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Research Article

Reducing Cost and Environmental Impact in Crohn's Disease Imaging: A Transdisciplinary Approach with Intestinal Ultrasound

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ABSTRACT
Introduction: Magnetic Resonance Enterography (MRE) is commonly used for assessing inflammatory bowel disease (IBD), particularly Crohn's disease (CD), but is associated with substantial financial and environmental costs. This study evaluated the potential economic and environmental benefits of implementing intestinal ultrasound (IUS) through a transdisciplinary clinical pathway.
Methods: A retrospective analysis was conducted at a tertiary referral hospital in India from October 2023 to September 2024. Adults with confirmed Crohn's disease who underwent IUS as part of routine clinical evaluation were included. The transdisciplinary team comprised five gastroenterologists, two radiologists, and four radiographers. Demographic, imaging, and institutional cost data were extracted from electronic medical records. Energy consumption and carbon emissions were estimated using published values and institutional estimates.
Results: A total of 26 unique patients underwent 34 IUS examinations during the study period, indicating that some patients underwent repeat examinations. IUS findings were considered sufficient to avoid 27 MRE examinations (79.4%) and 20 colonoscopies (58.8%), with these percentages calculated using the 34 IUS
examinations as the denominator. Avoidance of 27 MRE examinations was associated with an estimated reduction of 540 mL of gadolinium-based contrast agent and 36,450 mL of oral barium sulphate suspension. Based on the stated unit costs and the cost of the 34 IUS examinations, estimated net savings were US$28,345 compared with MRE and US$23,392 compared with endoscopy. Estimated energy savings were 304.83 kWh for avoided MRE examinations and 3,181 kWh for avoided endoscopies, corresponding to estimated carbon reductions of 458.19 kg CO_2e and 557.40 kg CO_2e, respectively.
Conclusion: An IUS-led pathway may provide substantial economic and environmental benefits for appropriate patients with Crohn's disease. Transdisciplinary collaboration among gastroenterologists, radiologists, and trained radiographers can support integration of IUS into routine care and contribute to more sustainable imaging pathways.
Implications for Practice: Integrating trained radiographers into IUS services may support workforce development, optimize imaging workflows, reduce unnecessary resource utilization, and promote environmentally responsible imaging practice.

Keywords: Diagnostic Imaging, Inflammatory Bowel Diseases, Ultrasonography, Value-Based Health Care.

INTRODUCTION

Inflammatory bowel disease (IBD), encompassing Crohn's disease (CD) and ulcerative colitis (UC), comprises chronic, relapsing inflammatory disorders of the gastrointestinal tract with no known curative treatment. These conditions significantly affect patients physically and psychosocially and

contribute to substantial healthcare expenditure and societal burden. A systematic analysis has projected that IBD will remain an important public health challenge because of increasing prevalence, mortality rates, and disability-adjusted life years (DALYs). Recent data from the Global Burden of Disease 2019 study have demonstrated increasing incidence and prevalence of IBD across Asia, including India, despite reductions in mortality and DALYs. A local study reported an IBD incidence rate of 1.06 per 100,000 persons, with a steadily increasing trend over the past decade. Evidence also suggests earlier disease onset and more aggressive clinical presentations among Asian populations compared with Western populations, potentially increasing the long-term economic burden of disease management.[1–5]

Although many Indian patients are supported by government-funded healthcare schemes and private insurance options, out-of-pocket expenditure remains common for diagnostic procedures such as colonoscopy and imaging examinations such as magnetic resonance enterography (MRE). MRE plays an important role in the diagnosis, monitoring, and treatment planning of CD. As clinical strategies increasingly emphasize early therapeutic intervention and treat-to-target models, the demand for timely and accurate imaging has intensified. However, MRE is relatively expensive and frequently requires gadolinium-based contrast agents (GBCAs), raising concerns regarding gadolinium retention and the implications of repeated exposure. These limitations highlight the need for alternative imaging approaches that are cost-effective, accurate, patient-friendly, and consistent with value-based healthcare principles.[6–9]

Intestinal ultrasound (IUS) has gained increasing recognition as a useful imaging tool for IBD assessment. When performed by appropriately trained operators, IUS provides real-time evaluation of bowel inflammation without ionising radiation or intravenous contrast. It is repeatable, non-invasive, relatively affordable, and potentially associated with a lower environmental burden than MRI-based techniques.[10–13]

Implementation of IUS within routine IBD care requires coordinated involvement from multiple professional groups, including gastroenterologists, radiologists, and radiographers. Standardized protocols and appropriate practitioner training are essential for maintaining examination quality and consistency. This highlights the importance of a transdisciplinary approach to successful implementation.

Although previous studies have examined the economic benefits of IUS, relatively limited attention has been directed toward the environmental implications of replacing resource-intensive imaging pathways with ultrasound-based assessment. Therefore, this study evaluated the impact of a transdisciplinary IUS pathway on healthcare costs, contrast-agent utilization, energy consumption, and carbon emissions in patients with Crohn's disease.

METHODS

Study Design and Clinical Pathway: A transdisciplinary IUS clinical pathway was implemented in October 2023 through collaboration between the Department of Gastroenterology & Hepatology and the Department of Diagnostic Radiology.

Before implementation of the pilot pathway, one gastroenterologist, one radiologist, and one radiographer completed advanced IUS fellowship training. Following their return in May 2023, local capability-building was undertaken through structured on-the-job training for a wider team of radiologists and radiographers. Protocol development and standardization were conducted collaboratively by the radiology team using best-practice guidance from the International Bowel Ultrasound Group (IBUS). Gastroenterologists also received targeted briefings to support clinical adoption and integration of IUS into routine practice.

Study Population: A retrospective analysis was conducted of IUS examinations performed between October 2023 and September 2024. Adults aged ≥18 years with a confirmed diagnosis of Crohn's disease who underwent IUS as part of clinical evaluation were eligible.

The study included 26 unique patients and 34 IUS examinations. The difference between the number of unique patients and examinations indicates that some patients underwent repeat IUS examinations during the study period. The available galley-proof information does not provide the patient-level distribution of repeat examinations; therefore, no specific number of repeat examinations per patient is assumed.

Imaging decisions were made by five gastroenterologists based on individual clinical assessment. Electronic medical records were reviewed for demographic characteristics,

clinical
history, imaging information, and subsequent care decisions.
An MRE or colonoscopy was considered "avoided" when IUS findings were considered sufficient to inform treatment escalation, de-escalation, or continuation of care without requiring the additional procedure.
The primary unit of analysis for procedure avoidance and associated economic and environmental estimates was the IUS examination rather than the unique patient. Accordingly, the 27 avoided MRE examinations and 20 avoided colonoscopies were evaluated against the 34 IUS examinations.
An individual IUS examination could potentially contribute to avoidance of an MRE, a colonoscopy, or both. Therefore, the MRE and colonoscopy avoidance categories should not be interpreted as mutually exclusive.

IUS Examination: IUS examinations were performed by four experienced radiographers, each with more than 10 years of ultrasound expertise, and two consultant radiologists specializing in abdominal imaging. Examinations were performed in a dedicated ultrasound suite with adjustable lighting.
Patients were not required to fast before imaging. Before each examination, the imaging team reviewed previous imaging, clinical documentation, and known anatomical variations related to the patient's disease.
Ultrasound systems included the Philips EPIQ 7G, Philips EPIQ Elite, and Canon Aplio 500.
Curved-array transducers (1–5 MHz and 2–9 MHz for Philips; 1–6 MHz for Canon) were used for rectal assessment and general anatomical orientation. High-frequency linear-array transducers (5–12 MHz for Philips; 7–14 MHz for Canon) were used for detailed assessment of the colon and terminal ileum. These transducers enabled bowel wall thickness measurements with a resolution of <0.1 mm and facilitated visualization of bowel-wall layering.
Colour Doppler signal was applied using linear probes calibrated to detect intramural flow at velocity settings of 2–5 cm/s to assess inflammatory activity.

Definition of Avoided Procedures: MRE and colonoscopy were classified as avoided when the IUS findings were considered sufficient by the treating clinical team to make a management decision without proceeding to the additional procedure.
Because the determination of avoidance was based on clinical decision-making, it represents an estimate of procedure substitution rather than a randomized comparison of diagnostic strategies.

Economic Analysis: The institutional unit costs reported in the study were:
- IUS: US$182 per examination
- MRE: US$1,279 per examination
- Endoscopy: US$1,479 per procedure

The net cost saving for each alternative pathway was estimated by subtracting the cost of the 34 IUS examinations from the estimated cost of the procedures avoided.
For MRE:
27 × US$1,279 = US$34,533
34 × US$182 = US$6,188
Net MRE-related saving = US$34,533 – US$6,188
= US$28,345
For endoscopy:
20 × US$1,479 = US$29,580
34 × US$182 = US$6,188

Net Endoscopy-Related Saving = US$29,580 – US$6,188 = US$23,392
Contrast Utilization: According to the institutional protocol, patients weighing <50 kg typically received 10 mL of GBCA, whereas patients weighing >50 kg received 20 mL. Each MRE required 1,350 mL of oral barium sulphate suspension.
The reported GBCA saving of 540 mL corresponds to:
27 × 20 mL = 540 mL
The reported oral contrast saving corresponds to: 27 × 1,350 mL = 36,450 mL
Because the manuscript provides different dose categories based on body weight but does not provide individual weights for the 27 avoided MRE examinations, the 540-mL estimate should be confirmed against the original patient-level records before final publication.

Environmental Analysis: Energy consumption and carbon emissions were estimated from published literature and institutional estimates. The values were used in table are to estimate the energy and carbon savings associated with avoided MRE and endoscopy procedures.

Per-Procedure Values Were:

Parameter	MRE	IUS	Endoscopy

Cost (US$)	1,279	182	1,479
Energy consumption (kWh)	11.8	0.51	159.56
Carbon emissions (kg CO_2e)	17.5	0.53	28.4

Ethical Considerations: The evaluation was classified as a service evaluation because the data were collected during routine clinical care. The original study report therefore stated that formal ethics review was not required. This statement should be retained only if it accurately reflects the institutional governance determination for the study.

RESULTS

Patient Characteristics: A total of 26 unique patients were included. These patients underwent 34 IUS examinations during the study period. Thus, patient count and examination count represent different units of analysis.

The cohort consisted of 16 males (61.5%) and 10 females (38.5%). The median age was 22.5 years.

Table 1. Patient Characteristics

Characteristic	**Value**
Unique patients	**26**
Male	**16 (61.5%)**
Female	**10 (38.5%)**
Median age	**22.5 years**
Total IUS examinations	**34**

The distinction between 26 unique patients and 34 examinations is important. Some patients underwent repeat IUS examinations; therefore, the number of examinations exceeded the number of unique patients.

Indications for IUS: Routine monitoring of stable Crohn's disease was the primary indication, accounting for 25 of 34 examinations (73.5%). Investigation of worsening symptoms and/or elevated inflammatory biomarkers, such as CRP or faecal calprotectin, accounted for eight examinations (23.5%). One examination was performed to assess treatment response following therapeutic escalation.

The percentages are calculated from 34 examinations. The treatment-response category is 1/34 = 2.94%, rounded to 2.9%.

Table 2. Indications for IUS In Crohn's Disease

Indication	Frequency (n)	Percentage (%)
Routine monitoring	25	73.5
Worsening symptoms and/or biomarkers	8	23.5
Assessment of treatment response	1	2.9
Total	**34**	**100.0**

Avoidance of MRE: IUS findings allowed the clinical team to avoid 27 MRE examinations.

The avoidance rate was: 27/34 × 100 = 79.4%

Therefore, the appropriate wording is:

"MRE was avoided in 27 of 34 IUS examinations (79.4%)."

All 25 IUS examinations performed for routine monitoring were reported as sufficient to avoid MRE. Among the eight examinations undertaken for worsening symptoms or biomarkers, MRE was avoided in two.

The term "avoidance" represents the clinical

decision that additional MRE was not required after IUS findings and should not be interpreted as evidence that IUS was diagnostically equivalent to MRE in every clinical scenario.

Avoidance of Colonoscopy: IUS findings were also associated with avoidance of 20 colonoscopies.
The avoidance rate was: 20/34 × 100 = 58.8%
Therefore:
"Colonoscopy was avoided in 20 of 34 IUS examinations (58.8%)."
The manuscript does not provide the exact overlap between examinations in which both MRE and colonoscopy were avoided. Therefore, the two values should be reported separately and should not be added together.

Contrast Avoidance: Avoidance of 27 MRE examinations was associated with an estimated saving of 540 mL of GBCA, assuming the 20-mL dose applied to each avoided examination.
The corresponding oral barium sulphate saving was: 27 × 1,350 mL = 36,450 mL.
These reductions may decrease unnecessary exposure to contrast agents and associated consumable waste.

Economic Findings: The cost of the 27 avoided **MRE Examinations** was: 27 × US$1,279 = US$34,533.
The cost of the 34 IUS examinations was: 34 × US$182 = US$6,188.
Thus:

Net MRE-Related Saving = US$28,345.
For Endoscopy: 20 × US$1,479 = US$29,580.
After accounting for the cost of 34 IUS examinations:
Net Endoscopy-Related Savings = US$23,392.
These are net savings, whereas US$34,533 and US$29,580 represent the gross costs associated with the avoided MRE and endoscopy procedures, respectively.
Environmental Findings; Each IUS examination was estimated to consume 0.51 kWh and emit 0.53 kg CO_2e.
MRE Comparison
Energy difference per procedure: 11.8 – 0.51 = 11.29 kWh
For 27 avoided MRE examinations: 11.29 × 27 =
304.83 kWh
Carbon difference per procedure: 17.5 – 0.53 =
16.97 kg CO_2e
For 27 avoided MRE examinations: 16.97 × 27 =
458.19 kg CO_2e
Endoscopy Comparison
Energy difference per procedure: 159.56 – 0.51 =
159.05 kWh
For 20 avoided endoscopies: 159.05 × 20 = 3,181 kWh
Carbon difference per procedure: 28.4 – 0.53 =
27.87 kg CO_2e
For 20 avoided endoscopies: 27.87 × 20 = 557.40 kg CO_2e
Thus, the combined estimated energy saving was 3,485.83 kWh, while the combined estimated carbon reduction was 1,015.59 kg CO_2e.

DISCUSSION

This study evaluated the economic and environmental implications of a transdisciplinary IUS pathway for patients with Crohn's disease. The findings indicate that integrating IUS into routine clinical assessment may reduce the need for resource-intensive imaging and endoscopic procedures while supporting clinical decision-making.
A central consideration in interpreting the findings is the distinction between unique patients and examinations. The study included 26 unique patients but recorded 34 IUS examinations. This indicates that some patients underwent repeat examinations during the study period. Consequently, procedure avoidance was evaluated using the examination as the unit of analysis. Thus, 27 MRE examinations represented 79.4% of the 34 IUS examinations, while 20 colonoscopies represented 58.8% of the same denominator.
This distinction prevents an apparent contradiction between 26 patients and 34 examinations. The number of examinations can exceed the number of unique patients when repeated assessments are performed during follow-up.
The study estimated that 27 MRE examinations and 20 colonoscopies were avoided following IUS-based clinical decision-making. Importantly, these categories should not be assumed to be mutually exclusive because the available data do not specify whether some IUS examinations resulted in avoidance of both procedures.
The economic analysis demonstrated substantial potential savings. Using the stated

institutional unit costs, 27 avoided MRE examinations represented a gross procedure cost of US$34,533. After subtracting the US$6,188 cost of the 34 IUS examinations, the estimated net saving was US$28,345. Similarly, the gross cost of 20 avoided endoscopies was US$29,580, corresponding to a net saving of US$23,392 after accounting for IUS costs.

This distinction between gross avoided expenditure and net cost saving is important. The manuscript should consistently refer to US$28,345 and US$23,392 as net cost savings, while US$34,533 and US$29,580 should be described as the gross costs of the avoided procedures if they are retained.

The reduction in contrast-agent use represents another potential benefit. The avoidance of 27 MRE examinations was associated with an estimated 540 mL reduction in GBCA use and 36,450 mL of oral barium sulphate suspension. This may be particularly relevant for patients with chronic disease who undergo repeated imaging over extended periods. However, the GBCA estimate depends on the assumed 20-mL dose and should therefore be confirmed against patient-level records.

GBCAs have been associated with retention in tissues and organs following repeated exposure, although the clinical consequences of retained gadolinium remain incompletely established.[8,9,20–28]

An IUS pathway that reduces unnecessary contrast-enhanced MRI examinations may therefore provide an additional benefit by limiting avoidable exposure.

The environmental analysis also demonstrated potentially substantial savings. Avoidance of 27 MRE examinations was associated with an estimated

304.83 kWh reduction in energy use and 458.19 kg CO_2e reduction. Avoidance of 20 endoscopies was associated with an estimated 3,181 kWh reduction and 557.40 kg CO_2e reduction.

Together, the estimated savings amounted to 3,485.83 kWh and 1,015.59 kg CO_2e. These findings support the broader concept that imaging pathways should consider environmental impact alongside clinical effectiveness and cost.[12,16–19,29–32]

MRI has a relatively high energy requirement, while endoscopy can also involve substantial energy consumption and disposable materials. IUS requires comparatively little energy and generally uses fewer consumables. Therefore, the environmental benefits of an IUS-led pathway may extend beyond energy consumption and carbon emissions to reduced use of contrast agents, oral contrast material, and procedure-related consumables.

IUS may also support value-based care by facilitating timely clinical assessment and treatment decisions. The current findings suggest that IUS was particularly useful for routine monitoring of stable patients, while its role in patients with worsening symptoms or biomarkers appeared more selective.

This is consistent with the concept of using lower-resource imaging when clinically appropriate rather than replacing MRI or endoscopy indiscriminately.

The transdisciplinary model is another important component of this pathway. Gastroenterologists contributed to clinical decision-making and adoption of IUS, radiologists contributed imaging expertise and oversight, and trained radiographers supported acquisition and delivery of IUS examinations. This collaborative approach may expand workforce capabilities and facilitate task-sharing in settings where appropriately trained professionals are available.

The use of trained radiographers in IUS is particularly relevant to workforce development. Structured training, fellowship experience, local mentorship, and collaboration with radiologists may allow radiographers to contribute effectively to bowel ultrasound services. Such models may improve access and support sustainable service delivery.[38]

The pathway also incorporated weekly IUS slots into clinical scheduling, allowing imaging to occur during the same clinical episode and facilitating rapid decision-making. This type of workflow integration may reduce delays between clinical assessment and treatment decisions.

Limitations

Several Limitations should be Considered.

First, the study was retrospective and single-centre, with only 26 unique patients and 34 IUS examinations. Therefore, the findings may not be generalizable to other healthcare systems.

Second, energy consumption and carbon emissions were estimated using published data and institutional averages rather than direct measurements. Actual energy consumption may vary according to equipment, operating conditions, facility characteristics, and local electricity sources.

Third, MRI scanners may remain continuously powered because of magnet-cooling requirements. Consequently, the marginal

energy attributable to an individual MRE examination may differ from an average procedure-level estimate.

Fourth, procedure avoidance was determined by clinical judgment rather than a standardized prospective protocol. Factors such as disease status, clinician preference, patient preference, and institutional pathways may have influenced whether MRE or colonoscopy was considered unnecessary.

Fifth, the study does not provide patient-level information regarding the distribution of repeat IUS examinations among the 26 patients. It also does not quantify the overlap between examinations associated with avoidance of MRE and those associated with avoidance of colonoscopy.

Sixth, the reported 540-mL GBCA saving assumes a 20-mL dose for all 27 avoided MRE examinations. Because the stated protocol included both 10-mL and 20-mL doses depending on patient weight, this value should be verified against the original patient-level data.

Finally, because this was a service evaluation rather than a prospective comparative trial, the findings demonstrate an association between implementation of the IUS pathway and estimated procedure avoidance rather than establishing causal superiority of IUS over MRE or endoscopy.

CONCLUSION

The integration of intestinal ultrasound into routine clinical care for patients with Crohn's disease may provide meaningful economic and environmental benefits.

In this evaluation, 26 unique patients underwent 34 IUS examinations. Some patients underwent repeat examinations, explaining why the number of examinations exceeded the number of unique patients. Using the examination as the unit of analysis, 27 MRE examinations (79.4%) and 20 colonoscopies (58.8%) were avoided.

Based on the stated institutional costs, the estimated net saving was US$28,345 compared with MRE and US$23,392 compared with endoscopy. Estimated environmental savings were 304.83 kWh and 458.19 kg CO_2e for avoided MRE examinations and 3,181 kWh and 557.40 kg CO_2e for avoided endoscopies.

These findings support the potential role of IUS as a cost-conscious and environmentally sustainable component of IBD imaging pathways when clinically appropriate. A transdisciplinary model involving gastroenterologists, radiologists, and appropriately trained radiographers can facilitate implementation, workforce development, and integration of IUS into routine care.

Future prospective multicentre studies should use standardized definitions of procedure avoidance, capture patient-level repeat examinations, document overlap between avoided procedures, directly measure energy consumption where possible, and undertake standardized lifecycle carbon assessments. Such studies will help determine the broader clinical, economic, and environmental value of IUS-led pathways in Crohn's disease management.

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