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Fat Fraction and Iodine Density in Bowel Inflammation: A DECTE VMI Cross-Sectional Study

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Abstract

Background:
Accurate differentiation between inflamed and normal bowel segments is critical in managing inflammatory bowel disease (IBD). Dual-energy computed tomography enterography (DECTE) offers quantitative biomarkers such as Fat fraction and iodine density, which may enhance diagnostic accuracy.

Aim:
To evaluate the utility of DECTE-derived Fat fraction and iodine density in distinguishing inflamed from normal bowel segments at various virtual monochromatic imaging (VMI) energy levels.

Methods:
A cross-sectional study was conducted at multicenter in Ahsa , Saudi Arabia, involving 160 adult patients diagnosed with Crohn's disease or ulcerative colitis. DECTE scans were analyzed to quantify Fat fraction and iodine density in inflamed and adjacent normal bowel segments. Receiver operating characteristic (ROC) analysis was performed to assess diagnostic accuracy across different VMI energy levels. Interobserver reliability was calculated using intraclass correlation coefficients (ICCs).

Results:
Inflamed segments had significantly lower Fat fraction (6.3±2.4%) and higher iodine density (3.7±0.9 mg/mL) compared to normal segments (12.7±3.8% and 1.8±0.6 mg/mL, respectively; $p<0.001$). Optimal diagnostic performance was observed at 50 keV for Fat fraction (AUC=0.92) and at 40 keV for iodine density (AUC=0.95). Interobserver reliability was excellent (ICC >0.90).

Conclusion:
Fat fraction and iodine density derived from DECTE provide reliable, non-invasive biomarkers for distinguishing inflamed from normal bowel tissue. These findings support the integration of DECTE into clinical workflows for IBD assessment and monitoring.

Keywords:
Inflammatory bowel disease; DECTE; Fat fraction; Iodine density; Virtual monochromatic imaging; Quantitative imaging; Bowel inflammation.

Introduction

Inflammatory bowel disease (IBD), encompassing Crohn's disease (CD) and ulcerative colitis (UC), represents a group of chronic, relapsing-remitting gastrointestinal disorders characterized by mucosal inflammation, transmural injury, and complications such as fibrosis, strictures, and abscess formation [1]. Despite significant advances in medical therapies and endoscopic techniques, precise and non-invasive differentiation between inflamed and non-inflamed bowel tissue remains a persistent clinical challenge. Imaging modalities, particularly computed tomography (CT) and magnetic resonance imaging (MRI), have become

indispensable in the diagnostic workup, therapeutic monitoring, and post-treatment surveillance of IBD [2,3].

Dual-energy computed tomography enterography (DECTE), an advanced imaging modality harnessing the attenuation properties of tissues at two distinct photon energy levels, has emerged as a promising tool in the evaluation of bowel pathologies [4]. This technique allows for the generation of material decomposition images, virtual monochromatic imaging (VMI), and quantification of parameters such as iodine density and fat fraction, offering both anatomical and functional insights into bowel segments [5]. DECTE facilitates reduced radiation dose, improved lesion conspicuity, and enhanced tissue characterization, rendering it a valuable adjunct in gastrointestinal imaging [6].

Among the innovative outputs of DECTE are the Fat fraction and iodine density maps. The Fat fraction reflects the quantification of tissue fat content derived from the dual-energy material decomposition technique, and has been primarily investigated in the context of hepatic steatosis and musculoskeletal pathologies [7,8]. Its potential in assessing mesenteric or bowel wall fat infiltration remains underexplored. On the other hand, iodine density mapping provides a surrogate marker for tissue perfusion and vascular permeability, which are often elevated in inflamed bowel segments due to neovascularization and increased mucosal blood flow [9,10]. Given that active inflammation in IBD is accompanied by both hyperemia and changes in tissue composition, the combined analysis of Fat fraction and iodine density may offer a multiparametric approach for differentiating inflamed from normal bowel tissue.

Previous studies have shown the utility of iodine quantification in active bowel inflammation, with correlations noted between iodine density values and endoscopic or histopathologic indices of disease activity [11,12]. For instance, Oto et al. demonstrated a significant elevation in iodine concentration in segments of active Crohn's disease compared to non-inflamed areas using DECT [13]. However, the potential role of Fat fraction in the context of bowel inflammation has not been well elucidated, particularly in differentiating chronic fibrotic segments from acutely inflamed ones—a key determinant in therapeutic decision-making [14]. Moreover, the interplay between iodine density and fat fraction values in various stages of bowel inflammation remains an open area for investigation.

Virtual monochromatic imaging (VMI), a derivative product of DECT, enhances lesion contrast at lower energy levels (typically 40–70 keV) and reduces beam-hardening artifacts, thereby improving diagnostic confidence in small bowel imaging [15]. VMI at lower keV levels can enhance the visualization of contrast-enhanced bowel walls and hypervascular lesions, which may be particularly useful in detecting subtle inflammation [16]. The choice of optimal keV levels, however, varies across studies and clinical scenarios. A standardized approach to selecting the most diagnostically relevant VMI energy level for differentiating inflamed from non-inflamed bowel tissue remains lacking.

To date, most DECT-based evaluations in bowel imaging have either focused on qualitative assessments or single-parameter quantification, such as iodine density alone. There remains a paucity of literature integrating both Fat fraction and iodine-based quantification in a systematic manner to delineate inflamed from non-inflamed bowel segments. Additionally, the impact of different VMI energy levels on the diagnostic performance of these quantitative parameters is not well established. A multiparametric DECTE approach, incorporating both Fat fraction and iodine density across varying VMI energy levels, could provide a more comprehensive imaging biomarker framework for intestinal inflammation.

The present study aims to address this gap by conducting a cross-sectional evaluation of inflamed versus normal bowel segments using DECTE-derived Fat fraction and iodine density values across

different VMI energy settings. By leveraging the material decomposition and energy-specific contrast enhancement capabilities of DECTE, we aim to identify a reproducible imaging pattern that correlates with bowel inflammation. We hypothesize that inflamed segments will demonstrate a significantly lower Fat fraction and higher iodine density relative to non-inflamed segments, with the greatest diagnostic discrimination observed at specific VMI keV thresholds. This work may have implications for both the non-invasive diagnosis of IBD and the longitudinal monitoring of therapeutic response, reducing reliance on invasive procedures such as colonoscopy or biopsy.

Our approach is anchored in the evolving paradigm of precision imaging in gastrointestinal diseases, wherein quantitative imaging biomarkers (QIBs) serve as objective tools to assess disease activity, guide treatment, and predict outcomes [17,18]. Furthermore, the incorporation of multiparametric DECT imaging into routine clinical workflows has the potential to enhance diagnostic accuracy while optimizing resource utilization. Ultimately, this research contributes to the growing body of evidence supporting advanced CT technologies in the functional imaging of complex bowel diseases, and may serve as a foundation for future prospective trials and machine-learning applications in radiomics-based diagnostics [19,20].

Methods

Study Design

This study employed a cross-sectional analytical design aimed at evaluating the diagnostic utility of DECTE-derived Fat fraction and iodine density in distinguishing between inflamed and normal bowel segments. This design was selected to enable a snapshot comparison of quantitative imaging biomarkers at a single point in time, facilitating an understanding of their discriminatory power without the confounding effects of longitudinal disease progression or therapy.

Study Setting

The study was conducted across multiple health centers in Al Ahsa, Saudi Arabia. The radiology departments at the participating centers are equipped with state-of-the-art dual-energy computed tomography scanners capable of performing enterographic studies with post-processing tools for iodine mapping and fat quantification. The study setting was selected for its accessibility to a patient population with confirmed or suspected inflammatory bowel disease and for its technical capacity to execute DECTE protocols.

Sample and Sampling

The target population for this study comprised adult patients attending the radiology and gastroenterology services at the participating centers in Al Ahsa, Saudi Arabia, who were referred for Dual-Energy CT Enterography (DECTE) to evaluate known or suspected inflammatory bowel disease (IBD), including Crohn's disease and ulcerative colitis.

A sample size of 160 participants was determined based on previous imaging-based cross-sectional studies in similar clinical contexts, with consideration of power analysis for paired comparisons of quantitative imaging parameters (Fat fraction and iodine density) between inflamed and non-inflamed bowel segments. The power calculation, using an expected medium effect size (Cohen's d = 0.5), a significance level (alpha) of 0.05, and 90% power, indicated a minimum sample of 142 patients. To account for potential exclusions due to image artifacts, motion blur, or incomplete data, an oversampling of approximately 12% was applied, resulting in a final target of 160 participants.

The study used a consecutive non-probability sampling method. All patients who met the eligibility criteria and presented for DECTE imaging were approached for participation. This technique was selected to reduce selection bias while ensuring feasibility and completeness of recruitment in a clinical setting.

Inclusion criteria were:

- Age ≥ 18 years;

- A confirmed clinical, endoscopic, or histological diagnosis of IBD (Crohn's disease or ulcerative colitis);
- Referral for DECTE as part of routine diagnostic assessment, disease monitoring, or evaluation of therapeutic response;
- Ability and willingness to provide informed consent.

Exclusion criteria were:

- History of bowel resection or abdominal surgery affecting the small or large intestine;
- Presence of abdominal neoplasms or severe ascites;
- Contraindication to intravenous iodinated contrast (e.g., contrast allergy or impaired renal function with eGFR < 30 mL/min/1.73 m²);
- Pregnant or lactating women;
- Poor bowel distension or inadequate oral contrast intake leading to non-diagnostic DECTE images.

Participants were enrolled after preliminary screening by a gastroenterologist or radiologist and were subsequently referred to the research team for consent and data collection. Detailed demographic and clinical information was collected via chart review and structured interviews, ensuring that sampling included a range of disease severities and anatomical involvement patterns.

To enhance the representativeness of the sample, both outpatients and day-case patients undergoing DECTE for IBD surveillance or symptom assessment were included. The sample encompassed a balanced distribution of males and females and a wide range of disease durations, from newly diagnosed to long-standing IBD cases, providing a heterogeneous but clinically realistic cohort for imaging-based comparison.

Each participant served as their own control, with measurements taken from inflamed and anatomically adjacent non-inflamed bowel segments. This within-subject sampling approach enhanced statistical efficiency and reduced the impact of inter-individual variation in tissue composition, contrast kinetics, and baseline vascularity.

The final sample of 160 patients was deemed adequate to perform robust subgroup analyses (e.g., by VMI energy levels or disease type), evaluate inter-observer agreement, and conduct receiver operating characteristic (ROC) analyses with sufficient power to detect diagnostic thresholds.

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Data Collection Tools

Data collection was carried out using dual-energy computed tomography enterography (DECTE) performed with a SOMATOM Force Dual-Source CT scanner (Siemens Healthineers, Erlangen, Germany) located in the radiology department of the participating centers, Al-Ahsa, Saudi Arabia. This state-of-the-art scanner offers high temporal resolution, improved spectral separation, and advanced post-processing capabilities essential for dual-energy imaging in gastrointestinal applications.

The dual-energy protocol involved dual-source image acquisition at 80 and 140 kVp, following intravenous administration of iodinated contrast medium (Omnipaque 350 mg I/mL) at a dose of 1.5 mL/kg body weight, delivered via a power injector at a rate of 3–4 mL/sec. A saline flush (30–40 mL) was used immediately after contrast injection to ensure optimal opacification. Image acquisition was timed during the enteric phase, approximately 60–70 seconds post-injection, to maximize bowel wall enhancement.

All patients received standardized bowel preparation instructions, including a 6-hour fasting period and oral ingestion of 1,000–1,200 mL of iso-osmotic polyethylene glycol solution 45–60 minutes before the scan to achieve adequate small bowel distension.

Post-processing of DECTE images was performed using Syngo.via (Siemens Healthineers), which enabled the generation of:

- Virtual Monochromatic Images (VMIs) at varying energy levels (40 to 140 keV);
- Iodine density maps (expressed in mg/mL);
- PFat fraction maps (expressed as percentage values).

Regions of interest (ROIs) were manually drawn on inflamed and anatomically adjacent non-inflamed

bowel segments by two experienced radiologists blinded to each other's measurements. ROI size and placement were standardized to minimize interobserver variability, with special care taken to avoid inclusion of intraluminal contents or perienteric fat.

Data Collection Procedure

The data collection process for this study was meticulously planned and executed over a six-month period at the radiology department of participating centers in Al Ahsa, Saudi Arabia. DECTE imaging and met the inclusion criteria were invited to participate in the study. Upon obtaining written informed consent, participants underwent standardized bowel preparation and DECTE scanning using the SOMATOM Force CT scanner under the supervision of a senior radiologic technologist and a consultant radiologist.

After completion of the scan, image datasets were transferred to a dedicated post-processing workstation running Syngo.via software. Two board-certified radiologists, each with more than seven years of experience in abdominal imaging, independently reviewed the images. Using dual-energy analysis tools, they extracted:

- **Iodine density values** from visually confirmed inflamed and normal bowel segments;
- **PFat fraction values** from the same corresponding ROIs.

If discrepancies in ROI placement or parameter extraction were noted, a third senior radiologist was consulted to adjudicate and finalize the measurements. All quantitative imaging data, along with clinical variables (age, gender, diagnosis, disease duration, medication use), were recorded in a secure electronic database accessible only to the research team.

This detailed and standardized approach ensured consistency across measurements and minimized variability associated with human input or image acquisition.

Data Analysis

Data were analyzed using IBM SPSS version 26.0. Descriptive statistics (means, standard deviations, frequencies) were used to characterize the sample. The Shapiro–Wilk test assessed normality. Paired t-tests or Wilcoxon signed-rank tests were used to compare iodine density and Fat fraction between inflamed and normal segments, as appropriate. Receiver Operating Characteristic (ROC) curve analysis was performed to assess diagnostic accuracy at various keV levels. Intraclass correlation coefficients (ICCs) were calculated to assess inter-observer reliability. A p-value of <0.05 was considered statistically significant.

Ethical Considerations

This study was approved by the Research Ethics Committee of the involved centers. All procedures were conducted in accordance with the Declaration of Helsinki and local ethical standards. Participation was voluntary and participants were informed of their right to withdraw at any time without affecting their clinical care. Written informed consent was obtained from each participant. Patient confidentiality was maintained throughout, with all data anonymized prior to analysis. The research team ensured that no harm would arise from participation and that imaging results would be communicated to treating physicians for appropriate clinical follow-up.

Results

Demographic and Clinical Characteristics of the Study Sample

The demographic and clinical profile of the 160 participants is comprehensively detailed in Table 1. The average age of the participants was approximately 36.7±9.4 years, with a slight predominance of male patients (56.3%). The body mass index (BMI) mean value (24.6±3.9 kg/m^2) indicates an overall normal to slightly overweight status in this cohort. A larger proportion of the sample was diagnosed with Crohn's disease (65.6%), compared to ulcerative colitis (34.4%). The mean duration since diagnosis was around 6.2±3.7 years, reflecting a chronic disease course among participants. A considerable percentage of participants reported significant gastrointestinal symptoms, such as abdominal pain (90.0%) and

diarrhea (83.1%). Therapeutically, more than half were being treated with biologics (57.5%), while fewer used immunosuppressants or steroids, highlighting the complexity and advanced therapeutic management prevalent among the sampled population.

Table 1: Demographic and Clinical Characteristics of Participants (n=160)

Variables	n (%) or Mean ± SD
Age (years)	36.7 ± 9.4
Gender (Male/Female)	90 (56.3%) / 70 (43.7%)
BMI (kg/m²)	24.6 ± 3.9
Disease Type	
– Crohn's Disease	105 (65.6%)
– Ulcerative Colitis	55 (34.4%)
Disease Duration (years)	6.2 ± 3.7
Disease Severity	
– Mild	30 (18.8%)
– Moderate	87 (54.4%)
– Severe	43 (26.9%)
Symptoms	
– Diarrhea	133 (83.1%)
– Abdominal Pain	144 (90.0%)
– Weight Loss	78 (48.8%)
Current Medications	
– Biologics	92 (57.5%)
– Immunosuppressants	60 (37.5%)
– Steroids	24 (15.0%)

Fat Fraction Comparison between Inflamed and Normal Bowel Segments

Table 2 provides a detailed comparison of Fat fraction values between inflamed and normal bowel segments. There was a statistically significant difference in Fat fraction, with lower values consistently recorded in inflamed bowel segments (overall mean = 6.3±2.4%) compared to normal segments (overall mean = 12.7±3.8%), $p < 0.001$. This trend persisted consistently when analyzed by

disease subgroups, underscoring Fat fraction's sensitivity as an imaging marker in identifying inflammatory changes within bowel tissues. Specifically, inflamed segments from Crohn's disease patients demonstrated notably lower Fat fractions compared to ulcerative colitis, reflecting potential differences in the pathophysiological manifestations of bowel inflammation between these two types of IBD.

Table 2: Fat Fraction (%) in Inflamed vs. Normal Bowel Segments by Disease Type

Segment Type	Overall (n=160)	Crohn's Disease (n=105)	Ulcerative Colitis (n=55)
Inflamed Bowel	6.3 ± 2.4	5.9 ± 2.2	7.1 ± 2.6
Normal Bowel	12.7 ± 3.8	12.3 ± 3.6	13.4 ± 4.1
p-value	<0.001	<0.001	<0.001

Iodine Density Comparison between Inflamed and Normal Bowel Segments

Table 3 demonstrates substantial differences in iodine density between inflamed and normal bowel segments. Inflamed segments exhibited significantly elevated iodine density values (mean = 3.7±0.9 mg/mL) compared to normal bowel segments (mean = 1.8±0.6 mg/mL, $p<0.001$). This consistent elevation aligns with enhanced vascular permeability and hyperemia typical in inflammatory bowel lesions, and this was observable across both Crohn's and ulcerative colitis groups. Notably, inflamed segments in Crohn's disease showed higher iodine densities compared to ulcerative colitis, suggesting possible greater microvascular involvement in Crohn's lesions.

Table 3: Iodine Density (mg/mL) in Inflamed vs. Normal Bowel Segments by Disease Type

Segment Type	Overall (n=160)	Crohn's Disease (n=105)	Ulcerative Colitis (n=55)
Inflamed Bowel	3.7 ± 0.9	3.9 ± 1.0	3.4 ± 0.8
Normal Bowel	1.8 ± 0.6	1.7 ± 0.5	2.1 ± 0.7
p-value	<0.001	<0.001	<0.001

Diagnostic Accuracy of Fat Fraction at Varying VMI Energy Levels

Table 4 explores the diagnostic accuracy of Fat fraction at different VMI energy levels using ROC analysis. The greatest diagnostic performance was observed at 50 keV (AUC = 0.92), with optimal sensitivity (89.4%) and specificity (84.4%). Lower and higher VMI energies showed slightly reduced, but still clinically relevant accuracy. This suggests that a 50-keV VMI setting may be most effective clinically for distinguishing inflamed from normal bowel tissues using Fat fraction.

Table 4: ROC Analysis of Fat Fraction at Various VMI Energy Levels

VMI Energy (keV)	AUC	Sensitivity (%)	Specificity (%)
40	0.91	88.8	83.8
50	0.92	89.4	84.4
60	0.89	86.3	81.3
70	0.85	81.9	78.1

Diagnostic Accuracy of Iodine Density at Varying VMI Energy Levels

As shown in Table 5, iodine density had optimal diagnostic accuracy at 40 keV (AUC=0.95), with excellent sensitivity (91.9%) and specificity (88.1%). Higher energy levels demonstrated lower but still strong diagnostic accuracy, emphasizing the superior performance of lower-energy VMIs for detecting active inflammation.

Table 5: ROC Analysis of Iodine Density at Various VMI Energy Levels

VMI Energy (keV)	AUC	Sensitivity (%)	Specificity (%)
40	0.95	91.9	88.1
50	0.93	89.4	86.9
60	0.90	86.9	83.8
70	0.87	84.4	80.6

Interobserver Reliability of Imaging Measurements

Finally, Table 6 summarizes interobserver reliability, demonstrating excellent reproducibility between radiologists for Fat fraction (ICC=0.92) and iodine density (ICC=0.95), confirming reliability in clinical and research settings.

Table 6: Interobserver Reliability Analysis

Parameter	ICC (95% CI)	Interpretation
Fat fraction	0.92 (0.89–0.95)	Excellent
Iodine density	0.95 (0.92–0.97)	Excellent

Discussion

This cross-sectional evaluation highlighted significant differentiation between inflamed and normal bowel segments through DECTE-derived Fat fraction and iodine density measurements. These findings affirm the potential clinical utility of dual-energy computed tomography enterography (DECTE) in non-invasive identification and characterization of bowel inflammation, complementing traditional clinical assessments and invasive procedures such as endoscopy and biopsy.

Our study demonstrates that Fat fraction values were markedly lower in inflamed segments compared to adjacent normal segments, which aligns with prior imaging studies showing altered tissue composition in inflamed bowel walls due to edema, fibrosis, and fat depletion secondary to active inflammatory processes [21–23]. Specifically, studies indicate chronic inflammation-associated lipolysis within bowel walls, resulting in reduced fat accumulation detectable by advanced imaging modalities [24]. Similar findings were reported in hepatic steatosis and inflammatory musculoskeletal diseases, where DECT quantified fat fraction effectively distinguished diseased from normal tissue [25,26]. Our results further substantiate Fat fraction's role as a sensitive imaging biomarker within gastrointestinal imaging.

The significantly increased iodine density in inflamed bowel segments noted in this study concurs with previous literature suggesting that iodine concentration correlates strongly with active inflammation, microvascular hyperemia, and neovascularization [27–29]. Enhanced vascular permeability and local hyperemia, hallmarks of active inflammation, are known to cause increased iodine uptake and subsequent high density in

inflamed regions [30]. Prior investigations by Tielbeek et al. similarly demonstrated iodine-based differentiation of inflammatory bowel disease (IBD) activity levels, reinforcing iodine quantification as an accurate indicator of inflammatory severity [31]. Furthermore, Liu et al. reported a positive correlation between iodine concentration and histopathological markers of inflammation, thus validating DECT iodine density as a quantitative marker for inflammation grading [32].

A notable observation in our study was the differential diagnostic performance of Fat fraction and iodine density across various VMI energy levels. Optimal diagnostic accuracy for Fat fraction was observed at 50 keV, while iodine density achieved peak accuracy at 40 keV. This aligns with recent studies reporting that lower virtual monochromatic energy levels enhance contrast resolution, thereby increasing lesion conspicuity in inflammatory conditions [33–35]. The identification of specific optimal keV values for different biomarkers has important implications for clinical practice, facilitating standardized and efficient imaging protocols tailored to the clinical scenario. According to De Kock et al., lower-energy monochromatic imaging significantly improves tissue contrast in vascular and inflammatory conditions, emphasizing the necessity of tailored imaging protocols for gastrointestinal applications [36].

Importantly, interobserver reliability for quantitative imaging parameters (Fat fraction and iodine density) demonstrated excellent reproducibility (ICC >0.90), reinforcing the clinical reliability and robustness of DECTE. Reliable quantification is particularly critical for clinical adoption, given its influence on diagnostic consistency and longitudinal patient management [37,38]. This high reproducibility underscores DECTE's feasibility in routine clinical practice, offering a reproducible, non-invasive alternative to frequent invasive biopsies for disease monitoring.

Clinically, our findings indicate that DECTE-derived biomarkers could significantly streamline diagnostic workflows for patients with IBD by reducing reliance on invasive procedures such as endoscopic biopsy, which carry inherent procedural risks and patient discomfort [39]. Imaging biomarkers like Fat fraction and iodine density could facilitate timely therapeutic decision-making, enabling more precise disease activity monitoring and potentially improving patient outcomes by facilitating early intervention and therapeutic adjustment [40].

Interestingly, subgroup analysis revealed subtle but noteworthy differences between Crohn's disease (CD) and ulcerative colitis (UC). Inflamed bowel segments in CD exhibited more pronounced reductions in Fat fraction and higher iodine density values than in UC. This observation aligns with known pathological differences between CD and UC, wherein CD typically demonstrates transmural inflammation and more significant microvascular changes compared to predominantly mucosal inflammation seen in UC [41,42]. These pathophysiological distinctions likely underpin the observed imaging differences and highlight the potential utility of DECTE in differentiating not just inflamed versus normal bowel, but potentially between types of inflammatory bowel diseases.

However, several limitations of this study must be acknowledged. First, its cross-sectional design precludes longitudinal assessment of these biomarkers in response to therapeutic interventions. Longitudinal studies assessing biomarker changes over time and in response to treatments are crucial to validating clinical utility further [43]. Second, despite the robust statistical power from our sample size, the single-center design potentially limits generalizability. Multicenter studies encompassing diverse populations and imaging platforms would provide stronger external validity and confirm the applicability of these findings across varied clinical settings [44]. Third, histopathological correlation, considered the gold standard for inflammation grading, was not performed routinely in all participants. Future studies integrating DECT findings with comprehensive histopathological

analysis are recommended to substantiate these imaging biomarkers further [45].

Future research directions could explore integration of machine learning algorithms and radiomic analysis with DECT imaging to enhance diagnostic accuracy, predict disease outcomes, and personalize treatment approaches [46]. Radiomics-based predictive models could leverage quantitative biomarkers like Fat fraction and iodine density, improving diagnostic accuracy and enabling more precise, patient-tailored clinical decision-making in gastroenterology [47–49]. Additionally, investigating patient-centered outcomes such as quality of life and symptom resolution relative to DECT-based biomarker monitoring could yield valuable clinical insights [50].

Implications of the Study

This study presents significant clinical and diagnostic implications for the management of inflammatory bowel disease (IBD). By demonstrating that Fat fraction and iodine density derived from Dual-Energy CT Enterography (DECTE) can effectively differentiate inflamed from non-inflamed bowel segments, this research paves the way for more precise, non-invasive assessment of disease activity. These quantitative biomarkers offer a potential alternative to repeated endoscopic procedures, thereby minimizing patient discomfort and procedural risks while enhancing monitoring efficiency. Furthermore, the identification of optimal virtual monochromatic imaging (VMI) energy levels—specifically 50 keV for Fat fraction and 40 keV for iodine density—provides a foundation for standardized imaging protocols that improve diagnostic accuracy. The study also underscores the applicability of DECTE in distinguishing between Crohn's disease and ulcerative colitis based on imaging patterns, supporting more tailored and targeted treatment planning. In research settings, these findings encourage future investigations into radiomics and artificial intelligence-driven decision-support systems, leveraging quantitative imaging data for predictive modeling and longitudinal disease tracking.

Limitations of the Study

While the study offers novel insights into DECTE-based imaging biomarkers, several limitations should be acknowledged. Firstly, the cross-sectional design restricts our ability to evaluate temporal changes in Fat fraction and iodine density in response to treatment or disease progression. Longitudinal studies are required to assess the dynamic behavior of these biomarkers over time. Secondly, although we ensured consistent ROI placement and achieved excellent interobserver reliability, the lack of routine histopathological confirmation across all cases limits direct pathological correlation. Additionally, variations in bowel preparation quality, contrast timing, and patient hydration may have introduced minor technical inconsistencies in imaging outcomes. Finally, while DECTE provides rich diagnostic information, its accessibility is currently limited to specialized imaging centers with advanced technology and post-processing capabilities, potentially restricting its widespread clinical adoption in resource-limited settings.

Conclusion

This study demonstrates that Fat fraction and iodine density, as derived from Dual-Energy CT Enterography, are powerful imaging biomarkers capable of distinguishing inflamed from normal bowel segments in patients with IBD. The strong diagnostic performance observed across different VMI energy levels—particularly 50 keV for Fat fraction and 40 keV for iodine density—reinforces the clinical utility of tailored imaging protocols. These findings contribute to the growing evidence base supporting DECTE as a valuable non-invasive tool in the diagnostic and monitoring arsenal for inflammatory bowel diseases. With excellent reproducibility and high diagnostic accuracy, DECTE holds promise in optimizing patient care through improved disease characterization, reduced reliance on invasive procedures, and more responsive treatment strategies. Future multicenter

and longitudinal studies are warranted to validate these biomarkers in diverse populations and assess their predictive value in treatment response and long-term outcomes

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