Alimentary Pharmacology & Therapeutics

WILEY

AP&T Alimentary Pharmacology & Therapeutics

SYSTEMATIC REVIEW OPEN ACCESS

Systematic Review: Ultrasound Goes Echo—Decarbonising Inflammatory Bowel Disease Care Through Intestinal Ultrasound

Sara Massironi[1] | Alessandra Zilli[2] | Federica Furfaro[1] | Mariangela Allocca[2] | Laurent Peyrin-Biroulet[3] | Vipul Jairath[4,5] | Silvio Danese[1,2]

[1]Medicine and Surgery, Vita e Salute San Raffaele University, Milan, Italy | [2]Gastroenterology and Endoscopy Unit, IRCCS Ospedale San Raffaele, Milan, Italy | [3]Department of Gastroenterology, University of Lorraine, CHRU-Nancy, Nancy, France | [4]Department of Epidemiology and Biostatistics, Western University, London, Ontario, Canada | [5]Division of Gastroenterology, Department of Medicine, Western University, London, Ontario, Canada

Correspondence: Sara Massironi (sara.massironi@libero.it)

Received: 6 July 2025 | **Revised:** 31 July 2025 | **Accepted:** 11 September 2025

Handling Editor: Sreedhar Subramanian

Funding: The authors received no specific funding for this work.

ABSTRACT

Background: Inflammatory bowel disease (IBD) is a chronic, resource-intensive condition requiring repeated diagnostic assessments. Healthcare contributes ~5% of global greenhouse gas emissions, and key diagnostic tools in IBD—gastrointestinal (GI) endoscopy, computed tomography (CT) and magnetic resonance imaging (MRI)—are associated with substantial environmental impacts. The environmental burden of these diagnostic pathways, however, remains underappreciated.

Aim: To systematically assess the carbon footprint and environmental impact of diagnostic imaging modalities commonly used in IBD, with particular focus on intestinal ultrasound (IUS) as a sustainable, low-carbon alternative.

Methods: A systematic review was conducted according to PRISMA 2020 guidelines. PubMed, Scopus and Embase were searched from inception to May 2025 for studies reporting the environmental impact of diagnostic modalities relevant to IBD care (GI endoscopy, CT, MRI and IUS). Studies providing quantitative or qualitative data on carbon footprint, energy consumption, waste generation or sustainability metrics were included. Data were synthesised narratively.

Results: Thirty-one studies were included. GI endoscopy generates approximately 7.8–56.4 kg CO_2-equivalent per procedure, largely driven by transportation, energy use and disposables. CT carries a carbon footprint of 7–10 kg CO_2e per procedure in direct life cycle assessments, while broader institutional and modelling estimates extend this to ~20 kg CO_2e depending on throughput, protocol and energy sources. MRI is substantially more energy-intensive, ranging from 17–22 kg CO_2e per scan in most studies, and up to 200–300 kg CO_2e for high-field (3T) systems when full life cycle impacts are included. In contrast, IUS produces only 0.5–1.5 kg CO_2e per scan, with minimal energy demand and negligible waste. IUS enables point-of-care assessments, reducing patient travel and associated emissions.

Conclusion: GI endoscopy, CT and MRI are indispensable in IBD care but carry considerable environmental costs. The broader adoption of IUS offers a clinically effective, low-carbon alternative that can contribute to more sustainable IBD management, aligning with planetary health goals.

Trial Registration: PROSPERO International Prospective Register of Systematic Reviews: CRD420251088016

1 | Introduction

The management of inflammatory bowel disease (IBD) presents a significant challenge, requiring long-term, resource-intensive care. Globally, healthcare contributes ~5% of greenhouse gas (GHG) emissions, underscoring its role as both a provider of health and a driver of environmental harm [1–5]. IBD, encompassing Crohn's disease (CD) and ulcerative colitis (UC), is a lifelong condition that demands repeated diagnostic assessments for disease monitoring, treatment decisions and cancer surveillance [6–8], exemplifying the carbon-intensive nature of modern healthcare [6, 9].

Colonoscopy and gastrointestinal (GI) endoscopy, computed tomography (CT) and magnetic resonance imaging (MRI) are cornerstones of IBD management, but are also among the most resource-intensive diagnostic tools [6, 7, 10]. These procedures, while clinically indispensable in many scenarios [11, 12], contribute substantially to healthcare-related CO_2 emissions (CO_2e) [12–16] through high energy consumption, widespread use of single-use devices, complex sterilisation processes, and travel by patients and healthcare providers [10, 13, 17–21].

In contrast, intestinal ultrasound (IUS) has emerged as a non-invasive, radiation-free, point-of-care imaging modality offering excellent diagnostic accuracy in IBD [22–30], supporting both disease diagnosis and longitudinal monitoring [30–33]. Unlike cross-sectional imaging, IUS offers clinical benefits with a minimal environmental footprint [34, 35], generating negligible waste and reducing travel-related emissions by often being performed at the bedside [34, 36].

Given the dual pressures of providing high-quality care and reducing healthcare's environmental impact, it is essential to evaluate the sustainability of diagnostic pathways alongside their clinical efficacy. The present systematic review aims to comprehensively assess the carbon footprint and environmental impact of key imaging modalities used in IBD management, focusing particularly on the potential of IUS as a sustainable, low-carbon alternative that can align clinical excellence with planetary health goals.

2 | Methods

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. A comprehensive literature search was performed in PubMed, Scopus and Embase databases from inception to May 2025. The search strategy combined keywords and MeSH terms related to IBD, diagnostic imaging modalities commonly used in IBD (colonoscopy/GI endoscopy, CT, MRI, IUS) and environmental impact (carbon footprint, life cycle assessment, sustainability, energy consumption, resource use). The detailed search strategy is provided in Appendices S1 and S2. The search was supplemented by manual screening of reference lists and relevant policy reports related to healthcare sustainability and climate–health frameworks.

2.1 | Eligibility Criteria

We included peer-reviewed articles and reports providing quantitative or qualitative data on the environmental impact of diagnostic imaging relevant to IBD care. Since only a limited number of studies were conducted directly in IBD populations, we also included studies assessing these modalities in broader gastrointestinal or cross-sectional imaging contexts, provided they reported outcomes applicable to IBD diagnostics. Eligible study designs were life cycle assessments (LCAs), prospective or retrospective audits, observational studies, conference abstracts with available new data, qualitative sustainability reports, and systematic and narrative reviews, which were included to retrieve additional relevant studies and references not identified in the primary search.

We excluded editorials, letters, conference abstracts without full data, non-peer-reviewed sources, papers lacking consistent or extractable data and studies focused solely on therapeutic interventions. No restrictions were applied regarding language, publication date or geographic location.

2.2 | Study Selection

All retrieved articles were exported and screened using Rayyan.ai, a web-based platform for systematic review management. Duplicates were automatically identified and removed. Two independent reviewers (S.M. and A.Z., blinded to each other's decisions) screened titles and abstracts for eligibility. Discrepancies were resolved through discussion or consultation with a third reviewer (S.D.).

2.3 | Data Extraction

Data were extracted independently by two reviewers (S.M. and A.Z.) using a standardised form, including: first author, year of publication, diagnostic modality assessed, environmental metric reported (e.g., kg CO_2e per procedure), methodological approach (e.g., LCA) and key findings related to environmental impact. Outcomes of interest were carbon footprint per procedure (kg CO_2e), energy consumption (kWh), waste generation (solid and liquid), transport-related emissions and any reported sustainability interventions.

2.4 | Quality Assessment

The methodological quality and risk of bias (RoB) of the included studies were assessed using tools adapted for environmental health research and study design. LCA studies were evaluated against ISO 14040/14044 standards, with particular attention to system boundaries, functional units and completeness of reported impact categories [37]. Observational audit studies (prospective or retrospective) were assessed using the Joanna Briggs Institute (JBI) critical appraisal checklists for prevalence and cross-sectional studies [38]. Narrative reviews, commentaries and descriptive reports were not formally appraised for risk of bias, but their transparency and reporting were qualitatively considered concerning criteria from the CASP qualitative appraisal tool [38, 39].

2.5 | Data Synthesis

Studies were grouped by diagnostic modality and summarised in structured tables. Where appropriate, findings were also presented in visual summaries. Data were synthesised narratively. Study-level RoB judgements, assessed as previously described, are summarised in the 'Risk of bias' column of Tables 1–3.

3 | Results

3.1 | Study Selection

The initial literature search across Embase, Scopus and PubMed yielded a total of 169 records. After the removal of 10 duplicates, 159 records underwent title and abstract screening. Based on predefined inclusion criteria targeting the environmental impact of diagnostic imaging and endoscopic pathways in IBD, 76 articles were selected for full-text evaluation. Additionally, one relevant study was manually retrieved from a conference report and included in the final synthesis [34]. Following a detailed assessment, 31 studies met the eligibility criteria and were included in the final qualitative synthesis. The study selection process is depicted in the PRISMA 2020 flow diagram (Figure 1).

The included studies focused on the environmental impact of three main diagnostic modalities used in IBD management: (1) gastrointestinal (GI) endoscopy/colonoscopy, (2) cross-sectional imaging (CT and MRI) and (3) ultrasound (US)-based modalities.

3.2 | Study Characteristics

Among the 31 included studies, 14 focused on the environmental impact of GI endoscopy [21, 40–52], 13 on cross-sectional imaging modalities (CT, MRI) [5, 10, 45, 53–62] and 7 on US [5, 34, 45, 53, 63–65]. Notably, three studies [5, 45, 53] contributed data to more than one diagnostic modality category (CT, MRI and US). The studies originated from a wide range of countries, reflecting broad international interest in sustainable gastroenterological care (see Tables 1–3). Most studies evaluated carbon dioxide equivalents (CO_2-eq), solid and liquid waste production, energy use (kWh) and water consumption, with some also reporting indirect emissions related to transportation, infrastructure and equipment sterilisation. Most included studies on endoscopy, CT and MRI reported data at the modality or departmental level (gastrointestinal endoscopy units or radiology departments) rather than exclusively in IBD-specific cohorts. By contrast, IUS studies were more disease-specific, with three studies evaluating IUS in IBD-specific cohorts [34, 63, 64]. LCA studies generally adhered to ISO 14040/14044 guidelines. However, the completeness of system boundaries and transparency of data sources varied across studies. Approximately 60% of LCA studies provided full inventory data and explicit allocation assumptions, while the remaining studies lacked detailed reporting on indirect emissions and waste management phases, indicating a moderate RoB. Observational and audit studies were of variable quality, with most studies providing relevant data, but several failed to comprehensively report key sustainability metrics, introducing potential underreporting bias. Narrative and scoping reviews included in the analysis were used primarily to retrieve additional references and did not directly contribute quantitative data.

3.2.1 | GI Endoscopy

Fourteen studies specifically assessed the environmental footprint of GI endoscopic procedures, focusing on carbon emissions, waste generation, energy consumption and sustainability interventions [21, 40–52] (Table 1).

Among the included studies, five employed formal LCAs [21, 40, 48–50], judged at low RoB due to transparent methodology and standardised reporting. Observational audits by Desai et al. [42], Rughwani et al. [44], Lacroute et al. [46] and Henniger et al. [47] were generally at moderate RoB, with strengths in real-world data but limitations in scope and generalisability. Elli et al. [43] used a modelling approach based on national datasets, also at moderate RoB, given reliance on assumptions. Four studies were reviews, commentaries or descriptive reports [41, 45, 51, 52], carrying a high RoB as they relied mainly on reported secondary data.

Across studies, GI endoscopy consistently emerged as a significant contributor to healthcare-related carbon emissions and resource consumption, with reported carbon footprints ranging from 7.8 to 56.4 kg CO_2e per procedure, depending on methodology and inclusion of patient travel [21, 40, 42–44, 46–50].

Lämmer et al. [40], using a comprehensive LCA in a Dutch university hospital, reported the highest emissions values, with a footprint of 56.4 kg CO_2e per colonoscopy, of which 76.5% was attributable to the transportation of patients and staff and 13.5% to disposables. Also, in other studies [40, 44, 46, 52], the main emission sources included patient and staff travel, energy consumption (including heating and electricity for procedure rooms) [47, 52] and single-use instruments [48, 49, 52]. In a prospective UK study, the carbon footprint per GI endoscopy was 38.5 kg CO_2-equivalent, which decreased to 6.5 kg CO_2e when patient travel was excluded. Travel alone may account for 83% of emissions, while electricity, medical gases and water contributed less substantially [44]. Similarly, Lacroute et al. [46] reported that ambulatory GI endoscopy procedures were associated with an average carbon footprint of 28.4 kg CO_2e, with major emission sources including patient and staff travel (45%), medical equipment use (32%) and energy consumption (12%).

Henniger et al. [47] reported a low annual carbon footprint of 62.7 tons CO_2e for a high-volume German endoscopy unit, corresponding to ~7.8 kg CO_2e per procedure, with heating and the use of consumables identified as the largest contributors. Their analysis excluded patient and staff travel, as well as capital goods such as endoscopes and washing machines [47]. Additionally, Desai et al. [42] conducted a prospective audit in a tertiary endoscopy unit and estimated a cumulative footprint of 1501 kg CO_2e per 100 procedures, corresponding to approximately 15 kg CO_2e per endoscopic procedure. The analysis included waste generation and energy consumption within the endoscopy unit but did not account for patient or staff travel, the full life cycle of endoscopes or upstream

TABLE 1 | Studies assessing the carbon footprint and environmental burden of GI endoscopy procedures.

First author	Year	Country/Region	Diagnostic modality	Study design	Environmental metric	Key findings	Risk of bias
Lämmer et al. [40]	2025	Germany	Colonoscopy	LCA	56.4 kg CO_2e/procedure	Colonoscopy generates 56.4 kg CO_2e, with transportation as the major contributor	Low
Perisetti et al. [41]	2023	USA	GI endoscopy (colonoscopy, EGD)	Narrative review	Qualitative review (no numeric data)	GHG emissions in GI endoscopy are substantial; reduction strategies are feasible	High
Desai et al. [42]	2024	USA	GI endoscopy (colonoscopy, EGD, ERCP)	Prospective observational audit	15 kg CO_2e/procedure (1500 kg/100 procedures)	Every 100 GI procedures produce 303 kg of solid waste, 1385 gallons of liquid waste and 1980 kWh; 20% recyclable.	Moderate
Elli et al. [43]	2024	Italy/Europe	GI endoscopy (colonoscopy, EGD)	Modelling analysis (carbon cost estimation)	~10–15 kg CO_2e/procedure (estimated from annual totals)	Inappropriate EGD/colonoscopy: 4133 tons CO_2/year in Italy; 30,804 tons in Europe	Moderate–high
Rughwani et al. [44]	2025	UK	GI endoscopy (colonoscopy, EGD)	Prospective audit	38.5 kg CO_2e/procedure (6.5 kg excluding travel)	Patient travel accounted for 83% of the footprint	Moderate
López-Muñoz et al. [21]	2023	Spain	GI endoscopy (colonoscopy, EGD)	LCA (instruments)	Varies by device; recycling reduced ~27% CO_2e	Carbon footprint varies by manufacturer; recycling recovered 61.7% of the instrument's weight	Low–moderate
Pohl et al. [45]	2023	Germany	GI endoscopy (mixed endoscopic procedures)	Commentary	Not quantified new primary measurements. Summarising published metrics (8–28 kg CO_2e/procedure)	Emphasised the large carbon footprint of gastroenterology practice	High
Lacroute et al. [46]	2023	France	GI endoscopy (colonoscopy, EGD)	Retrospective observational audit	28.4 kg CO_2e/procedure	Contributors: travel (45%), equipment (32%), energy (12%), consumables (7%), waste (3%)	Moderate
Henniger et al. [47]	2023	Germany	GI endoscopy (mixed endoscopic procedures)	Retrospective observational audit	7.8 kg CO_2e/procedure (62.7 tons/year ÷ 8000 procedures)	Main sources: heating and consumables; green electricity reduces emissions	Moderate
Le et al. [48]	2022	USA	GI endoscopy (ERCP)	Comparative LCA (single-use vs. reusable)	36–72 kg CO_2e/procedure (single-use) vs. 1.5 kg CO_2e/procedure (reusable)	Single-use duodenoscopes 24–47× higher footprint. Reusable uses more water but far lower CO_2e	Low

(Continues)

TABLE 1 | (Continued)

First author	Year	Country/Region	Diagnostic modality	Study design	Environmental metric	Key findings	Risk of bias
Pioche et al. [49]	2024	France	GI endoscopy (EGD)	Comparative LCA (single-use vs. reusable)	10.9 kg CO_2e (single-use) vs. 4.7 kg (reusable)	Single-use ~2.5× higher; reusable had higher water consumption	Low
Pioche et al. [50]	2024	France	Capsule endoscopy	LCA	~2.5 kg CO_2e/procedure	Capsule endoscopy has a much lower footprint than conventional endoscopy, with minimal waste	Low
Jain and Agrawal [51]	2023	India	GI endoscopy (mixed endoscopic procedures)	Descriptive report	Qualitative (no numeric data)	Local sustainability initiatives in India	High
Maida et al. [52]	2024	Italy	GI endoscopy (mixed endoscopic procedures)	Systematic review	Narrative synthesis	Major sources: energy-intensive equipment, single-use devices, travel; emphasised green practices	High

Abbreviations: EGD, oesophagogastroduodenoscopy; ERCP, endoscopic retrograde cholangiopancreatography; LCA, life cycle assessment.

supply chain emissions, suggesting that the true footprint may be even higher [42].

Other major contributors included single-use instruments [48, 49, 52], including biopsy forceps, syringes, snares and personal protective equipment, which accounted for an additional 13.5% of the footprint [52]. Energy consumption (including heating and electricity for procedure rooms) [47, 52], sedation-related resource use and sterilisation cycles added further impacts [40]. Bowel preparation regimens also contribute to upstream pharmaceutical emissions [40].

Importantly, Desai et al. [42] highlighted that 20% of waste was potentially recyclable but improperly discarded, due to systemic gaps in waste management. López-Muñoz et al. [21] demonstrated that targeted recycling could cut emissions by 27.4% and recover over 60% of instrument weight. In this article, single-use biopsy forceps alone had a footprint of 0.31–0.47 kg CO_2e 21. Jain and Agrawal [51] described sustainability initiatives in Indian endoscopy units (waste reduction, recycling, energy savings), but without quantitative estimates.

Inappropriate procedures were shown to further amplify the environmental burden. Elli et al. [43] estimated that inappropriate upper and lower GI endoscopy procedures in Italy contribute over 4000 metric tons of CO_2 annually, rising to $>$30,000 tons at a European scale.

Two high-quality LCAs highlighted the environmental burden of single-use devices [48, 49]. Le et al. [48] showed that single-use duodenoscopes generate 36.3–71.5 kg CO_2e per procedure versus 1.53 kg for reusable models. Manufacturing and disposal processes were the primary drivers of the elevated emissions in single-use models [48]. Similarly, Pioche et al. [49] reported 10.9 kg for single-use gastroscopes versus 4.7 kg for reusables, though the latter increased water use. The study emphasised that the production and reprocessing phases are the most environmentally critical stages in the life cycle of endoscopic equipment.

Pioche et al. [50], in another study, also assessed capsule endoscopy, reporting a markedly lower footprint of ~2.5 kg CO_2e per procedure, underscoring its environmental advantage over conventional endoscopy owing to minimal waste and lack of reprocessing needs.

Qualitative reviews reinforced these findings. A recent systematic review identified only nine full-length studies worldwide with quantitative estimates, stressing the need for standardised LCA reporting [41]. Of these, only three were cross-sectional studies providing quantitative estimates. Pohl et al. [45] synthesised previously reported estimates (8–28 kg CO_2e), which fall within the overall range of 7.8–56.4, and emphasised sustainability interventions such as reducing unnecessary procedures and adopting green energy practices. Maida et al. [52] positioned GI endoscopy among the top three hospital procedures in terms of waste production, estimating 13,500 tons of plastic waste annually in the United States alone, alongside millions of gallons of gasoline-equivalent emissions. Additional contributors include reprocessing cycles, energy use for lighting, anaesthesia machines, high-level disinfection, and transportation of both staff and patients [52].

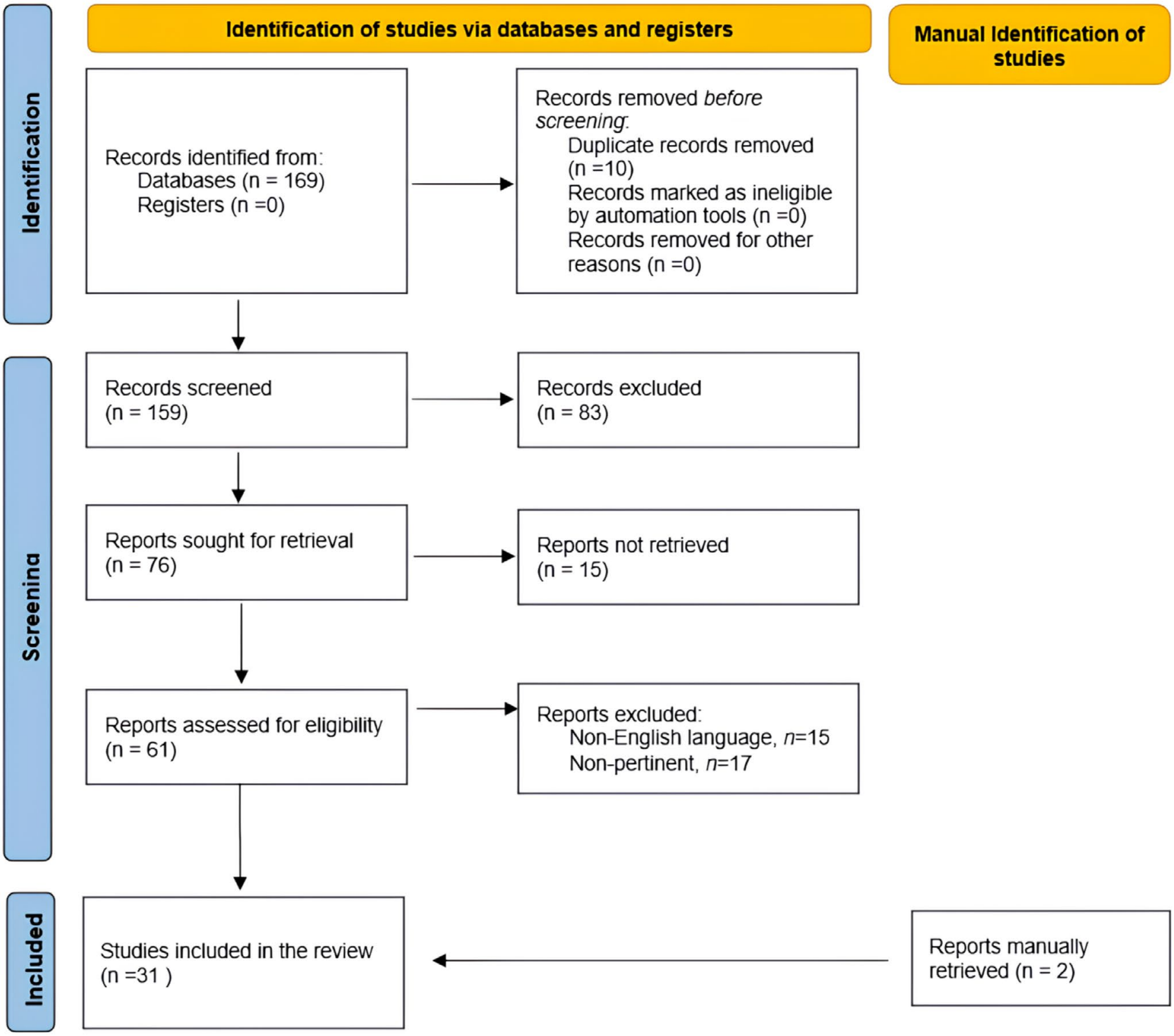

FIGURE 1 | PRISMA 2020 flow diagram of study selection process. The figure outlines the systematic search and selection process conducted across PubMed, Scopus and Embase databases, resulting in 30 studies included in the final qualitative synthesis. The selection followed PRISMA 2020 guidelines.

Taken together, these data confirm that GI endoscopy is among the most resource-intensive diagnostic procedures in IBD, with emissions largely driven by patient travel, single-use devices and energy use. This underscores the need to reassess its routine use for disease monitoring, especially in patients with quiescent disease, where non-invasive, lower carbon diagnostic alternatives such as IUS may provide comparable clinical information while dramatically reducing environmental harms [41].

3.2.2 | Cross-Sectional Imaging (CT and MRI)

The carbon footprint and energy consumption of cross-sectional imaging modalities, particularly CT and MRI, were evaluated across 13 studies [5, 10, 45, 53–62], highlighting considerable variability and potential areas for emissions reduction (Table 2).

Direct LCAs estimate a footprint of 7–10 kg CO_2e per abdominal CT scan [45, 53], while broader estimates derived from institutional energy-use data and modelling extend up to ~20 kg CO_2e, depending on utilisation, scan protocols and local energy grids. MRI scans are significantly more energy-intensive, ranging from 17–22 kg CO_2e per scan in most studies [45, 53, 55] to 200–300 kg CO_2e for high-field 3T systems [56]. Both modalities suffer from substantial non-productive energy consumption, particularly during standby and idle periods, which offers a critical area for intervention [57, 61]. Studies consistently highlight that power management protocols, equipment shutdown strategies and more stringent imaging justification could dramatically reduce the carbon footprint of cross-sectional imaging. The inclusion of environmental impact in imaging decision-making is increasingly recognised as an essential element of sustainable clinical practice [56]. Roletto et al. [66], through a systematic review of LCA studies, emphasised the need for standardised methodologies in measuring carbon footprints, reinforcing that

TABLE 2 | Studies analysing the carbon footprint and energy consumption associated with computed tomography (CT) and magnetic resonance imaging (MRI). Reported CT carbon footprints vary depending on study design and methodological scope. Direct life cycle assessments (LCAs) consistently estimate 7–10 kg CO_2e per abdominal CT scan [45, 53], while broader modelling studies and institutional energy-use data suggest values up to ~20 kg CO_2e per scan when accounting for scan protocol, scanner efficiency, throughput and local electricity mix [5, 54]. MRI footprints are consistently higher, ranging from 17–22 kg CO_2e per scan in most LCAs [45, 53, 55] to 200–300 kg CO_2e per scan for 3T systems when full life cycle and infrastructure demands are included [56].

First author	Year	Country/Region	Diagnostic modality	Study design	Environmental metric	Key findings	Risk of bias
McAlister et al. [53]	2022	Australia	General imaging (MRI, CT)	Prospective audit (national dataset)	MRI: 17.5 kg CO_2e; CT: 9.2 kg CO_2e	MRI has the highest per-scan footprint	Low–moderate
Heye et al. [10]	2020	Belgium	General imaging (CT, MRI)	Observational energy audit	MRI 22.5–32.3 kWh/exam; CT 17.8 kWh/exam; high standby power	Idle/standby use is substantial; shutdown protocols reduce ~25%–30% energy	Moderate
Vosshenrich et al. [57]	2024	Switzerland	Interventional imaging systems	Observational audit (energy monitoring)	Annual energy 3646–26,576 kWh/system; 89%–99% non-productive; 18.6 t CO_2e/year savings if shut down	Most consumption occurs when idle; turning systems off yields large savings	Low–moderate
Bastian et al. [58]	2024	Germany	Dual-energy CT	Observational audit	1.1–1.7 kWh/scan; up to 5868 kg CO_2e/year saved per scanner if powered off	Energy use correlates with protocol (kVp, mode, scan length); idle use matters	Moderate
Furlan et al. [59]	2023	International (G20)	General imaging (MRI, CT)	Modelling analysis (utilisation data)	2046–175,120 t CO_2e/year across G20 (avoidable variation)	Optimising utilisation could deliver large carbon savings at scale	Moderate–high
Esmaeili et al. [55]	2018	Iran	MRI	LCA	22.4 kg CO_2e/patient; only 38% from scanner operation	The majority of life cycle burden comes from electricity generation and consumables	Low
Esmaeili et al. [60]	2015	Iran	CT	LCA methodology	No quantitative footprint	Establishes the LCA approach/importance for CT	High
Kouropoulos [54]	2018	Greece	General imaging (CT, MRI)	Predictive modelling	~30% growth in CT/MRI emissions projected (2018 → 2030)	Forecasts rising imaging-related emissions without mitigation	High
Pohl et al. [45]	2023	Germany	General imaging (CT, MRI)	Commentary/review	MRI ≈ 20 kg CO_2e/scan; CT ≈ 7 kg CO_2e/scan	Secondary synthesis; no primary measurements	High

(Continues)

TABLE 2 | (Continued)

First author	Year	Country/Region	Diagnostic modality	Study design	Environmental metric	Key findings	Risk of bias
Woolen et al. [61]	2023	USA	MRI	Observational audit (operational intervention)	14.9 t CO_2e/year saved per scanner by overnight power-down	Operational changes (power management) yield sizable savings	Moderate
Merkle et al. [5]	2023	Switzerland/Germany	General imaging (urology context) (CT, MRI, PET-CT)	Mini review/expert commentary	CT: 20,000–35,000 kWh/year (~6000–10,500 kg CO_2e), MRI: 80,000–170,000 kWh/year (~24,000–51,000 kg CO_2e), PET-CT: 52,000 kWh/year (~15,600 kg CO_2e)	Highlights large annual footprints; powering off equipment during off-hours can significantly reduce emissions	Moderate–high
Picano et al. [56]	2021	Italy	MRI (3T)	Narrative review/viewpoint	200–300 kg CO_2e/exam (3T MRI); MRI + CT ≈ 0.77% of global CO_2 (2016)	Order-of-magnitude estimates; not primary LCA/audit data	High
Roletto et al. [62]	2024	Italy	General imaging	Systematic review (LCAs)	40%–91% non-productive energy; potential savings 14,180–171,000 kWh/year	Synthesises LCA methods; large idle energy share across devices	Moderate–high

Abbreviations: CO_2e, carbon dioxide equivalent; CT, computed tomography; LCA, life cycle assessment; MRI, magnetic resonance imaging; PET-CT, positron-emission tomography–CT; US, ultrasound.

the environmental burden of CT remains significant across healthcare systems.

3.2.2.1 | **Computed Tomography.** Several studies quantified CT-related emissions. Estimates from direct LCAs suggest that a single abdominal CT scan has a carbon footprint of between 7 and 10 kg CO_2e per procedure [5, 45, 53]. Pohl et al. [45] reported ~7 kg CO_2e per scan, while McAlister et al. [53] found ~9.2 kg CO_2e in a prospective Australian LCA. Merkle et al. [5] provided comprehensive energy assessments in urological practice, reporting that CT scanners consumed 20,000–35,000 kWh annually, corresponding to approximately 6000–10,500 kg CO_2e per scanner per year. Institutional energy consumption studies indicate that CT scanners may generate broader per-scan emissions that can rise by 30%, reaching up to ~20 kg CO_2e per scan, depending on throughput, scan parameters and local energy mix [54].

Standby energy consumption emerged as a modifiable contributor. Heye et al. [10] showed that shutdown protocols substantially reduce unnecessary consumption, while Bastian et al. [58] demonstrated that switching dual-energy CT scanners from idle to off mode could prevent up to 5868 kg CO_2e per scanner each year. Also Vosshenrich et al. [57] confirmed that over 90% of energy consumption in interventional imaging systems, including CT, occurs during non-productive periods, highlighting the importance of effective power management strategies. At a system level, Furlan et al. [59] estimated that reducing unwarranted CT and MRI across G20 countries could prevent up to 175,120 tons of CO_2e per year. While these estimates are not specific to IBD monitoring, they underscore the potentially large-scale environmental benefits of avoiding unnecessary imaging.

Importantly, Kouropoulos [54] projected that, without intervention, carbon emissions from CT and MRI combined would increase by approximately 30% globally between 2018 and 2030.

3.2.2.2 | **Magnetic Resonance Imaging.** MRI was consistently identified as the most energy-intensive and carbon-heavy imaging modality. Unlike CT, MRI does not involve ionising radiation but requires continuous cryogenic cooling, resulting in a baseline energy burden independent of patient throughput [60]. The carbon footprint of a single MRI scan varies considerably, ranging from 17 to 22 kg CO_2e per scan, depending on field strength, protocol duration and life cycle boundaries [10, 53, 55, 61], up to 200–300 kg for high-field 3T systems [56]. McAlister et al. [53] estimated an average carbon footprint of 17.5 kg CO_2e per MRI scan, while Pohl et al. [45] reported a slightly higher estimate of 20 kg CO_2e per scan. Esmaeili et al. [55] provided a detailed LCA, estimating a per-patient carbon footprint of 22.4 kg CO_2e, with substantial contributions from out-of-hospital electricity generation and consumable production. Energy consumption data presented by Merkle et al. [5] indicated that MRI systems used in urology can consume between 80,000 and 170,000 kWh/year, resulting in annual carbon emissions ranging from approximately 24,000 to 51,000 kg CO_2e per scanner. Picano [56] provided one of the highest emission estimates, reporting that a single 3 Tesla MRI scan may generate between 200 and 300 kg CO_2e per procedure. The study also estimated that MRI and CT combined accounted for 0.77% of global CO_2e in 2016, emphasising the critical need to include environmental

TABLE 3 | Reported carbon footprints for ultrasound (US)-based diagnostic modalities, with particular emphasis on intestinal ultrasound (IUS).

First author	Year	Country/Setting	Diagnostic modality	Study design	Carbon footprint (per exam or annual)	Key findings	Risk of bias
Nwaezeigwe et al. [34]	2025	Ireland, IBD clinic	IUS	Observational retrospective audit (conference abstract)	~1 kg CO_2e per scan; 3269 kg CO_2e avoided in 1 year	Replacing MRI/colonoscopy with IUS reduces emissions	Moderate—small sample
Dolinger and Kayal [63]	2023	USA, paediatric IBD	IUS	Expert commentary/review	No quantitative estimate	IUS is promoted as a sustainable alternative to colonoscopy and MRI in paediatrics	High—qualitative only
Dolinger and Kayal [64]	2023	USA, paediatric IBD	IUS	Narrative review	No quantitative estimate	Reviewed evidence supporting IUS as a clinically effective and environmentally sustainable	High—qualitative only
Martin et al. [65]	2018	USA, cardiology	US (echo-cardiography)	Narrative review/opinion	< 2 kg CO_2e per scan (estimated)	Echo is considered the most sustainable cardiac imaging tool	High–moderate—no primary data
Pohl et al. [45]	2023	Multinational	Abdominal US	Commentary/review	~1 kg CO_2e per scan	Ultrasound ~7× lower footprint than CT and ~20× lower than MRI	High
McAlister et al. [53]	2022	Australia, hospital setting	US (general)	Prospective life cycle assessment (LCA)	0.5–1.5 kg CO_2e per scan	Lowest among imaging modalities; it depends on the local electricity grid	Low—transparent ISO-based LCA
Merkle et al. [5]	2023	Germany, urology practice	US (general)	Energy consumption model (retrospective)	< 2000 kWh/year ≈600–750 kg CO_2e/year per scanner	Ultrasound has the lowest annual energy demand compared to CT/MRI	Moderate—modelled, not full LCA

sustainability considerations in the clinical decision-making process for imaging modalities.

Operational interventions can yield meaningful reductions. Woolen et al. [61] demonstrated that implementing power management strategies, such as switching MRI units to power-save mode during off-hours, can reduce annual emissions by 8.7–14.9 metric tons of CO_2 per scanner. Vosshenrich et al. [57] similarly highlighted that non-productive energy use dominates MRI operational footprints, accounting for over 90% of total energy consumption, which could be mitigated by powering off systems when not in use. Kouropoulos [54] emphasised the expected escalation in carbon emissions from MRI operations if global imaging demand continues to rise without sustainability interventions.

3.2.2.3 | Indirect Emissions. Beyond direct scanning, indirect emissions substantially add to the footprint of CT and MRI. These include equipment production, transportation, installation, maintenance and contrast media manufacturing [5, 60, 65]. Both modalities also rely on energy-intensive institutional infrastructure, including dedicated imaging suites, ventilation and cooling systems, extensive digital data storage and routine maintenance services [10, 61]. CT-specific contributors include high-power X-ray generation, equipment manufacturing, infrastructure energy consumption and long-term digital storage requirements [61]. MRI requires continuous 24/7 energy input to maintain cryogenic cooling, creating a significant baseline energy burden independent of patient throughput [10, 56, 60]. Indirect emissions, often underestimated, were consistently identified as a major component of cross-sectional imaging's environmental impact. Non-productive energy use is a dominant source of emissions. Idle and standby consumption account for > 90% of total energy use in many CT and MRI systems [57, 58]. Esmaeili et al. [60] emphasised that in-hospital idle energy consumption can exceed the energy used for image acquisition by a factor of 14–30 times, making it a critical area for carbon reduction. In subsequent work, Esmaeili et al. [55] quantified the life cycle impact of MRI procedures, estimating a per-patient carbon footprint of 22.4 kg CO_2e, with significant out-of-hospital contributions from electricity generation and consumable production. Woolen et al. [61] demonstrated that substantial CO_2 savings can be achieved by simple operational changes, such as implementing overnight shutdown protocols for MRI systems, saving 8.7–14.9 tons CO_2 per scanner annually. Similarly, Merkle et al. [5] and Vosshenrich et al. [57] emphasised that optimising equipment utilisation efficiency, not just procedure volume, is essential for carbon mitigation.

In addition to equipment and facility-related emissions, the long-term storage of medical imaging data represents an emerging contributor to the ecological cost of diagnostic imaging. The expansion of Picture Archiving and Communication Systems (PACS) and the reliance on energy-intensive data centres require continuous electricity for cooling and maintenance, thereby contributing significantly to GHG emissions [62].

Contrast media are another contributor: iodinated agents (CT) and gadolinium-based agents (MRI) entail environmental costs from production and disposal, with gadolinium persistence documented in wastewater and ecosystems [67, 68]. Additionally, transportation of patients and staff, due to the centralisation of imaging services, can account for a substantial proportion of total emissions. All these indirect emissions may account for over 60% of the total carbon footprint of imaging procedures [55].

Finally, predictive global modelling suggests that the carbon emissions from CT and MRI are expected to rise sharply due to increasing imaging demand worldwide, with indirect emissions from manufacturing, facility infrastructure and maintenance projected to make up a growing share of the total environmental impact [54].

3.2.3 | Intestinal Ultrasound

Ultrasound consistently emerged as the imaging modality with the lowest carbon footprint across all studies included [5, 34, 45, 53, 63–65] (Table 3). It was broadly recognised for its minimal energy requirements, negligible embedded carbon costs and absence of resource-intensive contrast agents or specialised infrastructure.

Three studies specifically addressed IUS and point-of-care ultrasound (POCUS) in the management of IBD [34, 63, 64]. Nwaezeigwe et al. [34] conducted a retrospective audit and estimated that IUS produced ~1 kg CO_2e per scan, with the substitution of cross-sectional imaging leading to a total saving of 3269 kg CO_2e over 1 year. This reduction was largely attributed to its bedside applicability, rapid execution and avoidance of referrals for CT, MRI, contrast agents and repeated patient transportation. Dolinger and Kayal [63, 64] further emphasised, in expert review/commentaries, that IUS represents a low-emission, clinically effective imaging option, particularly suitable for disease monitoring and treatment assessment in paediatric IBD. Both studies underscored that IUS combines environmental sustainability with clinical efficiency by minimising the number of high-emission diagnostic procedures required per patient.

Martin et al. [65] compared abdominal US (not specifically IUS) with CT and MRI in abdominal imaging, demonstrating that US had the lowest energy consumption and GHG among the three modalities. The study confirmed that US offers a dramatically reduced environmental impact compared to CT and MRI, without compromising diagnostic performance for many indications.

Quantitative estimates confirmed the low-carbon footprint of US-based modalities. McAlister et al. [53] reported an average emission of 0.5–1.5 kg CO_2e per scan in a prospective LCA, while Pohl et al. and Nwaezeigwe et al. provided a closely aligned estimate of approximately 1 kg CO_2e per procedure [34, 45]. Merkle et al. [5] reported an annual energy consumption for US machines at < 2000 kWh, corresponding to ~600–740 kg CO_2e per year per scanner, the lowest among diagnostic imaging modalities. Importantly, Merkle et al. [5] emphasised that further emission reductions could be achieved by powering off US equipment during periods of non-use, suggesting that minor operational changes could improve sustainability even further.

4 | Discussion

The rising burden of IBD presents not only clinical but also environmental challenges for healthcare systems [69–72]. As chronic diseases like IBD increasingly dominate healthcare resource utilisation [9], the cumulative carbon footprint of diagnostic and therapeutic pathways has become a significant, though historically under-recognised, contributor to healthcare-related GHG emissions [6, 73].

This systematic review demonstrates that GI endoscopy, CT and MRI, while essential for IBD care, are among the most resource-intensive diagnostic modalities, with substantial carbon footprints [21, 40, 42, 62, 65], whereas IUS represents a significantly lower carbon, patient-centred and clinically validated alternative for disease monitoring [5, 34, 45, 53, 63–65].

Colonoscopy continues to be a cornerstone in the management of IBD, enabling direct mucosal visualisation, histologic sampling, mucosal healing assessment and colorectal cancer surveillance [74–79], with its role strongly supported by international guidelines [78, 80]. However, it is also one of the most resource-intensive diagnostic procedures in IBD [21], generating an estimated 7.8–56.4 kg CO_2-equivalent per procedure [6, 21, 41–43, 52], with the majority of emissions stemming from patient transportation, disposable equipment use and facility-related energy consumption [21]. Additionally, GI endoscopy units produce significant amounts of solid and liquid waste per procedure, and substantial energy consumption, with large volumes of recyclable materials often discarded [42]. Sedation practices also influence the carbon footprint of endoscopy. Rughwani et al. [44] noted that anaesthesia choice contributes to variability in emissions, with higher impacts in settings using general anaesthesia compared with procedural sedation, although most studies did not stratify results by anaesthesia type, limiting comparability across healthcare systems. Future research should report such stratified data to allow more precise comparisons across healthcare systems.

Calls for system-level change are emerging. Several authors have advocated for the urgent incorporation of planetary health principles into endoscopy practice and training [81–83], and others have proposed practical strategies to reduce the carbon footprint of endoscopy, including leaner inventory management, teleconsultation pathways and decarbonised sterilisation systems [82].

Cross-sectional imaging, particularly CT and MRI, also plays a pivotal role in IBD [14, 30, 53, 55, 58, 59, 61], particularly for the assessment of transmural disease [30, 84], strictures, fistulae [6, 73] and abscesses in CD [30, 85–89]. MRI has become the preferred modality for longitudinal monitoring, particularly in younger patients, due to its superior soft-tissue resolution and lack of ionising radiation [12, 16, 18]. However, both CT and MRI remain energy-intensive procedures with substantial carbon footprints [53, 62].

Based on the reviewed studies, CT scans typically generate 7–10 kg CO_2e per examination in direct LCAs [53, 60], even reaching ~20 kg per scan in broader modelling and institutional energy-use studies, depending on utilisation, imaging protocols and electricity sources. Indeed, Merkle et al. [5] estimated annual CT scanner energy use in urological practice at 20,000–35,000 kWh/year (~6000–10,500 kg CO_2e/year) corresponding to ~12–21 kg CO_2e per scan if ~500 scans are performed annually. Similarly, Kouropoulos [54] projected a 30% increase in CT-related emissions by 2030 under current trends. Together, these findings underscore the contrast between the relatively modest per-scan footprint reported in controlled LCAs and the larger system-level impact observed in real-world practice.

MRI generates between 17 and 78 kg CO_2-equivalent per scan, and even more, depending on scanner type, imaging protocol and energy sources [53, 60]. While MRI avoids radiation and modern scanners and faster imaging protocols have improved energy efficiency, it presents an even greater environmental challenge due to its high energy demand, particularly for continuous cooling, which generates emissions even when the scanner is idle [10, 61].

The carbon footprint of CT and MRI in chronic disease monitoring is still under-quantified and variably reported. Roletto et al. [20] proposed a comprehensive LCA framework to standardise sustainability assessments in diagnostic imaging, and McGinnis et al. [90] emphasised the critical importance of adopting LCA methods in clinical imaging workflows. Nonetheless, these imaging pathways represent a substantial, albeit still inadequately measured, contribution to the carbon footprint of chronic IBD care [6, 73], and their cumulative environmental burden warrants consideration, given the need for repeated imaging over many years in this patient population [84].

In this landscape, IUS offers a compelling, low carbon and patient-centred alternative for many diagnostic and monitoring needs in IBD. With a per-examination carbon footprint estimated at 0.5–1.5 kg CO_2-equivalent [34, 53, 65], orders of magnitude lower than GI endoscopy, CT or MRI [34, 53], IUS significantly reduces the environmental impact of IBD care (Figure 2). Unlike cross-sectional imaging, IUS requires minimal energy, generates negligible waste [67, 68, 91, 92], typically limited to ultrasound gel and gloves [61, 92, 93], and does not rely on radiation, contrast agents or energy-intensive infrastructure [67, 68, 91, 92]. Its portability and point-of-care availability further minimise patient travel, a major emission source identified for GI endoscopy [22, 64, 91, 94–96] (Figure 3). Clinically, IUS enables real-time decision-making and supports tight disease control, allowing rapid therapeutic adjustments, without the scheduling delays often associated with endoscopy or radiology [28, 30, 64, 91, 95, 97, 98]. In parallel with these sustainability benefits, IUS has also gained strong clinical validation and is increasingly recognised worldwide for its ability to provide real-time assessment of transmural inflammation [29, 31, 35, 63, 64, 99–102], bowel wall thickness [22, 26, 35, 103–108], vascularity [22, 26, 35, 103–105], strictures [24, 84], pre-stenotic dilatation [84], fistulae [109, 110] and intra-abdominal abscesses [22, 109]. In both CD and UC, multiple prospective studies [25, 27, 85, 94, 98, 99, 110–116] and systematic reviews/meta-analyses [31–33, 84, 109, 117–120] have demonstrated its excellent sensitivity and specificity for detecting active inflammation, monitoring therapeutic response, and identifying disease complications. Importantly, IUS has proven comparable to magnetic resonance enterography (MRE) in several clinical scenarios, especially for the monitoring of small bowel disease activity and treatment response [22, 25, 84, 110, 113]. IUS is also minimally invasive, well-tolerated by patients, and can be performed at the point of care [36, 63, 94–96, 116, 121]. Therefore, IUS facilitates decentralised diagnostic models that improve access across both high- and low-resource settings [97]. Together, these features position IUS as a clinically effective solution that

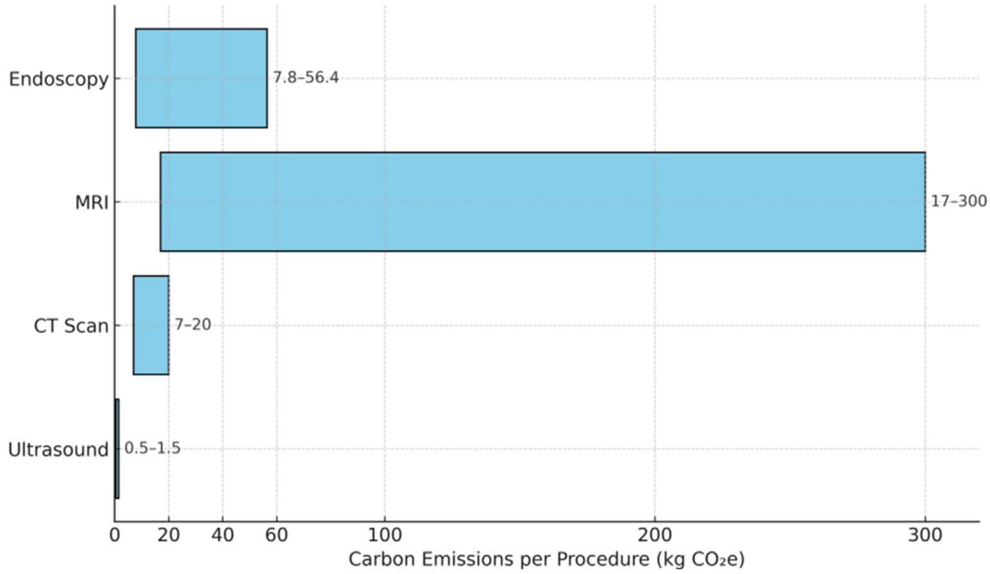

FIGURE 2 | Carbon footprint of diagnostic modalities used in inflammatory bowel disease (IBD) management. Estimates are shown as ranges derived from life cycle assessments (LCAs) and broader institutional or modelling studies. Ultrasound demonstrates the lowest footprint (0.5–1.5 kg CO_2e), followed by CT (7–10 kg CO_2e per scan in LCAs, up to ~20 in institutional data), gastrointestinal endoscopy (7.8–56.4 kg CO_2e) and MRI, which shows the widest variability (17–300 kg CO_2e).

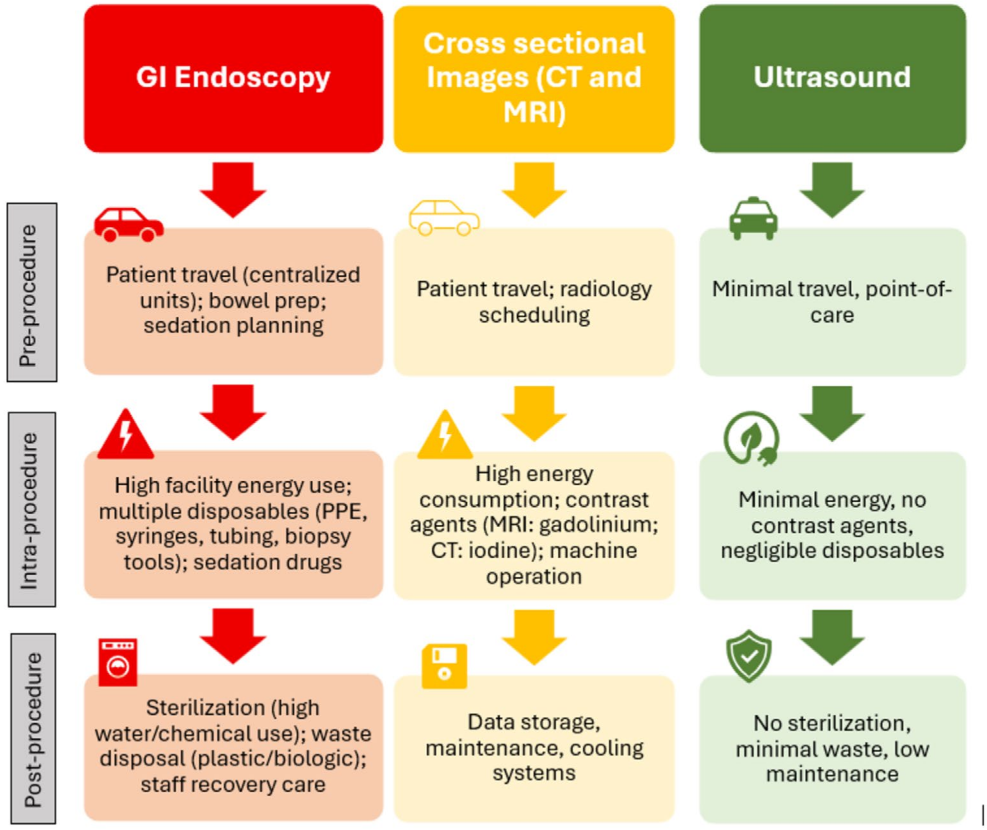

FIGURE 3 | Environmental impact points across diagnostic tools in inflammatory bowel disease (IBD). The figure summarises pre-, intra- and post-procedure contributors to carbon emissions and resource use for endoscopy, cross-sectional imaging (CT and MRI) and ultrasound (US). Endoscopy and cross-sectional imaging are associated with substantial travel, energy consumption, disposables and waste management, whereas US demonstrates minimal energy use, negligible disposables and reduced ancillary infrastructure needs.

could reshape chronic disease monitoring [122]. Despite these advantages, limitations remain. Operator dependence is often cited as a limitation. However, this is being addressed through standardised training programmes and international educational initiatives that have demonstrated reproducible learning curves [112] and high inter-observer agreement among trained clinicians [123]. Expanding access to formal IUS training thus represents a feasible and actionable strategy to promote both clinical excellence and diagnostic sustainability, making its wider adoption both feasible and clinically safe [122–124].

Additionally, IUS remains underutilised, particularly outside Europe [122]. This underuse reflects a combination of historical practice patterns, limited training availability [125], and insufficient integration into diagnostic algorithms and reimbursement frameworks [126]. To fully realise the potential of IUS, future efforts should prioritise its inclusion in gastroenterology training programmes, revise clinical guidelines to incorporate sustainability considerations, and adapt reimbursement policies to support low-carbon care pathways [34, 127].

It is also important to recognise that in clinical practice, IUS is often used in combination with faecal calprotectin or other laboratory biomarkers [128–130], and in some cases, abnormal results on IUS or biomarkers may lead to an earlier endoscopic reassessment. These additional steps carry their own environmental costs, which were not quantified in this review. Likewise, scaling up IUS availability will require training programmes and acquisition of new equipment, introducing an initial carbon cost, though this is likely outweighed by long-term benefits compared with more resource-intensive imaging modalities.

One of the strengths of this study is that it represents the first systematic review to comprehensively evaluate the environmental impact of diagnostic imaging used in IBD management, encompassing GI endoscopy/colonoscopy, CT, MRI and IUS. This review synthesises both quantitative and qualitative data, enabling direct comparison of carbon footprints across these different diagnostic modalities. Compared to previous sustainability research in endoscopy and diagnostic imaging, this review offers a more disease-specific analysis, focusing on chronic care pathways like IBD. Previous studies have acknowledged the environmental burden of diagnostic imaging, but often lacked detailed carbon quantification or did not explore disease-specific impacts over time. Our findings align with existing estimates of emissions per procedure but uniquely highlight the potential of IUS as a low-carbon, scalable alternative.

While this study offers novel insights, it is important to acknowledge its limitations. The included studies exhibit considerable heterogeneity in LCA methodologies and reporting standards, which may affect comparability. Roletto et al. [20] proposed a comprehensive LCA framework to standardise sustainability assessments in diagnostic imaging, and McGinnis et al. [90] emphasised the critical importance of adopting LCA methods in clinical imaging workflows. Further research is needed to conduct standardised, multicentre LCA across diverse healthcare settings to more accurately quantify the carbon impact of diagnostic pathways [20, 66]. Data on indirect emissions, such as those associated with patient transportation and equipment standby energy consumption, were inconsistently reported. There is also a need to evaluate the cumulative carbon footprint of IBD diagnostics over the full course of the disease. Additionally, most studies were conducted in Europe and North America, with only one Indian study, potentially limiting generalisability to low-resource settings. Longitudinal, real-world data on the cumulative carbon footprint over the full diagnostic journey of IBD patients remain limited.

Finally, an additional future consideration is the impact of artificial intelligence (AI) on the carbon footprint of diagnostic imaging. On one hand, AI-based image analysis could enhance efficiency by reducing the need for repeat or unnecessary examinations, thus potentially lowering overall emissions. On the other hand, the training and deployment of large AI models are themselves energy-intensive processes that contribute significantly to greenhouse gas emissions, particularly when relying on cloud-based data centres. The net environmental impact of AI in diagnostic imaging will therefore depend on the balance between these opposing forces, and warrants systematic evaluation in future research [131].

The experience in IBD with IUS offers a clear example of how healthcare can pursue low-carbon precision medicine without sacrificing diagnostic accuracy. Wider adoption of IUS would represent a pragmatic step towards decarbonising chronic disease management while preserving high-quality care [132] and aligning healthcare delivery with planetary health objectives [1–4].

In the context of escalating climate concerns, re-evaluating diagnostic pathways through the lens of planetary health is no longer optional but necessary [36, 133, 134].

Author Contributions

Sara Massironi: conceptualization, investigation, writing – original draft, methodology, software, formal analysis, project administration, data curation. **Alessandra Zilli:** investigation, validation, writing – review and editing, formal analysis, data curation. **Federica Furfaro:** investigation, writing – review and editing. **Mariangela Allocca:** investigation, writing – review and editing. **Laurent Peyrin-Biroulet:** writing – review and editing, validation, supervision. **Vipul Jairath:** validation, formal analysis, supervision. **Silvio Danese:** conceptualization, writing – review and editing, supervision.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

1. M. Lenzen, A. Malik, M. Li, et al., "The Environmental Footprint of Health Care: A Global Assessment," *Lancet Planetary Health* 4, no. 7 (2020): e271–e279.

2. M. A. Steenmeijer, J. F. D. Rodrigues, M. C. Zijp, and S. L. van der Waaijers- Loop, "The Environmental Impact of the Dutch Health-Care Sector Beyond Climate Change: An Input-Output Analysis," *Lancet Planetary Health* 6, no. 12 (2022): e949–e957.

3. M. J. Eckelman, J. D. Sherman, and A. J. MacNeill, "Life Cycle Environmental Emissions and Health Damages From the Canadian Healthcare System: An Economic-Environmental-Epidemiological Analysis," *PLoS Medicine* 15, no. 7 (2018): e1002623.

4. B. Andrieu, L. Marrauld, O. Vidal, M. Egnell, L. Boyer, and G. Fond, "Health-Care Systems' Resource Footprints and Their Access and Quality in 49 Regions Between 1995 and 2015: An Input-Output Analysis," *Lancet Planetary Health* 7, no. 9 (2023): e747–e758.

5. E. M. Merkle, F. Bamberg, and J. Vosshenrich, "The Impact of Modern Imaging Techniques on Carbon Footprints: Relevance and Outlook," *European Urology Focus* 9, no. 6 (2023): 891–893.

6. I. Carbery, G. Bhatnagar, R. Cooney, and C. Selinger, "How Can We Improve the Carbon Footprint of IBD Clinical Care?," *Frontline Gastroenterology* 15, no. e1 (2024): e55–e61.

7. S. Vieujean, V. Jairath, L. Peyrin-Biroulet, et al., "Understanding the Therapeutic Toolkit for Inflammatory Bowel Disease," *Nature Reviews Gastroenterology & Hepatology* 22, no. 6 (2025): 371–394.

8. M. Gill and R. V. Bryant, "Inflammatory Bowel Disease: Diagnosis and Management," in *Gastroenterology for General Surgeons*, ed. M. W. Wichmann, T. K. McCullough, I. C. Roberts-Thomson, and G. J. Maddern (Springer International Publishing, 2019), 55–73.

9. A. Wilkinson, E. Maslova, C. Janson, et al., "Environmental Sustainability in Respiratory Care: An Overview of the healthCARe-Based envirONmental Cost of Treatment (CARBON) Programme," *Advances in Therapy* 39, no. 5 (2022): 2270–2280.

10. T. Heye, R. Knoerl, T. Wehrle, et al., "The Energy Consumption of Radiology: Energy- and Cost-Saving Opportunities for CT and MRI Operation," *Radiology* 295, no. 3 (2020): 593–605.

11. A. M. Wijnands, R. Mahmoud, M. Lutgens, and B. Oldenburg, "Surveillance and Management of Colorectal Dysplasia and Cancer in Inflammatory Bowel Disease: Current Practice and Future Perspectives," *European Journal of Internal Medicine* 93 (2021): 35–41.

12. G. C. Nguyen, D. Low, R. Y. Chong, C. Diong, and T. Chawla, "Utilization of Diagnostic Imaging and Ionization Radiation Exposure Among an Inflammatory Bowel Disease Inception Cohort," *Inflammatory Bowel Diseases* 26, no. 6 (2020): 898–906.

13. N. Zakeri and R. C. Pollok, "Diagnostic Imaging and Radiation Exposure in Inflammatory Bowel Disease," *World Journal of Gastroenterology* 22, no. 7 (2016): 2165–2178.

14. R. Kandel, M. Merlano, P. Tan, et al., "Persistently High Rates of Abdominal Computed Tomography Imaging Among Patients With Inflammatory Bowel Disease Who Present to the Emergency Department," *Journal of the Canadian Association of Gastroenterology* 6, no. 2 (2023): 64–72.

15. C. Lu, X. Yao, M. Yu, and X. He, "Medical Radiation Exposure in Inflammatory Bowel Disease: An Updated Meta-Analysis," *BMC Gastroenterology* 24, no. 1 (2024): 173.

16. R. Shah, A. Elangovan, D. W. Jordan, J. Katz, and G. S. Cooper, "10-Year Trend of Abdominal Magnetic Resonance Imaging Compared With Abdominal Computed Tomography Scans in Inflammatory Bowel Disease," *Inflammatory Bowel Diseases* 28, no. 9 (2022): 1357–1362.

17. K. Ryu, W. J. Yoon, S. H. Kim, et al., "Current Status and Trends of Green Endoscopy," *Clinical Endoscopy* 58 (2025): 493–502.

18. M. S. Gee and M. G. Harisinghani, "MRI in Patients With Inflammatory Bowel Disease," *Journal of Magnetic Resonance Imaging* 33, no. 3 (2011): 527–534.

19. A. S. Alyami, "Imaging of Ulcerative Colitis: The Role of Diffusion-Weighted Magnetic Resonance Imaging," *Journal of Clinical Medicine* 13, no. 17 (2024): 5204.

20. A. Roletto, A. Savio, B. Marchi, and S. Zanoni, "Towards a Greener Radiology: A Comprehensive Life Cycle Assessment Framework for Diagnostic Imaging," *Environmental and Climate Technologies* 28, no. 1 (2024): 303–311.

21. P. López-Muñoz, R. Martín-Cabezuelo, V. Lorenzo-Zúñiga, et al., "Life Cycle Assessment of Routinely Used Endoscopic Instruments and Simple Intervention to Reduce Our Environmental Impact," *Gut* 72, no. 9 (2023): 1692–1697.

22. A. H. Al-Ani, R. Vaughan, B. Christensen, R. V. Bryant, and K. L. Novak, "Treat to Transmural Healing: How to Incorporate Intestinal Ultrasound Into the Treatment of Inflammatory Bowel Disease," *British Journal of Radiology* 95, no. 1137 (2022): 20211174.

23. G. Dell'Anna, F. Mandarino, L. Centanni, et al., "Transforming Gastrointestinal Diagnosis With Molecular Endoscopy: Challenges and Opportunities," *International Journal of Molecular Sciences* 26, no. 10 (2025): 4834.

24. G. C. Lovett, J. D. Schulberg, A. L. Hamilton, et al., "Crohn's Disease Stricture Response to Treatment Assessed With Magnetic Resonance Imaging and Intestinal Ultrasound: STRIDENT Randomized Trial," *Inflammatory Bowel Diseases* (2025), https://doi.org/10.1093/ibd/izaf073.

25. J. B. Brodersen, S. R. Rafaelsen, M. A. Juel, T. Knudsen, J. Kjeldsen, and M. D. Jensen, "Assessment of Treatment Response in Known Crohn's Disease—A Prospective Blinded Study Comparing the Diagnostic Accuracy of Intestinal Ultrasound, Magnetic Resonance Enterocolonography, Panenteric Capsule Endoscopy, and Fecal Calprotectin," *Inflammatory Bowel Diseases* 31 (2024): 1891–1901.

26. J. Huet, K. Mathieu, M. Dodel, et al., "Transmural Healing Assessed by Combination of Fecal Calprotectin and Intestinal Ultrasonography Is Associated With Reduced Risk of Bowel Damage Progression in Patients With Crohn's Disease," *Inflammatory Bowel Diseases* (2025), https://doi.org/10.1093/ibd/izaf068.

27. M. T. Dolinger, I. Aronskyy, E. A. Spencer, N. Pittman, and M. C. Dubinsky, "Early Intestinal Ultrasound Response to Biologic and Small Molecule Therapy Is Accurate to Predict Treat-to-Target Endoscopic Outcomes in Children With Ulcerative Colitis: Results From the Prospective Super Sonic-UC Study," *Journal of Crohn's and Colitis* 19, no. 5 (2025): jjaf075.

28. M. Chavannes, M. T. Dolinger, S. Cohen-Mekelburg, and B. Abraham, "AGA Clinical Practice Update on the Role of Intestinal Ultrasound in Inflammatory Bowel Disease: Commentary," *Clinical Gastroenterology and Hepatology* 22, no. 9 (2024): 1790–1795.e1.

29. C. Maaser, A. Sturm, S. R. Vavricka, et al., "ECCO-ESGAR Guideline for Diagnostic Assessment in IBD Part 1: Initial Diagnosis, Monitoring of Known IBD, Detection of Complications," *Journal of Crohn's and Colitis* 13, no. 2 (2019): 144–164.

30. T. Kucharzik, J. Tielbeek, D. Carter, et al., "ECCO-ESGAR Topical Review on Optimizing Reporting for Cross-Sectional Imaging in Inflammatory Bowel Disease," *Journal of Crohn's & Colitis* 16, no. 4 (2022): 523–543.

31. M. Fraquelli, A. Colli, G. Casazza, et al., "Role of US in Detection of Crohn Disease: Meta-Analysis," *Radiology* 236, no. 1 (2005): 95–101.

32. J. Ilvemark, T. Hansen, T. M. Goodsall, et al., "Defining Transabdominal Intestinal Ultrasound Treatment Response and Remission in Inflammatory Bowel Disease: Systematic Review and Expert Consensus Statement," *Journal of Crohn's & Colitis* 16, no. 4 (2022): 554–580.

33. M. Allocca, F. D'Amico, G. Fiorino, et al., "Systematic Review on Definitions of Intestinal Ultrasound Treatment Response and Remission in Inflammatory Bowel Disease," *Journal of Crohn's and Colitis* 19, no. 2 (2025): jjaf011.

34. M. Nwaezeigwe, M. Hanley, K. Lakshman, J. Sheridan, G. Cullen, and G. Doherty, "P0398 Point of Care Intestinal Ultrasound—Is It the Key to Reducing the Carbon Footprint of IBD Care?," *Journal of Crohn's and Colitis* 19, no. S1 (2025): i894.

35. M. Fraquelli, F. Castiglione, E. Calabrese, and G. Maconi, "Impact of Intestinal Ultrasound on the Management of Patients With Inflammatory Bowel Disease: How to Apply Scientific Evidence to Clinical Practice," *Digestive and Liver Disease* 52, no. 1 (2020): 9–18.

36. S. Bots, F. De Voogd, M. De Jong, et al., "Point-of-Care Intestinal Ultrasound in IBD Patients: Disease Management and Diagnostic Yield in a Real-World Cohort and Proposal of a Point-of-Care Algorithm," *Journal of Crohn's & Colitis* 16, no. 4 (2022): 606–615.

37. J. M. Zumsteg, J. S. Cooper, and M. S. Noon, "Systematic Review Checklist: A Standardized Technique for Assessing and Reporting Reviews of Life Cycle Assessment Data," *Journal of Industrial Ecology* 16, no. S1 (2012): S12–S21.

38. S. E. Kelly, S. P. J. Brooks, K. Benkhedda, et al., "A Scoping Review Shows That no Single Existing Risk of Bias Assessment Tool Considers

All Sources of Bias for Cross-Sectional Studies," *Journal of Clinical Epidemiology* 172 (2024): 111408.

39. K. Kolaski, L. R. Logan, and J. P. A. Ioannidis, "Guidance to Best Tools and Practices for Systematic Reviews," *Systematic Reviews* 12, no. 1 (2023): 96.

40. P. Lämmer, D. Oomkens, T. Stobernack, and M. Duijvestein, "Environmental Footprint of a Colonoscopy Procedure: Life Cycle Assessment," *Endoscopy International Open* 13 (2025): a25706599.

41. A. Perisetti, M. Desai, M. J. Bourke, et al., "Production and Possible Reduction of Greenhouse Gases Produced During GI Endoscopy Activity: A Systematic Review of Available Literature," *Gut* 72, no. 3 (2023): 493–500.

42. M. Desai, C. Campbell, A. Perisetti, et al., "The Environmental Impact of Gastrointestinal Procedures: A Prospective Study of Waste Generation, Energy Consumption, and Auditing in an Endoscopy Unit," *Gastroenterology* 166, no. 3 (2024): 496–502.e3.

43. L. Elli, S. La Mura, A. Rimondi, et al., "The Carbon Cost of Inappropriate Endoscopy," *Gastrointestinal Endoscopy* 99, no. 2 (2024): 137–145.e3.

44. H. Rughwani, R. Kalapala, A. Katrevula, et al., "Carbon Footprinting and Environmental Impact of Gastrointestinal Endoscopy Procedures at a Tertiary Care Institution: A Prospective Multi-Dimensional Assessment," *Gut* 74, no. 6 (2025): 926–934.

45. H. Pohl, R. Baddeley, and B. Hayee, "Carbon Footprint of Gastroenterology Practice," *Gut* 72, no. 12 (2023): 2210–2213.

46. J. Lacroute, J. Marcantoni, S. Petitot, et al., "The Carbon Footprint of Ambulatory Gastrointestinal Endoscopy," *Endoscopy* 55, no. 10 (2023): 918–926.

47. D. Henniger, M. Windsheimer, H. Beck, et al., "Assessment of the Yearly Carbon Emission of a Gastrointestinal Endoscopy Unit," *Gut* 72 (2023): 1816–1818.

48. N. N. T. Le, L. V. Hernandez, N. Vakil, N. Guda, C. Patnode, and O. Jolliet, "Environmental and Health Outcomes of Single-Use Versus Reusable Duodenoscopes," *Gastrointestinal Endoscopy* 96, no. 6 (2022): 1002–1008.

49. M. Pioche, H. Pohl, J. A. Cunha Neves, et al., "Environmental Impact of Single-Use Versus Reusable Gastroscopes," *Gut* 73, no. 11 (2024): 1816–1822.

50. M. Pioche, J. A. Cunha Neves, H. Pohl, et al., "The Environmental Impact of Small-Bowel Capsule Endoscopy," *Endoscopy* 56, no. 10 (2024): 737–746.

51. M. Jain and V. Agrawal, "Making Endoscopy Practice Environmentally Sustainable-Early Experience From Central India," *Indian Journal of Gastroenterology* 42 (2023): 860–862.

52. M. Maida, A. Vitello, E. Shahini, et al., "Green Endoscopy, One Step Toward a Sustainable Future: Literature Review," *Endoscopy International Open* 12, no. 8 (2024): E968–E980.

53. S. McAlister, F. McGain, M. Petersen, et al., "The Carbon Footprint of Hospital Diagnostic Imaging in Australia," *Lancet Regional Health—Western Pacific* 24 (2022): 100459.

54. G. P. Kouropoulos, "A Predictive Model for the Estimation of Carbon Dioxide Emissions of Magnetic Resonance Imaging (MRI) Units and Computed Tomography (CT) Scanners," *Journal of Urban and Environmental Engineering* 12 (2018): 172–187.

55. A. Esmaeili, C. McGuire, M. Overcash, K. Ali, S. Soltani, and J. Twomey, "Environmental Impact Reduction as a New Dimension for Quality Measurement of Healthcare Services," *International Journal of Health Care Quality Assurance* 31, no. 8 (2018): 910–922.

56. E. Picano, "Environmental Sustainability of Medical Imaging," *Acta Cardiologica* 76, no. 10 (2021): 1124–1128.

57. J. Vosshenrich, D. Mangold, C. Aberle, et al., "Interventional Imaging Systems in Radiology, Cardiology, and Urology: Energy Consumption, Carbon Emissions, and Electricity Costs," *AJR—American Journal of Roentgenology* 222, no. 6 (2024): e2430988.

58. S. Bastian, E. André, F. L. Jesús, et al., "Assessing Environmental Sustainability in Dual-Energy CT: Exploring Energy Consumption and Ecological-Economic Impact in Low Utilization Times," *Academic Radiology* 31, no. 11 (2024): 4528–4537.

59. L. Furlan, P. Di Francesco, E. Tobaldini, et al., "The Environmental Cost of Unwarranted Variation in the Use of Magnetic Resonance Imaging and Computed Tomography Scans," *European Journal of Internal Medicine* 111 (2023): 47–53.

60. A. Esmaeili, J. M. Twomey, M. R. Overcash, S. A. Soltani, C. McGuire, and K. Ali, "Scope for Energy Improvement for Hospital Imaging Services in the USA," *Journal of Health Services Research & Policy* 20, no. 2 (2015): 67–73.

61. S. A. Woolen, A. E. Becker, A. J. Martin, et al., "Ecodesign and Operational Strategies to Reduce the Carbon Footprint of MRI for Energy Cost Savings," *Radiology* 307, no. 4 (2023): e230441.

62. A. Roletto, M. Zanardo, G. R. Bonfitto, D. Catania, F. Sardanelli, and S. Zanoni, "The Environmental Impact of Energy Consumption and Carbon Emissions in Radiology Departments: A Systematic Review," *European Radiology Experimental* 8, no. 1 (2024): 35.

63. M. T. Dolinger and M. Kayal, "Intestinal Ultrasound Is the Ideal Patient-Centric, Point-of-Care Tool for Clinical Decision Making in the Inflammatory Bowel Disease Practice," *Crohn's & Colitis 360* 5, no. 3 (2023): otad029.

64. M. T. Dolinger and M. Kayal, "Intestinal Ultrasound as a Non-Invasive Tool to Monitor Inflammatory Bowel Disease Activity and Guide Clinical Decision Making," *World Journal of Gastroenterology* 29, no. 15 (2023): 2272–2282.

65. M. Martin, A. Mohnke, G. M. Lewis, N. R. Dunnick, G. Keoleian, and K. E. Maturen, "Environmental Impacts of Abdominal Imaging: A Pilot Investigation," *Journal of the American College of Radiology* 15, no. 10 (2018): 1385–1393.

66. A. Roletto, A. Savio, and S. Zanoni, "Life Cycle Assessment Framework for Diagnostic Imaging" (CONECT International Scientific Conference of Environmental and Climate Technologies, 2024).

67. R. E. Lenkinski and N. M. Rofsky, "Contrast Media-Driven Anthropogenic Gadolinium: Knowns and Unknowns," *Radiology* 311, no. 1 (2024): e240020.

68. M. Rogosnitzky and S. Branch, "Gadolinium-Based Contrast Agent Toxicity: A Review of Known and Proposed Mechanisms," *Biometals* 29, no. 3 (2016): 365–376.

69. B. Caron, S. Honap, and L. Peyrin-Biroulet, "Epidemiology of Inflammatory Bowel Disease Across the Ages in the Era of Advanced Therapies," *Journal of Crohn's & Colitis* 18, no. S2 (2024): ii3–ii15.

70. M. Agrawal and T. Jess, "Implications of the Changing Epidemiology of Inflammatory Bowel Disease in a Changing World," *United European Gastroenterology Journal* 10, no. 10 (2022): 1113–1120.

71. V. Sojitra, P. R. Naradasu, K. M. Patel, R. Patel, S. Patel, and H. D. Desai, "Evolving Burden of Inflammatory Bowel Disease in Women From 1990–2019: Global, Regional, National Variations, Age Dynamics, and Implications for Global Health," *Inflammatory Bowel Diseases* 30, no. S1 (2024): S30–S31.

72. R. Claerman, B. Devleesschauwer, S. Nayani, and R. De Pauw, "Burden of Inflammatory Bowel Disease in Belgium, 2020," *European Journal of Public Health* 34, no. S3 (2024): 511–512.

73. E. M. B. Hendrix, D. C. de Jong, M. J. de Jong, et al., "P0027 the Carbon Footprint of Remote Monitoring of IBD Patients—A Green Opportunity for Sustainable Outpatient Care," *Journal of Crohn's and Colitis* 19, no. S1 (2025): i368–i369.

74. A. Dal Buono, R. Gabbiadini, F. Furfaro, et al., “Endoscopic Surveillance in Inflammatory Bowel Diseases: Selecting a Suitable Technology,” *Frontiers in Medicine* 9 (2022): 855652.

75. F. P. Núñez, N. Krugliak Cleveland, R. Quera, and D. T. Rubin, “Evolving Role of Endoscopy in Inflammatory Bowel Disease: Going Beyond Diagnosis,” *World Journal of Gastroenterology* 27, no. 20 (2021): 2521–2530.

76. R. Gabbiadini, F. D'Amico, A. De Marco, et al., “Colorectal Cancer Surveillance in Patients With Inflammatory Bowel Diseases: Chromoendoscopy or Non-Chromoendoscopy, That Is the Question,” *Journal of Clinical Medicine* 11, no. 3 (2022): 509.

77. C. W. Huang, H. H. Yen, and Y. Y. Chen, “Endoscopic Techniques for Colorectal Neoplasia Surveillance in Inflammatory Bowel Disease: A Systematic Review and Network Meta-Analysis,” *United European Gastroenterology Journal* (2025), https://doi.org/10.1002/ueg2.70017.

78. J. E. East, M. Gordon, G. B. Nigam, et al., “British Society of Gastroenterology Guidelines on Colorectal Surveillance in Inflammatory Bowel Disease,” *Gut* (2025), https://doi.org/10.1136/gutjnl-2025-335023.

79. W. A. Bye, T. M. Nguyen, C. E. Parker, V. Jairath, and J. E. East, “Strategies for Detecting Colon Cancer in Patients With Inflammatory Bowel Disease,” *Cochrane Database of Systematic Reviews* 9, no. 9 (2017): CD000279.

80. M. Gordon, G. B. Nigam, V. Sinopoulou, et al., “Update From 2010 (Standard Operating Procedure): Protocol for the 2024 British Society of Gastroenterology Guidelines on Colorectal Surveillance in Inflammatory Bowel Disease,” *BMJ Open Gastroenterology* 11, no. 1 (2024): e001541.

81. S. Sebastian, A. Dhar, R. Baddeley, et al., “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,” *Gut* 72, no. 1 (2023): 12–26.

82. V. Kaul, “Green Endoscopy,” *American Journal of Gastroenterology* 119, no. 9 (2024): 1714–1718.

83. V. Rossa-Roccor, E. S. Acheson, F. Andrade-Rivas, et al., “Scoping Review and Bibliometric Analysis of the Term ‘Planetary Health’ in the Peer-Reviewed Literature,” *Frontiers in Public Health* 8 (2020): 343.

84. D. Bettenworth, A. Bokemeyer, M. Baker, et al., “Assessment of Crohn's Disease-Associated Small Bowel Strictures and Fibrosis on Cross-Sectional Imaging: A Systematic Review,” *Gut* 68, no. 6 (2019): 1115–1126.

85. S. A. Taylor, S. Mallett, G. Bhatnagar, et al., “Diagnostic Accuracy of Magnetic Resonance Enterography and Small Bowel Ultrasound for the Extent and Activity of Newly Diagnosed and Relapsed Crohn's Disease (METRIC): A Multicentre Trial,” *Lancet Gastroenterology & Hepatology* 3, no. 8 (2018): 548–558.

86. J. Rimola, J. Torres, S. Kumar, S. A. Taylor, and T. Kucharzik, “Recent Advances in Clinical Practice: Advances in Cross-Sectional Imaging in Inflammatory Bowel Disease,” *Gut* 71, no. 12 (2022): 2587–2597.

87. K. Taylor, E. Robinson, R. Balasubramaniam, et al., “A British Society of Gastrointestinal and Abdominal Radiology Multi-Centre Audit of Imaging Investigations in Inflammatory Bowel Disease,” *British Journal of Radiology* 98, no. 1169 (2025): 734–743.

88. S. A. Taylor, S. Kumar, T. Parry, et al., “Magnetic Resonance Enterography to Predict Subsequent Disabling Crohn's Disease in Newly Diagnosed Patients (METRIC-EF)-Multivariable Prediction Model, Multicentre Diagnostic Inception Cohort,” *European Radiology* (2025), https://doi.org/10.1007/s00330-025-11636-8.

89. S. Kumar, A. Plumb, S. Mallett, et al., “METRIC-EF: Magnetic Resonance Enterography to Predict Disabling Disease in Newly Diagnosed Crohn's Disease-Protocol for a Multicentre, Non-Randomised, Single-Arm, Prospective Study,” *BMJ Open* 12, no. 10 (2022): e067265.

90. S. McGinnis, C. Johnson-Privitera, J. D. Nunziato, and S. Wohlford, “Environmental Life Cycle Assessment in Medical Practice: A User's Guide,” *Obstetrical & Gynecological Survey* 76, no. 7 (2021): 417–428.

91. A. Jauregui-Amezaga and J. Rimola, “Role of Intestinal Ultrasound in the Management of Patients With Inflammatory Bowel Disease,” *Life* 11, no. 7 (2021): 603.

92. A. K. Asthana, “Intestinal Ultrasound in Inflammatory Bowel Disease,” *Journal of Gastroenterology and Hepatology* 31, no. S1 (2016): 21–22.

93. A. Dignass, F. D'Amico, F. Gomollón, et al., “P808 Use of Intestinal Ultrasound Influences the Proportion of Suboptimally Controlled Patients: IBD Podcast Study Results,” *Journal of Crohn's and Colitis* 18, no. S1 (2024): i1494–i1495.

94. M. Chavannes, L. Hart, P. Hayati Rezvan, J. R. Dillman, and D. B. Polk, “Bedside Intestinal Ultrasound Predicts Disease Severity and the Disease Distribution of Pediatric Patients With Inflammatory Bowel Disease: A Pilot Cross-Sectional Study,” *Inflammatory Bowel Diseases* 30, no. 3 (2024): 402–409.

95. N. Grunshaw, W. Harrison, H. Owen, and P. J. Smith, “Effect of Combined Rapid Access Point-Of-Care Intestinal Ultrasound Clinic on the Management of Inflammatory Bowel Disease,” *Frontline Gastroenterology* 15, no. 5 (2024): 373–379.

96. F. A. E. de Voogd, B. Verstockt, C. Maaser, and K. B. Gecse, “Point-of-Care Intestinal Ultrasonography in Inflammatory Bowel Disease,” *Nature Reviews Gastroenterology & Hepatology* 18, no. 4 (2021): 209–210.

97. M. T. Dolinger, E. Calabrese, F. Pizzolante, and M. T. Abreu, “Current and Novel Uses of Intestinal Ultrasound in Inflammatory Bowel Disease,” *Gastroenterology & Hepatology* 19, no. 8 (2023): 447–457.

98. M. T. Dolinger, I. Aronskyy, A. Kellar, E. Spencer, N. Pittman, and M. C. Dubinsky, “Early Intestinal Ultrasound Response to Biologic Therapy Predicts Endoscopic Remission in Children With Ileal Crohn's Disease: Results From the Prospective Super Sonic Study,” *Journal of Crohn's & Colitis* 18, no. 7 (2024): 1002–1011.

99. M. Allocca, E. Filippi, A. Costantino, et al., “Milan Ultrasound Criteria Are Accurate in Assessing Disease Activity in Ulcerative Colitis: External Validation,” *United European Gastroenterology Journal* 9, no. 4 (2021): 438–442.

100. M. Allocca, T. Kucharzik, and D. T. Rubin, “Intestinal Ultrasound in the Assessment and Management of Inflammatory Bowel Disease: Is It Ready for Standard Practice?,” *Gastroenterology* 164, no. 6 (2023): 851–855.

101. N. Krugliak Cleveland, J. St-Pierre, A. Kellar, and D. T. Rubin, “Clinical Application of Intestinal Ultrasound in Inflammatory Bowel Disease,” *Current Gastroenterology Reports* 26, no. 2 (2024): 31–40.

102. T. Kucharzik, B. M. Wittig, U. Helwig, et al., “Use of Intestinal Ultrasound to Monitor Crohn's Disease Activity,” *Clinical Gastroenterology and Hepatology* 15, no. 4 (2017): 535–542.e2.

103. A. Barchi, F. D'Amico, A. Zilli, et al., “Recent Advances in the Use of Ultrasound in Crohn's Disease,” *Expert Review of Medical Devices* 20, no. 12 (2023): 1119–1129.

104. F. D'Amico, S. Massironi, M. Allocca, and S. Danese, “Advancing Transmural Remission as a Treatment Target in Crohn's Disease: The Future of Tight-Control Strategy?,” *United European Gastroenterology Journal* 11 (2023): 948–950.

105. F. Zorzi, D. T. Rubin, N. K. Cleveland, G. Monteleone, and E. Calabrese, “Ultrasonographic Transmural Healing in Crohn's Disease,” *American Journal of Gastroenterology* 118, no. 6 (2023): 961–969.

106. D. Turner, A. Ricciuto, A. Lewis, et al., “STRIDE-II: An Update on the Selecting Therapeutic Targets in Inflammatory Bowel Disease

(STRIDE) Initiative of the International Organization for the Study of IBD (IOIBD): Determining Therapeutic Goals for Treat-to-Target Strategies in IBD," *Gastroenterology* 160, no. 5 (2021): 1570–1583.

107. J. F. Colombel, G. D'Haens, W. J. Lee, J. Petersson, and R. Panaccione, "Outcomes and Strategies to Support a Treat-to-Target Approach in Inflammatory Bowel Disease: A Systematic Review," *Journal of Crohn's & Colitis* 14, no. 2 (2020): 254–266.

108. A. Dignass, S. Rath, T. Kleindienst, and A. Stallmach, "Review Article: Translating STRIDE-II Into Clinical Reality—Opportunities and Challenges," *Alimentary Pharmacology & Therapeutics* 58, no. 5 (2023): 492–502.

109. J. Panés, R. Bouzas, M. Chaparro, et al., "Systematic Review: The Use of Ultrasonography, Computed Tomography and Magnetic Resonance Imaging for the Diagnosis, Assessment of Activity and Abdominal Complications of Crohn's Disease," *Alimentary Pharmacology & Therapeutics* 34, no. 2 (2011): 125–145.

110. M. Allocca, G. Fiorino, C. Bonifacio, et al., "Comparative Accuracy of Bowel Ultrasound Versus Magnetic Resonance Enterography in Combination With Colonoscopy in Assessing Crohn's Disease and Guiding Clinical Decision-Making," *Journal of Crohn's & Colitis* 12, no. 11 (2018): 1280–1287.

111. S. Bots, K. Nylund, M. Löwenberg, K. Gecse, and G. D'Haens, "Intestinal Ultrasound to Assess Disease Activity in Ulcerative Colitis: Development of a Novel UC-Ultrasound Index," *Journal of Crohn's and Colitis* 15, no. 8 (2021): 1264–1271.

112. J. B. Brodersen, M. D. Jensen, M. A. Juel, J. Kjeldsen, T. Knudsen, and S. R. Rafaelsen, "Intestinal Ultrasound in Patients With Suspected Crohn's Disease—Results of a Prospective Evaluation by Trainees," *Scandinavian Journal of Gastroenterology* 58, no. 12 (2023): 1405–1411.

113. L. Calavrezos, P. Bannas, M. Warncke, C. Wiegard, S. Huber, and C. Manthey, "Transabdominal Ultrasound and Magnetic Resonance Enterography in Inflammatory Bowel Disease: Results of an Observational Retrospective Single-Center Study," *Ultrasound International Open* 8, no. 1 (2022): E22–E28.

114. F. A. de Voogd, S. J. Bots, E. A. van Wassenaer, et al., "Early Intestinal Ultrasound Predicts Clinical and Endoscopic Treatment Response and Demonstrates Drug-Specific Kinetics in Moderate-to-Severe Ulcerative Colitis," *Inflammatory Bowel Diseases* 30, no. 11 (2024): 1992–2003.

115. T. Kucharzik, R. Wilkens, M. A. D'Agostino, et al., "Early Ultrasound Response and Progressive Transmural Remission After Treatment With Ustekinumab in Crohn's Disease," *Clinical Gastroenterology and Hepatology* 21, no. 1 (2023): 153–163.e12.

116. D. Sathananthan, A. Rajagopalan, L. Van De Ven, et al., "Point-of-Care Gastrointestinal Ultrasound in Inflammatory Bowel Disease: An Accurate Alternative for Disease Monitoring," *JGH Open* 4, no. 2 (2020): 273–279.

117. A. Dal Buono, F. Faita, A. Armuzzi, et al., "Assessment of Activity and Severity of Inflammatory Bowel Disease in Cross-Sectional Imaging Techniques: A Systematic Review," *Journal of Crohn's & Colitis* 19, no. 2 (2025): jjaf023.

118. C. Lu, R. Rosentreter, M. Delisle, et al., "Systematic Review: Defining, Diagnosing and Monitoring Small Bowel Strictures in Crohn's Disease on Intestinal Ultrasound," *Alimentary Pharmacology & Therapeutics* 59, no. 8 (2024): 928–940.

119. S. Sagami, T. Kobayashi, Y. Miyatani, et al., "Accuracy of Ultrasound for Evaluation of Colorectal Segments in Patients With Inflammatory Bowel Diseases: A Systematic Review and Meta-Analysis," *Clinical Gastroenterology and Hepatology* 19, no. 5 (2021): 908–921.e6.

120. E. A. van Wassenaer, F. A. E. de Voogd, R. R. van Rijn, et al., "Diagnostic Accuracy of Transabdominal Ultrasound in Detecting Intestinal Inflammation in Paediatric IBD Patients—A Systematic Review," *Journal of Crohn's & Colitis* 13, no. 12 (2019): 1501–1509.

121. M. Allocca, F. Furfaro, G. Fiorino, L. Peyrin-Biroulet, and S. Danese, "Point-of-Care Ultrasound in Inflammatory Bowel Disease," *Journal of Crohn's & Colitis* 15, no. 1 (2021): 143–151.

122. B. P. Abraham, D. Reddy, and A. Saleh, "Integrating Intestinal Ultrasound Into an Inflammatory Bowel Disease Practice: How to Get Started," *Crohn's & Colitis 360* 5, no. 3 (2023): otad043.

123. C. Bezzio, D. Pitoni, D. G. Ribaldone, et al., "P0224 Learning Curve in Intestinal Ultrasound: Advancing From Basic Skills to Advanced Competencies—Insights From the IUS IG-IBD (Italian Group for the Study of Inflammatory Bowel Disease) Master Program," *Journal of Crohn's and Colitis* 19, no. S1 (2025): i639.

124. G. R. Madsen, R. Wilkens, T. Boysen, et al., "The Knowledge and Skills Needed to Perform Intestinal Ultrasound for Inflammatory Bowel Diseases—An International Delphi Consensus Survey," *Alimentary Pharmacology & Therapeutics* 56, no. 2 (2022): 263–270.

125. A. Costantino, C. Af Björkesten, M. L. Vaiano, et al., "P396 Bowel Ultrasound Training in European and Mediterranean Countries: Results of a Survey," *Journal of Crohn's and Colitis* 18, no. S1 (2024): i818–i819.

126. T. Mengel-Jørgensen and M. B. Jensen, "Variation in the Use of Point-of-Care Ultrasound in General Practice in Various European Countries. Results of a Survey Among Experts," *European Journal of General Practice* 22, no. 4 (2016): 274–277.

127. Z. Or and A. V. Seppänen, "The Role of the Health Sector in Tackling Climate Change: A Narrative Review," *Health Policy* 143 (2024): 105053.

128. D. Huynh, D. Rubtsov, D. Basu, and M. M. Khaing, "The Diagnostic Utility of Biochemical Markers and Intestinal Ultrasound Compared With Endoscopy in Patients With Crohn's Disease and Ulcerative Colitis: A Systemic Review and Meta-Analysis," *Journal of Clinical Medicine* 13, no. 11 (2024): 3030.

129. F. Furfaro, F. D'Amico, A. Zilli, et al., "Noninvasive Assessment of Postoperative Disease Recurrence in Crohn's Disease: A Multicenter, Prospective Cohort Study on Behalf of the Italian Group for Inflammatory Bowel Disease," *Clinical Gastroenterology and Hepatology* 21, no. 12 (2023): 3143–3151.

130. S. Dubian, C. Yzet, F. Brazier, et al., "Fecal Calprotectin, Intestinal Ultrasound, and Their Combination for the Diagnosis of Inflammatory Bowel Disease," *Clinics and Research in Hepatology and Gastroenterology* 49, no. 3 (2025): 102549.

131. J. Wu, T. Liu, and J. Sun, "Impact of Artificial Intelligence on Carbon Emission Efficiency: Evidence From China," *Environmental Science and Pollution Research International* 32 (2023): 19450–19461.

132. S. Lucas, A. Chauhan, and M. Garg, "Letter: Delays to Diagnosis of IBD-Challenges Requiring a Systematic Approach," *Alimentary Pharmacology & Therapeutics* 57, no. 12 (2023): 1477–1478.

133. N. Redvers, K. Wright, J. Hartmann-Boyce, and S. Tonkin-Crine, "Planetary Health for Health Systems: A Scoping Review and Content Analysis of Frameworks," *PLOS Global Public Health* 5, no. 6 (2025): e0004710.

134. T. Piggott, M. Raja, C. T. J. Michels, et al., "Considering Planetary Health in Health Guidelines and Health Technology Assessments: A Scoping Review Protocol," *Systematic Reviews* 13, no. 1 (2024): 163.

Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Appendix S1:** apt70385-sup-0001-AppendixS1.docx. **Appendix S2:** apt70385-sup-0002-AppendixS2.docx.