66]

Disparities in the access to digital information and technologies (the 'digital divide') and its various contributing factors have been identified and must be addressed in any programme of change incorporating these strategies.[67]

Working group 2: sustainable endoscopic procedure-related practices

Practice position statement 2:1

We recommend that, where clinically appropriate, combined procedures ('bidirectional' upper and lower GI endoscopy) should be booked on the same day.

While there is a paucity of evidence for the carbon footprint of bidirectional endoscopy (compared with separate-day procedures), it can be assumed that combining procedures would be associated with the minimisation of patient travel and hospital visits, use of resources such as personal protective equipment (PPE)[9] and clinical consumables (plastic peripherals, tubing, instruments such as biopsy forceps can be shared between procedures)[68]; water and energy; administrative tasks. There is considerable clinical evidence to support the use of bidirectional endoscopy where appropriate, including shorter stays, reduced medical costs such as single-time sedation and fewer missed workdays[69] and that this approach can be employed in differing healthcare funding environments.[70]

Upper GI endoscopy before colonoscopy has been shown to be the optimal sequence since it leads to reduced sedation levels and shorter recovery times.[71 72] It is therefore reasonable to recommend that, where clinically appropriate, bidirectional endoscopy should be preferred as a strategy to minimise the carbon footprint of the two procedures being done on different days. In addition, where appropriate additional tests such as CT staging for cancers and any blood tests should all be performed on the same day and medical treatment prescriptions required postendoscopy also given on the same day.

Practice position statement 2:2

The environmental impact of a pathway employing single-use endoscopes is not yet clear. We recommend that their use should be restricted to select indications and environmental impact taken into account.

The emergence of single-use endoscopes for GI endoscopy is a relatively new phenomenon,[73] while there is more data available for other indications (eg, endotracheal intubation, bronchoscopy and cystoscopy).[74 75] The avoidance, wherever possible, of the use of new ('virgin') plastics is a general central tenetof environmental sustainability.[76] While this appears to be at odds with the introduction of single-use endoscopes, robust life-cycle assessment and estimation of the waste and carbon footprint of the entire endoscopy pathway has yet to be completed. Although single-use disposable endoscopes may incur lower acquisition costs, no reprocessing costs and no risk of cross-contamination, there are major concerns around plastic pollution and increase in net waste raised by early attempts to measure the impact of these technologies compared with existing practice.[77–79]

The clinical argument for the introduction of single-use endoscopes is the elimination of transmissible infections through endoscopes. In GI endoscopy, infectious outbreaks predominantly linked to duodenoscopes have been widely publicised[80–85] and are related to the finding of resistant biofilms or infectious microparticles on endoscopes that have been through an established decontamination process.[86–88] However, these data are incomplete and may vastly overestimate the risk of transmissible infection through either gastroscopes or colonoscopes.[89–91] It is worth noting that, in healthcare environments with strictly regulated and centrally determined decontamination procedures, there have been no such reported outbreaks.[92–94] A recent study[95] concluded that CO_2 emissions associated with single-use scopes is 24–47 times that of reusable scopes, with manufacturing accounting for over 90% of the greenhouse gas emissions. In this specific context, the use of disposable elevator caps might be a more sustainable alternative to disposable complete duodenoscopes[95–98] and is recommended for further evaluation by national bodies.[99] A reduction in transmissible infections after ERCP may therefore be achieved by innovations to endoscope design, optimising decontamination and reprocessing[100] as well as adoption of quality assurance measures.[77] A biofilm is an inevitable byproduct of an endoscope coming in contact with biological fluids in the digestive tract and important for transmission of infections. An essential element of destroying this biofilm relies on a chemical disinfectant being able to destroy a polysaccharide network, both by manual disinfection followed by automated disinfection.[78] The biofilm in the distal attachment of duodneoscopes are resistant to chemical disinfection due to their complex architecture. Gastroscopes and Colonoscopes do not have the complex distal architecture that duodenoscopes do, and hence are easier to clean. Practically no cases of gastroscope or colonoscope related transmission of infection have been reported in the United Kingdom, due to stringent policies for scope disinfection and manual cleaning of the biopsy channel. The distal attachment in duodenoscopes has been considered the most important site for bacterial colonisation and disposable distal attachments are a potential option for minimising transmission. More research needs to be done to compare bacterial colonisation in biofilms in these scopes compared with fully disposable single-use duodenoscopes. It needs to be emphasised that inadequate scope reprocessing (including drying) is the leading cause of biofilm-related scope contamination. More data on the infectious potential of endoscopes (either correctly or inadequately processed) are therefore required to make sense of this claim in the context of single-use instruments.[79]

It is acknowledged that reprocessing of reusable scopes is resource-heavy, using as much as 22–30 gallons of water per cycle, disinfectants, detergents and up to 25 kW electricity per day.[7] Single-use disposable endoscopic supplies generate approximately 2 kg of waste per procedure and although waste from reprocessing would decrease, overall disposable waste was projected to be increased by 40% even after accounting for reprocessing.[101] Single-use endoscopes have an impact on natural resources during production, and are likely to have a greater carbon footprint in manufacturing and transport, generating more waste outside of the procedure itself. A preliminary life cycle analysis using single-use endoscopes, with an assumed infection rate of 0.02%, was estimated to generate 20 times the CO_2 emissions of reusable duodenoscopes with production accounting for 96% of the carbon footprint.[102] These data are in conflict with studies using disposable bronchoscopes and ureteroscopes which did not demonstrate a higher carbon footprint.[103 104]

At present, given the uncertainty, we recommend that single-use duodenoscopes be restricted to highly selective indications where: infectious risk is of heightened concern; safe and effective decontamination represents a significant challenge; the risk of not performing endoscopy is an overriding concern. In all situations, an honest acknowledgement of the environmental impact should be a key consideration for decision-makers.

Practice position statement 2:3

Design of new decontamination units must include sustainability as an explicit criterion for procurement of hardware and consumables.

The resource-heavy process of endoscope reprocessing may be subdivided into precleaning, cleaning, disinfection, rinsing, drying and cleaning of reusable components.[4] Each endoscopy wash machine incurs approximately 24.67 kWh equating to 0.017tonnes of CO_2 equivalent per day[7] and the use of sterile water in decontamination is mandated by manufacturers and guidance from societies.[105] The washers, dryers and storage solutions—either combined or independently—should therefore enable an endoscope decontamination process that is sustainably enhanced by reducing the amount of water required per endoscope cleaned (expressed in litres per cycle); reducing energy consumption overall (expressed in CO_2 equivalent per cycle); reducing plastic usage and waste (expressed in g per cycle).[106]

The chemicals needed in the wash cycle should minimise environmental impact with suggested characteristics of pH neutrality, biodegradability, marine life safety certification. Consideration could also be given to whether these are created and supplied with minimal environmental impact (containers, shipping, plastic waste and recycling programmes including collection of empty containers from site, electric delivery fleet). In addition, consideration of safety of the chemicals used for the personnel involved in decontamination should also be considered. Consumables should be made from materials that are either themselves made from recycled or sustainably sourced materials and/or can be recycled at end-of-use. It is not clear at present whether such products exist, but it is likely that these can be manufactured and increasing demand from users will drive innovation in this field.

Practice position statement 2:4

Water is used in endoscope decontamination, peri-procedural flushes and for immersion colonoscopy. We recommend that an agreed standard operating procedure should exist to ensure rationalisation and minimisation of water use.

Practice position statement 2:5

We recommend that tap water may be used for manual flushes through the biopsy valve during endoscopy, but not through automated flushing systems. The use of filtered water could be an alternative, subject to local agreement and protocols, in all scenarios.

Practice position statement 2:6

We recommend further research into sustainable alternatives to mitigate the environmental impact of sterile water use in the endoscopy unit, while meeting infection control standards.

A significant amount of sterile water packaged in plastic bottles is used in endoscopy.[107] Endoscope manufacturers' guidance specifies the use of sterile water in decontamination and through auxiliary water-jet channels. In addition, sterile bottled water is often used for intraprocedural mucosal washing of colon with pump irrigation, water-assisted colonoscopy, filling syringes and endoscope reprocessing. The use of sterile water incurs energy consumption and environmental impact at several stages including: the industrial production of the water itself; creation of plastic containers and packaging; transport of these containers to sites; discarding the empty containers (bags or bottles) into a non-recyclable waste stream. The use of sterile water during colonoscopy should be subject to departmental review and all staff should be aware of the environmental impact of sterile water use in the endoscopy pathway and adding the use of sterile water in the clinical pathway must be justified.

For instance, there is a wide literature to support water immersion (WI) colonoscopy wherever clinical familiarity allows this to take place—this technique also positively impacts procedural key performance indicators (painless insertion, decreasing sedation requirement, improve bowel cleanliness) as well as patient-centred outcomes (improved tolerance) and overall experience (advantageous for therapeutic applications).[108] The average volume of water used is estimated at 336 mL per gastroscopy (7.05 L for 21 oesophago gastro dudoenoscopy (OGDs)); 241 mL per sigmoidoscopy (5.3 L for 24 sigmoidoscopies) and 782 mL per colonoscopy (17.2 L for 22 colonoscopies).[107] If not all water of the 1000 mL container is used for the procedure itself, the remaining water could be employed in other steps in the use of endoscopes, for example, 'bed-side' cleaning.

In addition, reusable bottles and water from potable water filtration systems installed on taps could be considered.[109] However, a number of issues need to be taken into account. The use of tap water has been brought into focus with the specific aim of reducing environmental impact.[109–111] There is a categorical differentiation between tap water, water of drinking quality (potable) and sterile water. The use of sterile water is mandated by current BSG, European Society of Gastrointestinal Endoscopy (ESGE) and European Society of Gastroenterology and Endoscopy Nurses and Associates guidance,[94 106] with derogation for the specific use-case of manual flushes through the working channel of any endoscope, where tap water can be used. Tap water cannot be used in any other scenarios. In a recent update, the Healthcare Infection Society Working Party[105] states that 'water of at least the same quality as "final rinse water" for endoscopes can be used instead of sterile water in automated flushing systems and sterile water bottles'. The quality of the water must be tested and controlled as per guidance for final rinse water.

While the use of sterile water from industrial production described above has not been subject to lifecycle analysis, it is likely that any site-based system enabling the production of 'sterile' water would be favourable, negating the industrial production, packaging, transport and waste steps. Examples would include local reverse osmosis, ultrafiltration or autoclave-sterilisation systems. If local infection control and water quality monitoring procedures are in place, industrially produced and packaged sterile water need not be used in these 'in-room' steps. To accommodate this, a number of factors would need to be included in an agreed plan. These would include (but not be limited to): decontamination and reuse procedures for endoscope water bottles (for air/water channels and irrigation through the auxiliary channels of newer endoscopes); water filters, if used, must be locally evaluated following infection control policies and procured within guidance; a replacement and monitoring programme for all consumables must be established.

Practice position statement 2:7

We recommend that endoscopy departments should consider local protocols to minimise the use of histopathology in appropriate clinical pathways.

The carbon footprint of routine histopathology from GI biopsies has been determined and is not subject to 'economies of scale'. It is estimated that the processing of every three histology pots is equivalent to the carbon emissions of driving 2 miles in an average car[112] (taking into account the pot itself, but not biopsy forceps or instruments used to obtain the sample).

The use of routine or 'confirmatory' biopsies should be discouraged, and consideration given to whether the result of those biopsies will change patient management. In many cases, other tests may be used (and often results are available prior to superfluous biopsies being taken): stool antigen testing for *Helicobacter pylori*, serology for coeliac autoantibodies and digital photo documentation of ileal intubation as well as macroscopic normality.[113] If non-invasive testing is negative, there may be clinically appropriate scenarios in which biopsies are still necessary, but routine biopsies of normal appearances must be avoided if they do not alter management. It has been estimated that upper GI endoscopy itself influences the clinical management of patients in approximately only one-sixth of cases[114] and biopsies are taken in most (83%) cases. Optical Biopsy instead of histopathology has been suggested for diminutive polyps by the ESGE, in certain situations, and with regular audit and training and with regular audit and training, by the ESGE.[115 116] The 'resect and discard' strategy has been discussed in some guidelines[31] and considered to be feasible in a meta-analysis,[117] but potential barriers such as the fear of missing high-grade dysplasia and remuneration considerations prevent wide adoption.[118] The rationalisation of endoscopy itself must go hand-in-hand with biopsy protocols and departments should agree protocols to minimise unnecessary use of histopathology. The advent of artificial intelligence in endoscopic diagnosis and characterisation may also help in reducing the need for histopathology in several settings,[119] but further work is required before the impact of such a pathway could be confirmed.

Practice position statement 2:8

We recommend that use of endoscopy accessories should be carefully considered and planned preprocedure. This is an important endoscopic non-technical skill and could be part of training alongside endoscopic technique.

Endoscopic procedures use multiple accessories, the majority of which are currently non-recyclable and hence incinerated at high temperatures. These include biopsy forceps, biopsy containers, cold and hot snare catheters, snare diathermy pads and others. The risk of cross-contamination and patient safety concerns have led to the almost ubiquitous use of single-use accessories,[120–122] but such disposable equipment is likely to increase net waste.[101] To mitigate the environmental impact of disposable accessories, training endoscopists and staff in preventing excess and inadvertent use of accessories by appropriate planning preprocedure is recommended.[123] Innovation in equipment design, to facilitate waste minimisation, is required in this field.

Practice position statement 2:9

We recommend that the significant adverse environmental effects of nitrous oxide must be considered against its clinical efficacy in GI endoscopy. Staff and patients should be provided information on the environmental impact of nitrous oxide.

A wide range of methods have been studied to alleviate pain and discomfort during colonoscopy, including: different types of sedation; antispasmodics; sublingual hyoscyamine spray; patient-controlled analgesia; nitrous oxide (NOX); variable stiffness colonoscopes, WI or exchange; electro-acupuncture; music; positional manoeuvring. Entonox (a 50:50 mixture of NOX and oxygen) has analgesic and sedative properties and is a useful analgesic agent in many clinical scenarios with a good safety profile, rapid onset of action and washout.[124] In GI endoscopy, a Cochrane meta-analysis[125] demonstrated efficacy, but in relatively small numbers of patients with some studies returning equivocal results.

NOX is an important GHG with approximately 300 times the greenhouse effect of carbon dioxide. It is estimated to persist in the atmosphere, once released, for over a century and also destroys the ozone layer. Most NOX emissions are not associated with healthcare, but given the above characteristics, it accounts for nearly half of the medical gas 'footprint' from hospitals.[126 127] Furthermore, it is a major cause of ongoing ozone depletion.[128] Introduction of NOX capture and catalytic destruction devices in Swedish hospitals and maternity units resulted in a 50% reduction in GHG emissions in maternity services,[129] but this is an additional cost pressure (as well as manufacturing demand for new equipment). Consideration should be given to substituting for other low-impact methods. Judicious use to reduce waste in delivery systems and installation of catalytic destruction systems to reduce environmental escape could have a considerable impact on reducing GHG emissions. The continued use of NOX must be subject to the hospital's overall medical gases strategy, taking into account the environmental impact of its production, transport and delivery, use and atmospheric escape. Furthermore, information about the environmental impact of NOX should be available for staff and patients to make fully informed choice in relation to its use (online supplemental appendix 1). Propofol infusions are associated with lower GHG emissions than NOX but they create more medical waste in the form of syringes, syringe tubing, antireflux valves, additional intravenous catheters, delivery pumps.[130]

Working group 3: sustainability in endoscopy environment

Practice position statement 3:1

We recommend endoscopy units adopt sustainable reporting practices such as electronic documentation and reporting and report dissemination.

A significant proportion (30%) of all hospital waste is paper.[131] The recognition of this has led to the NHS goal to reduce paper use by 50% by 2022,[132] while ensuring supplies are from recycled stock. Printer supply chains, volatile organic compounds released from solvents and paper all contribute to GHG emissions.[133] An institution in the USA created a model to investigate the environmental effect of electronic health records and found a positive net effect on the environment, eliminating 1000 tonnes of paper records.[134] Incorporating a 'paperless endoscopy unit' principle using comprehensive electronic records for all administrative, nursing and endoscopic documentation could be achieved in most settings.[135] Such a system will have the added benefit of efficiency, ensuring quality control and reducing labelling errors. If wider hospital systems do not support electronic documentation and reporting, practical measures such as reducing the number of print copies, and encouraging its recycling, printing in black and white and using recycled paper should be considered.[136]

Practice position statement 3:2

We recommend reduction in personal protective equipment (PPE) use where possible and maximising availability of reusable PPE in endoscopy.

The COVID-19 pandemic has resulted in high volume use of single-use PPE during endoscopy including face masks, gowns, aprons and gloves.[137] A recent study conducted in the UK over a 6-month period, during the pandemic, indicated generation of 591 tonnes of CO_2 equivalent per day with the biggest impact from gloves, aprons, face shields and masks.[138] The same study found that use of reusable rather than disposable gowns would reduce carbon footprint by two-thirds. While it is important that infection control measures are followed, and risk to staff is minimised, the phasing out of unnecessary PPE and single-use items is advisable and a policy to rationalise the use of gloves and single-use masks would be beneficial.[139 140] Reusable gowns are already available and used in healthcare settings such as operating theatres and endoscopy units.[141] Furthermore, the environmental impact of gloves can be reduced by using powder coating gloves rather than chlorination to reduce stickiness.[142] In addition, cohorting of COVID-19-positive patients in dedicated endoscopy lists may also minimise PPE-related waste.[4] Where single-use PPE cannot be reduced, several studies have suggested recycling as a way of tackling the mass amount of single-use plastic waste generated. A recent study suggests that face masks and gloves could be transformed into fuel energy via pyrolysis, a high temperature decomposition process.[143] Similarly, thermal technologies can also compress the PPE in rectangular plastic blocks to produce new plastic products thereby reducing the waste volumes and associated transport.[144]

Practice position statement 3:3

We recommend flexible working patterns for appropriate team members should be actively encouraged, to enable remote working where possible.

GHG emissions associated with staff commuting contribute 4% of the NHS carbon footprint.[145] Travel emissions to and from the endoscopy unit are affected by transport mode and vehicle occupancy with 85% of trips to and from work being single occupancy. While types of travel cannot be dictated and are subject to distance and a number of other factors, walking, bicycles and efficient public transportation is one of the actions endoscopy staff can take to reduce GHG emissions associated with staff commuting.[146]

In addition, the COVID-19 pandemic has shown that many staff are able to carry out their roles remotely and do not always have to be at the hospital, providing they have access to suitable technology to work remotely and in some cases from home. Working from home reduces both air pollution and GHG emissions from travel as well as having local health co-benefits.[147] Home working also promotes flexible working,[148] and in the report 'delivering a "net-zero"' NHS,[12] flexible working patterns have been recommended, particularly to support alternative, more sustainable travel. Flexible working for staff has also been shown to improve patient care, staff morale and work-life balance.[149] These may include administration staff working from home, endoscopists doing administrative work from home and phone pre-assessments for endoscopic procedures and reporting of capsule endoscopy, etc being done remotely.

Practice position statement 3:4

We recommend low flow devices on water taps. If hands are not visibly soiled, then use of other appropriate hand disinfectants should be considered.

The most common water saving recommendations focuses around installing low flow devices on taps and toilets.[150] Sensor-activated taps have been shown to reduce water usage by ensuring water is not left running continuously.

Numerous studies also highlight opportunities for reduction in water use during/for surgical scrubbing. While in endoscopy, full hand disinfection is not required, these studies are still relevant for our practice. Switching from an 'elbow-on' tap operating system to a leg-operated tap was found to save 5.7 L of water per scrub.[151] Method of hand hygiene should also be considered, a study on surgical scrubbing in the UK found using alcohol-based hand gel could save approximately 930 000 L of water per year for an average UK hospital.[152] Recently, Duane *et al*[153] conducted a hand hygiene life cycle analysis and concluded that alcohol-based hand gel was more environmentally sustainable than handwashing with soap. However, it should be noted that this study compared the hand hygiene methods at population level use rather than within a hospital setting in which the alcohol gel might not be suitable for clinical use. Alcohol gel can only replace water, however, when hands are not visibly soiled or in contact with potential spore-forming pathogens such as *Clostridium difficile*.

Practice position statement 3:5

We recommend that energy to power endoscopy units should come from renewable sources, wherever possible.

Endoscopy units are energy-intensive environments, the environmental impact of which depends on the structural configuration of units, demand and the energy source. The energy hierarchy should be followed wherever possible, reducing demand/consumption, improving energy efficiency followed by using renewable energy sources.[154] Units should seek opportunities to move away from their reliance on fossil fuels and generators and focus on decarbonising energy sources where possible. However, this may be challenging if units are not standalone, which is commonplace for endoscopy units, and would therefore require whole hospitals to decarbonise their energy sources.[155] An example of this is the Antrim Area Hospital in Northern Ireland, which has a wind turbine and solar panels installed which provide enough electricity for the hospital at night and two-thirds during the day.[156]

Practice position statement 3:6

We recommend energy-efficient lighting and motion sensors for endoscopy units, where appropriate. In addition, aside from critical equipment such as drying cabinets, we recommend all equipment, including computers and machines, should be turned off when not in use.

A systematic review of GHG emissions in theatres identified electricity usage as a carbon hotspot, which can be extrapolated to endoscopy units on a smaller scale.[157] Endoscopy units are consumers of electricity for lighting, computers and endoscopy equipment.[158] Sources of electricity waste include the usage of energy inefficient bulbs (eg, incandescent and halide) and the lack of attention to whether lights and devices such as computers are switched off when not in use and at the end of the working day.[4]

Many studies advocate the reduction in 'out-of-hour' energy usage[18] through 'power down' initiatives turning off lights and equipment when not in use.[159 160] Asfaw *et al* also recommend a 'power down' checklist driven by frontline staff.[161] This is not applicable to critical equipment such as drying cabinets which often need to be left on for infection control purposes. Other innovative drying and prolonged storage solutions which replace the need for drying cabinets are being developed but these are not in widespread use.

Light-emitting diodes (LEDs) are more efficient lighting systems than traditional incandescent bulbs,[162] having a longer lifespan and reducing energy use by 65%.[163 164] Installation of LEDs with occupancy sensors in a unit resulted in GHG emissions cut by two-thirds and a 62% cut in lighting costs.[163]

Practice position statement 3:7

We recommend the waste hierarchy must be followed and triage of contaminated, non-contaminated and recyclable waste should be a priority for all endoscopy units.

Endoscopy is the third largest waste generating department in a hospital.[3] Gayam *et al* estimated an endoscopy unit performing 40 endoscopies per day produces 13 500 tonnes of plastic waste per year.[8] These studies highlight the need for endoscopy to urgently reduce its GHG emissions associated with waste disposal.[4] Units must first follow the 'reduce' and 'reuse' principles of the waste hierarchy. Where there is still waste being generated, recycling must be made a priority. Multiple studies from endoscopy and intensive care units show that 20%–30% of waste is potentially recyclable.[7 165 166] Recycled hospital waste (21–65 kg CO_2 equivalent) has a carbon footprint of up to 50 times less than high temperature incinerated waste (1074 kg CO_2 equivalent).[167] By improving recycling rates, there is opportunity to make significant environmental and financial gains.

Practical measures to promote recycling include correct segregation of waste, more accessibility to recycling bins and targeting

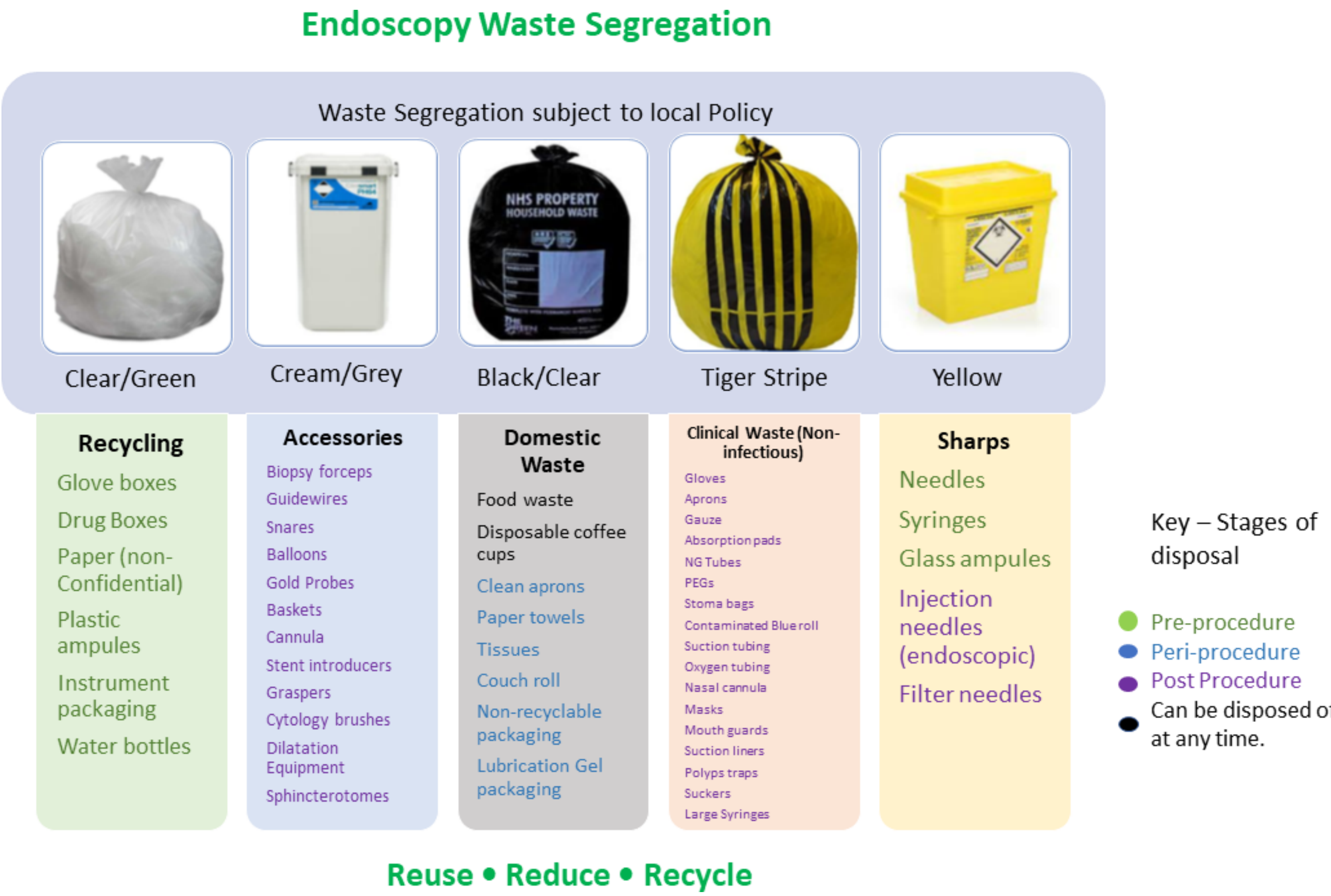

Figure 1 Waste segregation in endoscopy. NG, naso gastric; PEG, percutaneous endoscopic gastrostomy.

ergonomic layouts of recycling bins.[4] Endoscopy units must therefore ensure they have the correct waste set up ensuring that recycling bins are placed in each and every endoscopy units/treatment room. Easily displayed signage on common endoscopy items that can be recycled should be placed above bins.[168] Endoscopy unit materials which are regulated waste material meant for 'red bag containers' include containers with blood or blood products, items saturated with blood, soiled materials from patients on contact precautions, suction canisters, sharp bin materials. Disposable gloves and gowns used for endoscopic procedures should not be placed into these containers. Nearly every endoscopic tool from biopsy forceps to endoscopic suturing devices are manufactured in bulky plastic wrap and pending development of more biodegradable products by the industry, diverting non-soiled plastic waste to recycling within the endoscopy unit will prevent a large amount of plastic being sent to landfill. In a recent quality improvement project which determined the volume of recyclable waste generated within endoscopy suggested that the use of a green bin reduced GHG emissions and financial cost.[169] Incorporating proper waste management into the hospital quality measures is an important step in improving performance. A proposed waste segregation scheme is given in figure 1.

Practice position statement 3:8

We recommend education of all endoscopy staff in waste management.

Alongside better waste infrastructure, there must be staff education to improve waste management. A survey of healthcare staff across four US hospitals found that 57% of staff reported being unclear on what items are recyclable in an operating room.[170] Similarly, Mosquera *et al* found that educational intervention significantly reduced infectious healthcare waste volume.[171] Waste education could be achieved via an e-learning module or video, mandatory training, staff teaching sessions and reinforced during daily safety briefs on endoscopy units. In addition, dedicated green endoscopy champions in endoscopy units to provide information such as waste allocation and other sustainable principles are recommended.[172]

Practice position statement 3:9

We recommend heating, ventilation and air conditioning setbacks to minimise air exchanges when endoscopy rooms are not in use.

High ventilation requirements make hospitals energy intensive. Heating, ventilation and air conditioning (HVAC) is typically responsible for the greatest proportion of end-use energy in hospitals[173] and has been shown to be responsible for 90%–99% of theatre energy use.[174] While there are no data on HVAC energy requirements for an endoscopy room, they are required to be negatively pressurised resulting in significant energy usage.[175] While there are specific ventilation requirements, hospital ventilation is often left running during non-occupation (eg, overnight). Several studies have looked at air cleanliness in unoccupied operating rooms. There is evidence of no difference in microbial levels from operating rooms where the ventilators are setback to reduce air flow in unoccupied operating rooms overnight compared with continuous ventilator usage.[176 177] Existing literature reviewed also shows that ventilation setbacks maintain

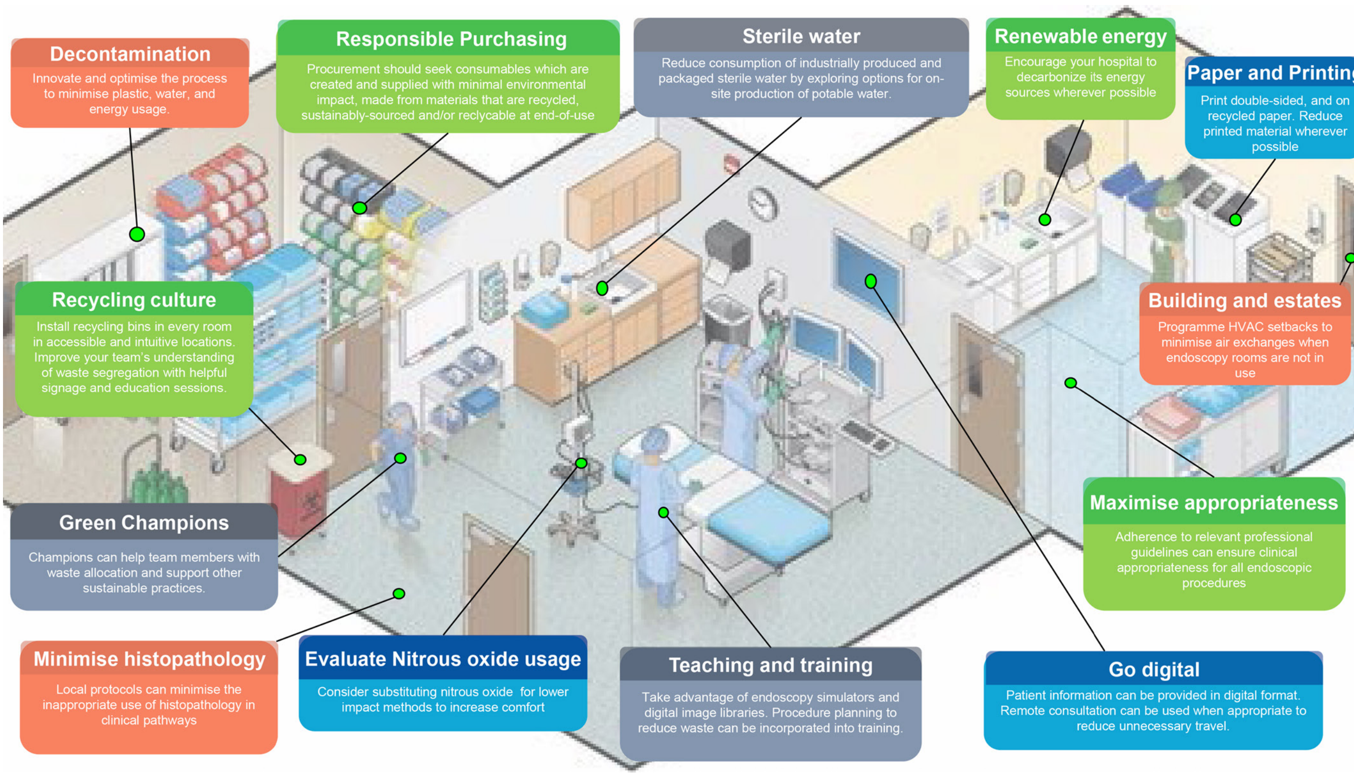

Figure 2 Practical tips for a green endoscopy unit. HVAC, heating, ventilation and air conditioning.

the air pressure needs required for operating rooms which would also apply to endoscopy rooms.[178 179] A degree rise or reduction in temperature in winter/summer can reduce energy costs by 5%.[173]

Working group 4: sustainability considerations postendoscopic procedures

Practice position statement 4:1

Patients should be encouraged to bring their own reusable drinks bottle or cup for the purpose of refreshments.

Food and catering are responsible for approximately 6% of total emissions within the NHS.[180] Approximately 2 million endoscopic procedures are performed in the UK per year,[4] and most of these patients will be provided with a postendoscopy drink, generally served in a plastic or polystyrene cup, and a snack of biscuits or toast.

Single-use cups have similar environmental impacts regardless of the material from which they are made.[181] If single-use cups are to be used, then paper has the lowest associated carbon footprint, and recycling halves the environmental impact by a further 40% to approximately 10 g CO_2 equivalent per cup. However, if 1 million paper cups were used by endoscopy units in the UK (a conservative estimate), this would still contribute 10 tonnes of CO_2 equivalent in emissions.

While some analyses suggest that reusable cups are associated with a threefold reduction in GHG emissions compared with disposable,[182] the comparative environmental impact benefit of institutional adoption of reusable cups over single use is dependent on a number of site-specific variables, including: energy mix, waste management strategy end-of-life technology used, recycling infrastructure and the efficiency of washing machines.[182] However, if patients already own a reusable drinks bottle or cup, they could be encouraged to bring their own. This could be communicated in the patient information leaflet prior to the appointment. Some hospitals in the UK have already used this approach; it has not led to any complaints and, anecdotally, has allowed the endoscopy unit to run more efficiently.

Practice position statement 4:2

Patient information leaflets and discharge instructions should be offered to patients in a digital format. For those patients requesting information in paper form, this should be printed on recycled paper with double-sided printing.

The JAG advises that all patients undergoing endoscopic procedures are given written information explaining aftercare and follow-up arrangements in addition to a copy of the endoscopy report. Many will also be provided with relevant written information if they are given a new diagnosis. Patients usually leave the endoscopy unit with two pieces of A4 paper in addition to their report. Although paper consumption alone accounts for a relatively small proportion of the overall environmental impact of the healthcare system,[183] a unit carrying out 12 000 procedures per year would use 24 000 sheets of paper for this purpose alone, which equates to 109 kg CO_2 equivalent.[183] Digitising paper information leaflets would reduce endoscopy's environmental impact, reduce the need for storage space and may also be preferred by patients.[184] The operational efficiency advantages of digitisation in this context have not been formally evaluated, nor is it yet clear which mode of digital information delivery has the highest level of acceptability with patients.

One option would be to offer patients a QR code linking to an electronic version of the relevant information, which can be stored on their mobile phone or tablet device for reference at a later date.[184] The discharging nurse would have a laminated sheet with all relevant QR codes, including those in different languages. For those who decline electronic versions consideration should

Research Themes

Pre procedure	
	Large multicentre prospective trials to further evaluate the performance of non-endoscopic technologies
	Determine the environmental impacts of non-endoscopic diagnostic pathways (colon capsule endoscopy, Cytosponge, CT colonography)
Procedural	
	Comprehensive environmental impact assessment of an endoscopic procedure. Identify the 'hotspot' areas within the process which contribute most to this impact
	Engineer and design of effective accessories, consumables and packaging to minimise waste and maximise recyclability and biodegradability
	Comparative life cycle assessment of single use versus reusable endoscopes
	Determine the net effect of artificial intelligence systems on histopathology demand
Postprocedure	
	Determine the environmental impacts of the endoscope decontamination processes
	Innovate improvements to the endoscope decontamination process which reduce per-cycle water, energy and plastic use.
	Develop effective wash cycle chemicals with optimal pH neutrality, biodegradability, and which meet marine life safety certification requirements
	Develop solutions to drying and prolonged storage of endoscopes which replace the need for energy-intensive drying cabinets
	Determine the incidence of clinically significant infection arising from contaminated endoscopes in the context of gastroscopy, duodenoscopy and colonoscopy.
	Determine the effect of endoscope modification (eg, disposable elevator caps) on endoscope contamination rate
General	
	Evaluate the efficacy and environmental impact of strategies for site-based production of 'sterile' water for example local reverse-osmosis, ultrafiltration or autoclave-sterilisation systems.
	Determine the optimal level and materials for an effective PPE policy to minimise overuse and environmental impacts
	Stakeholder review (clinicians, patients, policy makers) to understand barriers to change and how to best integrate environmental impact data into decision making
	Evaluation of educational interventions to improve environmentally sustainable practices
	Define environmental key performance measures for a sustainable endoscopy unit

Figure 3 Research themes. PPE, personal protective equipment.

be given to using recycled paper, double-sided printing and storing as few copies of each leaflet as possible, especially if not used on a frequent basis.[185 186]

Practice position statement 4:3

Remote consultation should be seen as the default means of providing postendoscopy follow-up. Patient selection and engagement are critical to ensure success and avoid widening health inequalities.

Many countries have seen a shift towards remote consultation (accelerated by the COVID-19 pandemic) and evidence-based guidance is now available for telephone and video consultations.[187] Remote consultation can reduce waiting times when compared with face-to-face appointments, and they have the potential to significantly decrease GHG emissions across the healthcare economy, primarily through reduced travel-associated emissions. The environmental impact varies between urban and rural settings as well as general and more specialised care.[188] Most studies have focused on the environmental impact of travel with few studies using life cycle assessment methodology.

The success of remote consultation as a means of providing high-quality healthcare has been well documented in recent studies,[189] but is highly context specific; endoscopic-specific literature is lacking. One study examined its use in GI practice and found high levels of satisfaction for both patients and providers with video consultations.[190] Another study demonstrated that patients seen for follow-up care, medication-related issues and pre procedural appointments were particularly satisfied with their virtual visits.[191]

However, telemedicine may exacerbate health inequalities by 'widening the digital divide': one study showed that 0% of patients who indicated their health as 'poor' reported using telemedicine in the past year.[192] The most common barriers from the patient's perspective are age, level of education, computer literacy, bandwidth and unawareness of services, whereas providers struggled with cost, reimbursement, legal liability, privacy confidentiality, security of data, effectiveness, old equipment and efficiency.

Practice position statement 4:4

Adoption of less-invasive tools may represent an opportunity to reduce the environmental impact associated with endoscopic surveillance, but their use in this context is currently limited to trials and pilot settings.

Endoscopic surveillance carries a significant burden for both patients and healthcare systems. Given the resource intensity that accompanies hospital-based procedures, appropriately reducing the number of unnecessary endoscopic surveillance procedures performed is also likely to be an effective route to mitigation of endoscopy's environmental impact. The less-invasive alternatives to endoscopy proposed for use in surveillance include FIT, CCE and Cytosponge.

Given the very low rate of progression to neoplasia for non-dysplastic Barrett's oesophagus (0.3%/year), there is a need to better identify those patients who benefit from endoscopic surveillance. Cytosponge could play a role in this risk stratification process,[38] and while its use in this context is not yet in national guidelines, its use is being rolled out in Scotland.[193] Evidence from further large-scale, longitudinal follow-up may support wider uptake for this indication.

In the UK, approximately 15% of the half a million colonoscopies performed each year are performed for polyp surveillance.[31] While FIT is deemed to have validity in guiding referral for colonoscopy in bowel cancer screening and in patients with low-risk symptoms of colorectal cancer (CRC), current British,[31] European[32] and American[194] guidelines do not deem there to be sufficient evidence to safely use FIT for polyp surveillance, with concerns that such a strategy would carry an unacceptable CRC miss rate. British[31] and European[32] guidelines also conclude that there is insufficient evidence at present to support the use of CCE in this context.

It is important to emphasise that there are no published data on the environmental impact of many of these less-invasive technologies, and so comparative ecological benefit cannot always be entirely assumed until a life cycle assessment is formally undertaken.

DISCUSSION

We present the first set of societal consensus statements on sustainable practice in GI endoscopy. The case for mitigating the environmental impact of healthcare in general, and GI endoscopy in particular, is clear. High volumes of procedures, multiple single-use items with non-renewable waste streams, water use in procedural flushes as well as decontamination will all contribute to this effect. 'Outside the endoscopy room' contributors including patient and staff travel, education and training and conference travel must also be taken into consideration as our specialty is responsible for these factors too. In this consensus, we provide a blueprint for practical actions promoting sustainability through the entire endoscopy journey of patients from preprocedural, procedural and postprocedural stages (figure 2).

The case for change, therefore, is urgent and compelling, receiving widespread support internationally. We sought to distil current knowledge from environmental science and practice, from other fields or disciplines, to apply to our own practice. While many statements, therefore, are unsupported by direct evidence, there are sufficient data from related scenarios that support a logical deduction towards more environmental practices.

There is a pressing need for high-quality research to better inform individual choices and practice change, but individual intervention (at the departmental level) can achieve considerable impact in the meantime. Estimates of the carbon footprint of endoscopy should be sufficient to describe the scale of the problem and stimulate change.

The tension between some environmentally sustainable practices and infection control imperatives (recycling in particular) should be acknowledged. We must not jeopardise patient safety in a push to 'net zero', but neither should this be a barrier to change wherever possible. Some protocols, for instance, water use, can be subdivided to allow sustainable alternatives to emerge. The principles surrounding infection control practices (often established well before sustainable practice was conceptualised) should therefore be scrutinised and reviewed at local and national levels.

Engagement with industry is vital in our move to an optimally sustainable practice. Healthcare systems have significant financial influence to nudge suppliers and manufacturers to encourage innovation and change.

We hope that these consensus statements will provide meaningful guidance to individuals and units to take immediate steps to becoming more sustainable, as well as stimulating further research and innovation. Multimodal change is needed as soon as possible to meet perhaps the greatest clinical challenge of our lifetime.

Recommendations for future research

The literature review and Delphi consensus process for the document identified a number of key gaps in evidence relating to sustainability in endoscopy. Overall, the research is limited and there is an urgent need for large-scale studies addressing the key knowledge gaps. Gastroenterologists and endoscopists are not fully trained to understand sustainability research and so need to work closely with environmentalists, engineers and economists to design these studies in a scientific manner. This will need collaborative research including academic groups, universities, professional societies and the industry on a scale and speed similar to the research on the COVID-19 pandemic. The key research areas and the relevant questions to be addressed are highlighted in figure 3.

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