Review Article

CT Enterography in the Evaluation of Small Bowel Disorder

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Abstract
The small bowel presents unique diagnostic challenges due to its length, location, and mobility. Conventional imaging methods often fail to provide adequate visualization. CT Enterography (CTE) has emerged as a valuable, non-invasive imaging modality specifically designed to evaluate small bowel pathology. To assess the role and diagnostic utility of CT Enterography in the evaluation of various small bowel disorders, including inflammatory, neoplastic, vascular, and infectious conditions. CT Enterography utilizes neutral oral contrast agents and thin-section multidetector CT imaging, allowing high-resolution visualization of the bowel wall and surrounding structures. It provides information on mural thickening, mucosal enhancement patterns, and extraintestinal findings, which are critical for diagnosis and management planning has shown high sensitivity and specificity in detecting Crohn's disease and its complications, such as fistulas, strictures, and abscesses. It also aids in identifying small bowel tumors, ischemia, and obscure gastrointestinal bleeding. Compared to traditional small bowel follow-through and capsule endoscopy, CTE offers faster, more comprehensive evaluation with the advantage of extraluminal assessment. CT Enterography is a powerful diagnostic tool in the assessment of small bowel disorders. It plays a pivotal role in both initial diagnosis and follow-up, particularly in inflammatory bowel diseases. Its non-invasive nature, rapid acquisition, and ability to detect both intraluminal and extraluminal pathology make it indispensable in modern radiologic practice.

Keywords: CT enterography, small bowel imaging, Crohn's disease, small bowel, gastrointestinal bleeding, inflammatory bowel disease.

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Introduction

The length, location, and motility of the small intestine make it difficult to diagnose. When it comes to identifying early or mild small intestinal pathology, traditional imaging techniques like barium tests and conventional CT have low sensitivity. CT enterography (CTE) produces high-resolution pictures of the small intestine by combining multi-detector CT technology with neutral oral contrast. It is now a first-line imaging technique for Crohn's disease and other small intestinal disorders. The method, uses, and prospects for CTE in small intestinal imaging are reviewed in this article.

CT Enterography: Technical

Patients with Crohn's disease frequently undergo CT enterography (CTE). The right approach is needed to produce high-quality diagnostic images. Reviewing the procedures and methods that can maximize CTE for individuals with suspected or confirmed Crohn's disease is the aim of this dissertation. We'll go over the following: [1] how to begin a CT enterography program; [2] workflow concerns, such as educating and preparing patients and ordering physicians; [3] choices and administration schedules for oral contrast media; [4] intravenous contrast media injection for uniphasic and multiphasic investigations; [5,6] image reconstruction and interpretation; [7] imaging Crohn's patients in the acute or emergency department setting; [8] limitations of CTE as well as alternatives like MRE or barium fluoroscopic examinations; [9] dictation templates and a common nomenclature for reporting findings of CTE in Crohn's disease; and [9] CTE radiation dose reduction strategies and the use of iterative reconstruction in lower dose examinations. The Abdominal Radiology Society Consensus MDCT Enterography Acquisition Protocol for Crohn's Disease provides a summary of many of the topics covered.

Active inflammatory disease

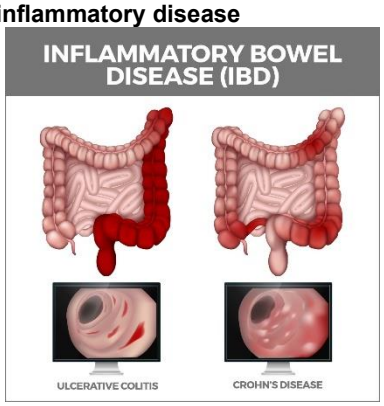

Figure: 1- Showing the Inflammatory Bowel Diseases

Depending on whether the activity is acute inflammatory or chronic fibro stenosing, as well as whether there are consequences like fistula or abscess, Crohn's disease can present itself in a variety of ways at CTE. Active inflammatory small bowel Crohn's disease is characterized by extra enteric signs including engorged vasa recta ("comb sign"), greater attenuation of the mesenteric fat, and enteric abnormalities such mural hyperplasia, bowel wall thickening, and mural stratification on CTE. The most sensitive CTE findings, indicating active inflammatory Crohn's disease, are the mural hyperenhan cement and thickening of the gut wall. Early research indicated that the strongest correlation between disease activity and intestinal wall thickness, but more current research has indicated that mural hyperenhancement might be a more sensitive indicator. When the wall of a distended bowel loop is thicker than 3 mm, it is referred to as intestinal wall thickening. With up to 82% of patients presenting with it, it is the most common CT finding in Crohn's disease. describes engorged vasa recta that resemble combs and pierce the intestinal wall perpendicular to the bowel lumen. The most specific CT finding for active Crohn's disease is increased mesenteric fat attenuation combined with the "comb" sign. Twelve It is associated with widespread, active, and clinically advanced Crohn's disease. Compared to individuals with normal vasculature, those with CTE who exhibit the "comb sign" are also said to have higher levels of C reactive protein and a more rigorous drug regimen [10,11,12,13,14,15,16,17].

Characterisation of small bowel pathology

General principles

When it comes to aberrant small bowel, the differential diagnosis is broad. Below is a more thorough explanation of the more prevalent small bowel disorders. The more general diagnostic rules that control the accurate interpretation of small intestinal anomalies must be understood while interpreting CT enterography. The pattern of contrast enhancement, length of involvement, degree and symmetry of wall thickening, location in the proximal/distal jejunum/ileum, location of pathology within the small bowel wall (mucosal/submucosal/serosal), and associated abnormality in the adjacent mesentery or vessels are some of the criteria that Macari et al. [18] described to help characterize abnormal small bowel segments.

Enhancement pattern

The three categories of small bowel wall enhancement patterns are homogenous, heterogeneous, and reduced. Vasculitis, Crohn's disease, venous thrombosis with concomitant bowel oedema or ischaemia, and intramural hemorrhage are examples of benign disorders that typically exhibit target appearance with stratification of the layers of the small intestinal wall (mural stratification). Chronic inflammatory diseases, especially those that cause fibrosis in the small intestinal wall (such as Crohn's disease, ischaemia, and radiation), should be taken into consideration if wall augmentation is uniform and modest (i.e., comparable to muscle) [18,19,20]. Active Crohn's disease is often accompanied by homogeneous hyperenhancement, which is often linked to increased density in the surrounding mesenteric fat. In fact, Bodily et al. [21] have suggested that a cutoff of 109HU can be used to diagnose activity in small bowels affected by Crohn's disease with a fair degree of accuracy. Adenocarcinomas, peritoneal deposits, metastases, and gastrointestinal stromal tumors are examples of small bowel neoplasms that exhibit heterogeneous enhancement. Bowel ischaemia is commonly characterized by decreased enhancement [22,23,24] which typically occurs prior to the formation of intramural gas and consequent perforation.

Length of small bowel involvement

Three categories of small bowel involvement length can be distinguished for differential diagnosis purposes: diffuse (.40 cm), segmental (6–40 cm), and focal (.5 cm) [25]. Neoplasms, endometriosis, small bowel diverticulitis, foreign body perforations, small bowel ulcers (due to non-steroidal anti-inflammatory drug use), and infrequently granulomatous processes such as Crohn's disease and tuberculosis are associated with focal thickening of the small bowel wall [26,27,28,29,30].Intramural hemorrhage, Crohn's disease, lymphoma, infectious enteritis, and ischaemia—especially from superior mesenteric vein (SMV) thrombosis or superior mesenteric artery (SMA) embolus—all have segmental involvement [31,32,33,34]. Prior radiotherapy should be taken into consideration in patients with segmental involvement and prior malignancy [35]. Hypoalbuminemia, low-flow intestinal ischaemia, vasculitis, graft versus host disease, and viral enteritis are frequently the causes of diffuse involvement of the small bowel [30, 36–38].

Small bowel tumours

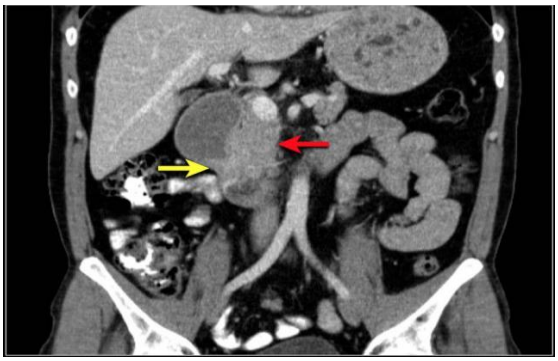

Figure : 2-This structure are shown in Small bowel tumours.

Five percent of gastrointestinal tumors are small bowel neoplasms [39]. One may argue that CT enterography is a better method for detecting small intestinal tumors than MR enterography because of its high spatial resolution and relative insensitivity to motion and breathing artifacts. For instance, Pilleul et al. [40] found that CT enterography had an 84.7% sensitivity and a 96.9% specificity for detecting small intestinal tumors. The more frequent small intestinal tumors are listed in Table 8, along with details on their incidence and imaging features. According to the authors' observations, small intestinal tumors are

typically found in patients who haveIron deficiency anemia or concealed gastrointestinal hemorrhage after negative conventional and capsule endoscopy results Endoscopy reveals a little submucosal abnormality for additional research in "tip of the iceberg" or metastatic illness instances. N endoscopy-negative patients who exhibit weight loss and/or luminal blockage complaints. On the other hand, they might be an accidental discovery.

Gastrointestinal bleeding

Once more, CT enterography is preferable than MRI enterography for the examination of chronic blood loss due to its typically good image quality. Crucially, there is evidence that suggests CT could be used in addition to capsule endoscopy. For instance, 10/22 (45%) of the 22 patients in a study with occult gastrointestinal bleeding had positive MDCT results [41]. CT enterography revealed three lesions that were missed by capsule endoscopy, and eight of these patients had positive results from either the procedure or a later clinical diagnosis [42]. As previously mentioned, multiphase CT scanning may improve the diagnostic yield for patients with occult gastrointestinal bleeding; nevertheless, the higher radiation dose must be taken into account.and three lesions that were missed by capsule endoscopy were discovered by CT enterography. As previously mentioned, multiphase CT scanning may improve the diagnostic yield for patients with occult gastrointestinal bleeding; nevertheless, the higher radiation dose must be considered, especially in non-acute settings. Multiphase CT enterography may be suitable in non-emergency situations where active bleeding is suspected because the risk-benefit ratio is significantly lower in older patients. Lastly, there is no doubt that CT enterography plays a part in locating symptomatic (bleeding) areas, such as Meckel's diverticulum. which typically manifests in younger individuals. Meckel's diverticulum affects 2–3% of people, and it is equally common in men and women. However, male patients are more likely to have symptoms. Meckel's diverticulum complications can cause clinical symptoms like diverticulitis, peptic ulceration with hemorrhage, intestinal blockage from diverticular inversion, volvulus, intussusception, diverticulum inclusion in a hernia, enterolith formation, and diverticulum neoplasia.

Crohn’s disease

Adults with Crohn's disease can be diagnosed and evaluated with great accuracy using CT enterography. With high reader confidence, it is frequently able to make an initial diagnosis (in conjunction with endoscopic biopsy where feasible) or rule out any disease that is only mild or early. Furthermore, a single examination can evaluate the disease's location, severity, and extent in addition to extraluminal symptoms and consequences. A more thorough discussion of CT radiation exposure is provided below. However, radiologists and clinicians alike must make sure that cumulative radiation exposure is carefully considered when choosing the best imaging modality for evaluating Crohn's disease, especially with the availability of more sophisticated MRenterography and ultrasound techniques. The patient's age must be taken into account.their prior medical history, imaging and endoscopic tests, overall health, the particular clinical concern, the accessibility of imaging platforms, and the availability of interpretative radiological competence. Although CT is rarely used as a first-line test in younger patients without a prior diagnosis, it is frequently performed in those with suspected extra intestinal complications, according to a recent survey on the use of small bowel imaging of Crohn's disease within National Health Service radiological practice [43].

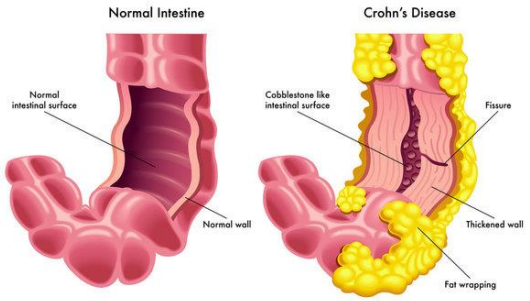

Figure:3 - This structure are shown in Crohn’s disease and Normal Intestine.

The mesenchymal border of the small bowel is primarily affected by Crohn's disease, which commonly results in asymmetric inflammation and fibrosis. with the antimesenteric border pseudosacculation. Pre-stenotic dilatation aids in the definition, location, and evaluation of a stricture's functional relevance. The mesenteric veins (vasa recta), which pierce the gut wall perpendicular to the intestinal lumen and provide the so-called "comb sign," expand and engorge when there is active inflammation However, it is questionable if this indicator is useful in routine clinical practice. For instance, Koh et al.'s MRI study [44] found that an increase in mesenteric vascularity had a 78% sensitivity and a 57% specificity in identifying active Crohn's disease.

Advantages of CT Enterography

Excellent Visualization of the Small Bowel

CTE offers high-resolution pictures of the mucosal, mural, and extramural layers of the small intestine. This is very helpful for identifying diseases like Crohn’s [45].

Detection of Extraintestinal Manifestations

It assists in identifying issues that are not visible with conventional small bowel follow-through, such as fistulas, abscesses, and mesenteric inflammation [46].

Noninvasive and Well-Tolerated

Because CTE only involves oral contrast consumption, it is less invasive and more comfortable than procedures like double-balloon enteroscopy or CT enteroclysis [47].

Quick Acquisition Time

Because the entire research is completed quickly—within minutes—it can be used with individuals who are very sick [48].

High Sensitivity and Specificity for Active Disease

In Crohn's disease, CTE has a good diagnostic accuracy for detecting penetrating disease, strictures, and active inflammation [49].

Useful for Monitoring Treatment Response

CTE can evaluate alterations in lymphadenopathy, enhancement, and thickness of the intestinal wall, offering objective indicators of treatment response [50].

Superior Detection of Acute Complications

Because of its quick acquisition and better ability to detect blockage, ischemia, or perforation, CTE is frequently chosen over MR enterography in emergency situations [51].

Treatment response

CTE can be used to evaluate the effectiveness of treatment for Crohn's disease, which is characterized by improvements in the engorged vasa recta and a decrease in mural hyperenhancement and bowel wall thickness. [52,53,54] In 16/20 (80%) of the patients, Hara et al.8 found a correlation between symptoms and the CTE interpretation of the disease's development or regression. According to Wu et al.23, there is a strong association between CTE results and clinical remission. Their findings showed that, utilizing a combination of clinical, endoscopic, pathologic, and laboratory data as the criteria of disease remission, mural hyperenhancement and bone wall thickening—the most sensitive indicators of active illness—were dramatically reduced following successful therapy. Additionally, they noticed that the shift from trilaminar or bilaminar stratification with mucosal hyperenhancement to homogeneous or bilaminar stratification without mucosal hyperenhancement altered the pattern of mural stratification. Furthermore, postoperative recurrence of Crohn's disease, which is most commonly observed at or immediately proximal to the anastomotic site, can be assessed using CTE.

Radiation dose reduction issue

Because Crohn's disease patients are typically younger and are expected to have more follow-up CT scans, radiation concerns are a significant concern in CTE. [55] In their 15-year analysis of IBD patients, Desmond et al. [56] found that the percentage of CT scans that contributed to cumulative effective dosage rose from 46.3% during the first five years to 84.7% during the last five years. This increase is likely due to the increased use of CT. Alongside these cutting-edge technology, a fairly recent study of Koreangies exists. The first is to reduce the quantity of dynamic CT phases. According to Wold et al. [57] arterial phase imaging does not aid in the identification of active Crohn's disease. At CTE, single-phase imaging is adequate.

Radiation exposure

CT enterography uses ionizing radiation, in contrast to MR enterography or capsule endoscopy. According to Brenner and Hall [58] radiation exposure may be the cause of 1.5–2% of all malignancies in the United States. According to the BEIR VII risk model, CT may be the cause of 0.7% of cohorts' lifetime malignancies. The average effective dosage of an abdominal pelvic CT examination is around 15 mSv [60] and the typical dose for CT enterography at our institution is similarly 15 mSv. Therefore, recently published statistics on the risk of carcinogenesis in adult patients owing to CT quote much lower-risk percentages of 0.02–0.04% [59].Pediatric individuals will have a larger effective dose and since younger patients are more likely to need more scans during their lifetime, using small bowel MRI rather than CT in younger patients should be carefully considered. According to the authors, CT enterography is a suitable method when applied sparingly and to the appropriate patient populations. In the near future, diagnostic-quality CT images at much lower radiation doses are likely to be available thanks to the recent development of novel approaches such the adaptive statistical iterative reconstruction algorithm [61].

Future Directions

The diagnostic potential of computed tomography enterography (CTE) is being improved by emerging technologies like dual-energy CT, low-dose protocols, and AI-based image analysis. The combination of radiomics and machine learning may enable automated evaluation of disease activity and response to treatment. CTE has become a crucial imaging modality for assessing small bowel disorders, especially in conditions like Crohn's disease. As developments continue, its role in clinical practice is being shaped in a number of ways.

Integration of Artificial Intelligence (AI) and Machine Learning

AI is being used more and more to enhance CTE scan interpretation. For example, a study by Gupta et al. (2024) presented a computer vision algorithm that helps distinguish intestinal tuberculosis from Crohn's disease by automating the calculation of the visceral-to-subcutaneous fat (VF/SF) ratio.

Furthermore, CTE image classification has been accomplished with remarkable accuracy and using deep learning models such as ResNet10.

Radiation Dose Reduction Techniques

Minimizing radiation exposure is essential because chronic conditions like Crohn's disease require repeated imaging; innovations like iterative reconstruction algorithms (e.g., Adaptive Statistical Iterative Reconstruction, iDose) have shown that they can reduce radiation doses by 35–72% without sacrificing image quality.

Enhanced Imaging Protocols

Small bowel pathology can now be seen more clearly thanks to developments in CT technology, such as multidetector CT scanners with thinner slices and better contrast agents. For instance, neutral contrast chemicals make it possible to evaluate ulcers and mucosal enhancement more accurately.

Comparative Efficacy with MR Enterography

CTE offers better spatial resolution and quicker picture capture, whereas MR Enterography (MRE) has the benefit of no radiation exposure. Both modalities have similar diagnostic accuracy, according to studies, although in some situations, CTE might be more affordable and available.

Discussion

CT Enterography (CTE) has emerged as a cornerstone imaging modality for assessing a wide range of small bowel pathologies, particularly in inflammatory bowel diseases like Crohn's disease. Its superior spatial resolution, rapid acquisition, and ability to delineate both luminal and extraintestinal abnormalities make it an indispensable diagnostic tool. Compared to traditional imaging modalities such as barium studies or standard CT, CTE significantly improves lesion detection and provides more comprehensive anatomical detail.

One of the key advantages of CTE is its accuracy in detecting **active inflammation**, **fistulas**, **abscesses**, and **strictures**, especially in Crohn's disease. Mural hyperenhancement, wall thickening, and the "comb sign" remain reliable radiologic indicators of active disease. Additionally, CTE proves effective in characterizing small bowel tumors and locating sources of gastrointestinal bleeding when other modalities like capsule endoscopy are inconclusive.

However, CTE is not without limitations. The **use of ionizing radiation** is a major concern, particularly in younger patients requiring serial follow-ups. Though advanced dose-reduction techniques like iterative reconstruction algorithms (ASIR, iDose) have mitigated this to an extent, MR Enterography (MRE) remains preferable for certain patient groups due to the absence of radiation. Nonetheless, CTE is often favored in acute or emergency settings because of its availability, speed, and superior detection of complications like perforation or ischemia.

Furthermore, advancements in **artificial intelligence (AI)** and **machine learning** are showing promise in automating image analysis, improving diagnostic accuracy, and reducing interobserver variability. AI-driven tools, such as algorithms for distinguishing between Crohn's disease and intestinal tuberculosis, and deep learning-based pattern recognition, are gradually being integrated into clinical workflows.

Overall, while radiation exposure is an ongoing concern, the diagnostic confidence, accessibility, and versatility of CTE ensure its continued relevance in gastrointestinal imaging.

Conclusion

CT Enterography is a powerful, non-invasive imaging technique that offers detailed evaluation of small bowel disorders. It plays a pivotal role in diagnosing and monitoring Crohn's disease, identifying small bowel neoplasms, and assessing obscure gastrointestinal bleeding. With its high diagnostic accuracy and ability to evaluate both intestinal and extraintestinal pathology, CTE has become a first-line modality in many clinical settings.

Despite concerns about radiation exposure, the development of dose-reduction technologies and enhanced imaging protocols have significantly improved its safety profile. Emerging applications of artificial intelligence and dual-energy CT further enhance its diagnostic potential. In conclusion, when used judiciously and tailored to individual patient needs, CT Enterography remains an essential and evolving tool in the radiologic evaluation of the small bowel.

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