The Value of Imaging in the Diagnosis and Follow-up of Crohn' s Disease Complicated by Intestinal Strictures: Postprint

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Abstract

Intestinal stricture is a common complication of Crohn' s disease. Intestinal stricture is a common complication of Crohn' s disease. Fifteen percent of CD patients may develop intestinal stricture within ten years of initial diagnosis. CD-associated intestinal strictures can be classified into inflammatory, fibrotic, and mixed types based on pathological features. Patients with inflammation-predominant strictures can achieve symptom relief through medical therapy, whereas fibrotic strictures require interventional or surgical treatment of the affected bowel segments. Therefore, comprehensive imaging assessment of the number, location, and morphology of strictures, as well as differentiation of bowel wall inflammation and fibrosis, is of great importance for clinical decision-making. This article will review the diagnostic sensitivity and specificity of major imaging modalities, including endoscopy, CT, MRI, and transabdominal ultrasound, for intestinal strictures. In recent years, several novel imaging techniques have achieved significant progress in differentiating inflammatory and fibrotic changes in strictured bowel walls, and are expected to be widely applied in clinical practice to further improve the diagnosis and treatment of CD-related intestinal strictures.

Full Text

Abstract

Intestinal stricture is one of the most common complications of Crohn' s disease (CD), with approximately 15% of patients developing strictures within ten years of initial diagnosis. CD-associated intestinal strictures can be classified pathologically as inflammatory, fibrotic, or mixed types. Patients with predominantly inflammatory strictures may achieve symptomatic relief through pharmacological therapy, whereas those with fibrotic strictures typically require interventional

or surgical management of the affected bowel segments. Consequently, comprehensive imaging evaluation of stricture number, location, morphology, and differentiation of intestinal wall inflammation from fibrosis is crucial for clinical decision-making. This article reviews the diagnostic sensitivity and specificity of major imaging modalities—including endoscopy, CT, MRI, and transabdominal ultrasound—in detecting intestinal strictures. In recent years, several novel imaging techniques have made significant advances in distinguishing inflammatory from fibrotic changes in strictured bowel walls, holding promise for broad clinical application and improved management of CD-associated intestinal strictures.

Keywords: Crohn' s disease; intestinal stricture; imaging

1. Current Status of Diagnosis and Treatment of Crohn' s Disease Complicated by Intestinal Stricture

Crohn' s disease is a chronic relapsing inflammatory bowel disorder in which intestinal stricture represents a frequent complication. Strictures can involve any segment of the gastrointestinal tract, most commonly the terminal ileum and ileocecal region. Due to the transmural nature of CD-associated inflammation, fibrosis may involve the entire bowel wall thickness, leading to wall thickening, rigidity, luminal narrowing, and even obstruction [1]. A population-based cohort study demonstrated that over 5% of patients present with a stricturing phenotype as their initial manifestation, and 15% develop intestinal strictures within ten years of diagnosis [2].

Based on etiology, CD-associated strictures can be categorized as primary or secondary (postoperative anastomotic). Pathologically, they are classified as inflammatory, fibrotic, or mixed types. Patients with inflammatory strictures may respond to conservative medical therapy, as corticosteroids and anti-tumor necrosis factor inhibitors can alleviate obstructive symptoms [3]. However, medical treatment only delays surgical intervention, with over 80% of patients requiring their first bowel resection within ten years of CD diagnosis [4]. For fibrotic strictures, no effective medical therapy currently exists, necessitating endoscopic balloon dilation, strictureplasty, or segmental bowel resection [5]. Surgical intervention carries inherent risks, including a 10% reoperation rate at the original site [6] and a 4% incidence of anastomotic leak or abscess formation following strictureplasty [6]. Multiple surgeries may result in short bowel syndrome, severely impairing digestive and absorptive function and compromising nutritional status and life expectancy. Therefore, accurate characterization of stricture type and severity is essential for selecting appropriate therapy and optimizing patient outcomes.

Imaging assessment of CD-associated strictures must accurately determine the number, location, and severity of strictured segments while distinguishing inflammatory from fibrotic components to guide clinical management, evaluate therapeutic response, and monitor postoperative course. Current imaging

modalities include intraluminal evaluation and cross-sectional techniques such as endoscopy, CT, MRI, and ultrasound. This review summarizes both conventional and emerging imaging techniques for CD-associated intestinal strictures, discussing their respective advantages and limitations.

2. Endoscopy

2.1 Diagnostic Capabilities

Endoscopy is the routine first-line examination for CD diagnosis. The 3rd European Evidence-Based Consensus on Crohn' s Disease recommends endoscopic evaluation of colonic and terminal ileal strictures [7]. Endoscopy enables direct intraluminal visualization of the digestive tract, allowing determination of stricture location, segmental involvement, and severity based on scope passage and maneuverability (Figure 1 [Figure 1: see original paper]). The Crohn' s Disease Endoscopic Index of Severity (CDEIS) [8] and the Simple Endoscopic Score for Crohn' s Disease (SES-CD) [9] are widely used in clinical research, both incorporating luminal stricture assessment in their activity indices. Additionally, endoscopic biopsy of strictured segments enables histopathological evaluation, with 3.5% of strictures harboring dysplasia or malignancy [7].

2.2 Therapeutic Applications

Endoscopic balloon dilation (EBD) has evolved into a common non-surgical treatment for short-segment (4 cm), endoscopically traversable strictures [10]. EBD is associated with few complications and high safety, with a perforation rate of approximately 3% [11]. Long-term symptomatic remission can be achieved in 17-82% of CD patients with strictures [12], with cumulative surgery-free rates of 80%, 57%, and 52% at one, three, and five years, respectively [11]. Long-segment strictures and severe mucosal inflammation are primary predictors of EBD failure [13].

Strictureplasty serves as an alternative to bowel resection, which, while relieving obstruction, may compromise absorptive function and cause short bowel syndrome. Strictureplasty is indicated for multiple strictures within long segments, particularly in patients with >100 cm of involved bowel or existing short bowel syndrome [14]. Yamamoto et al. [15] pooled data from 1,112 CD patients undergoing strictureplasty, reporting a 28% five-year recurrence rate, with 90% occurring at non-surgical sites. Strictureplasty provides significant value in symptom relief and reducing reoperation rates.

Needle-knife stricturotomy is a novel technique for fibrotic strictures or refractory cases unresponsive to balloon dilation, offering reduced risk of endoscopic bleeding and perforation [16].

2.3 Limitations

Endoscopic assessment of multisegmental or deep mural lesions is challenging, providing limited comprehensive evaluation. As an invasive procedure, patient acceptance is relatively low. Intraluminal examination offers only mucosal information, and severely obstructed segments that cannot be traversed preclude definitive evaluation of stricture characteristics.

3. Computed Tomography Enterography (CTE)

CTE represents a crucial non-invasive imaging modality for comprehensive CD assessment, demonstrating 85-93% sensitivity and 100% specificity for intestinal stricture diagnosis [4]. Diagnostic accuracy reaches 100% for single strictures but decreases to 83% for determining stricture number [4] (Figure 2 [Figure 2: see original paper]).

CTE features such as bowel wall thickening with abnormal enhancement and mesenteric hypervascularity correlate strongly with highly inflammatory CD strictures [17]. Chiorean et al. [18] developed a standardized CTE scoring system in 44 CD patients with strictures, correlating CTE scores with histopathology from 47 resected specimens. The study demonstrated 76.6% accuracy for inflammatory lesions and 78.7% for fibrostenotic lesions. Further prospective studies are needed to definitively differentiate inflammatory from fibrotic mural changes. Although widely used clinically, CTE requires bowel preparation, making it unsuitable for obstructed patients, and radiation exposure warrants careful consideration for longitudinal follow-up and repeated assessments.

4. Magnetic Resonance Imaging (MRI)

4.1 Conventional Magnetic Resonance Enterography

MRI plays a vital role in CD diagnosis and assessment. Magnetic resonance enterography (MRE) accurately evaluates CD-associated intestinal strictures, determining their number, location, and severity, with 90% diagnostic accuracy, 75-100% sensitivity, and 90.9-95.7% specificity [19, 20]. MRE has been applied in treatment response monitoring, with one study identifying stricture length <12 cm, proximal luminal diameter of 18-29 mm, marked delayed-phase enhancement, and absence of fistulas as predictors of successful adalimumab therapy [21].

4.2 Advanced MRI Techniques for Fibrosis Assessment

Novel MRI techniques have achieved breakthroughs in qualitative and quantitative assessment of intestinal fibrosis. Diffusion-weighted imaging (DWI) utilizes water molecule diffusion through tissues of varying cell density to generate image contrast; inflamed tissues with high cellularity show restricted diffusion and appear hyperintense. A meta-analysis reported 92.9% sensitivity and 91% specificity for DWI in evaluating CD bowel inflammation [22]. Dynamic contrast-

enhanced MRE measures enhancement parameters during delayed phases, as fibrotic bowel walls demonstrate prolonged contrast retention, enabling differentiation of inflammation from fibrosis [23]. Magnetization transfer imaging (MTI) is highly sensitive to collagen content changes in strictured tissue, accurately distinguishing fibrotic from non-fibrotic bowel. Animal studies demonstrated significantly higher MT ratios in rats with advanced intestinal fibrosis compared to non-fibrotic controls ($P<0.05$) [24].

4.3 Limitations

MRI is limited by high cost, long examination times, and requirement for rigorous bowel preparation, resulting in relatively low patient tolerance and limited widespread clinical adoption.

5. Transabdominal Ultrasound (TAUS)

5.1 Conventional TAUS

TAUS has gained widespread application in CD diagnosis and follow-up, demonstrating high sensitivity and specificity for complication detection. Conventional TAUS achieves 100% sensitivity and 63% specificity for diagnosing CD-associated intestinal strictures [25, 26] (Figure 3 [Figure 3: see original paper]). Using surgical pathology as the reference standard, small intestine contrast ultrasonography in 49 CD patients showed 97.5% sensitivity and 100% specificity for single strictures, and 75% sensitivity and 100% specificity for multiple strictures [27]. TAUS offers high diagnostic accuracy without radiation exposure and with simple operation, making it ideal for follow-up and therapeutic monitoring.

5.2 Advanced Ultrasound Techniques for Fibrosis Assessment

Novel ultrasound techniques have made substantial progress in characterizing fibrosis severity. Contrast-enhanced intestinal ultrasound shows potential for distinguishing inflammatory from fibrotic CD strictures. The degree of bowel wall color Doppler vascularization on contrast-enhanced ultrasound correlates significantly and negatively with fibrotic stenosis severity [28], and ultrasound findings correlate significantly with histopathological scores for both inflammation (Spearman' s $r=0.53$) and fibrotic stenosis (Spearman' s $r=0.50$) [29].

Shear wave elastography (SWE) generates shear waves through acoustic radiation force impulse, measuring propagation velocity to derive tissue elasticity values. Chen et al. [30] examined resected CD stricture specimens using SWE, demonstrating 87.5% sensitivity and 57.9% specificity for distinguishing mild/moderate from severe fibrosis using a cutoff value of 22.55 kPa. Dillman et al. [31] showed in animal models that fibrotic bowel walls exhibited significantly higher shear wave velocity (SWV) than acutely inflamed walls, enabling differentiation of inflammatory from fibrotic lesions. These advanced ultrasound

techniques show excellent clinical potential for characterizing bowel wall pathology in CD-associated strictures.

6. Positron Emission Tomography/Computed Tomography (PET-CT)

18F-FDG PET/CT primarily evaluates tissue function and metabolism and has been increasingly applied in inflammatory bowel disease assessment. Louis et al. [32] reported 100% detection (14/14) of severe endoscopic lesions, including deep ulcers and strictures. 18F-FDG PET/CT detects 87% of severe inflammatory lesions but only 7% of superficial mild inflammatory or ulcerative lesions [33, 34].

Jacene et al. [35] studied 17 CD patients with obstructive symptoms, 13 of whom underwent surgery. Preoperative 18F-FDG PET/CT demonstrated FDG uptake in bowel walls, with postoperative pathological correlation revealing FDG accumulation in both acutely inflamed and severely fibrotic/hypertrophic walls, suggesting PET/CT may not reliably differentiate inflammatory from fibrotic strictures. However, another study using endoscopy with histology as the reference standard examined 37 stricture lesions and found that 18F-FDG PET/CT combined with MRI and TAUS identified 100% of clinically symptomatic CD strictures requiring intervention [36]. Therefore, the ability of 18F-FDG PET/CT to distinguish inflammatory from fibrotic strictures requires further investigation.

7. Summary and Future Directions

Imaging assessment that accurately defines stricture number, location, morphology, and severity plays a vital role in diagnosing and managing CD-associated intestinal strictures. Although endoscopy is the most commonly used evaluation method, transmural CD assessment requires integration of cross-sectional and longitudinal imaging modalities such as CT, MRI, and transabdominal ultrasound rather than sole reliance on luminal evaluation. Advanced ultrasound and MRI techniques demonstrate promising capabilities for assessing bowel wall inflammation and fibrosis and are gaining increasing recognition for potential broad clinical application. Currently, no guidelines endorse a standard method for diagnosing and characterizing CD-associated strictures. While individual imaging modalities continue to mature, comprehensive approaches for early detection, treatment evaluation, and prognostic assessment remain incomplete, warranting further in-depth clinical investigation.

Table 1

Clinical Value of Different Imaging Modalities in Diagnosing CD-Associated Intestinal Strictures

Imaging Modality	Advantages	Limitations
Endoscopy	Direct visualization, enables biopsy and endoscopic therapy	Contraindicated in bowel obstruction, invasive
CTE	Non-invasive, widely available	Requires bowel preparation, radiation exposure
MRI	No radiation, high accuracy	Expensive, long examination time
TAUS	High accuracy, simple operation	Susceptible to bowel gas; operator-dependent
PET/CT	Accurate identification of severe lesions	Expensive, insensitive to mild lesions

Figure Legends

Figure 1. A 42-year-old female patient with CD following right hemicolectomy. Endoscopy demonstrates anastomotic stricture (white arrow).

Figure 2. A 52-year-old male patient with CD following subtotal colectomy. CTE shows anastomotic luminal narrowing (white arrow).

Figure 3. A 45-year-old male patient with CD. Transabdominal ultrasound demonstrates focal stricture of small bowel segment 5 with proximal luminal dilation (white arrow).

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Note: Figure translations are in progress. See original paper for figures.