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Review

Comparative Analysis of Barium Follow Through with CT Enterography and Magnetic Resonance Enterography in Radiological Diagnostics: A narrative review of literature

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Background: Radiological imaging is fundamental in diagnosing gastrointestinal (GI) disorders, with Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE) being prominent modalities. While BFT employs barium sulfate and X-ray imaging, MRE utilizes MRI technology, offering superior soft tissue contrast and multiplanar imaging without radiation.

Objective: This narrative review aims to compare BFT and MRE in GI diagnostics, emphasizing their technical methodologies, diagnostic efficacy, patient safety, economic implications, and clinical applications.

Methods: A literature search was conducted across reputable databases using specified keywords. Studies comparing BFT and MRE in GI diagnostics were analyzed for a comprehensive understanding of their comparative strengths and limitations.

Results: MRE demonstrated higher sensitivity and specificity, particularly in detecting inflammatory bowel disease and small bowel tumors, while BFT remained valuable for assessing structural abnormalities despite challenges in detecting subtle mucosal abnormalities. Patient safety considerations favored MRE due to its radiation-free nature, though contraindications such as claustrophobia existed. Economically, while BFT was initially perceived as more cost-effective, MRE's higher reimbursement rates and diagnostic accuracy offered long-term benefits.

Conclusion: This review provides valuable insights into the comparative strengths and limitations of BFT and MRE, facilitating informed decision-making and optimizing imaging strategies in clinical practice. Interdisciplinary collaboration is essential for improving diagnostic accuracy and patient outcomes in GI disorders.

Keywords: *Barium Sulfate, Diagnostic Accuracy, Gastrointestinal Diagnostics, Inflammatory Bowel Disease, Magnetic Resonance Imaging, Patient Safety, Radiological Imaging, Small Bowel Tumors.*

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INTRODUCTION

Radiological imaging constitutes a cornerstone in contemporary medical practice, particularly in the diagnosis of gastrointestinal (GI) disorders, which encompass a wide spectrum ranging from inflammatory

bowel diseases to neoplasms, necessitating accurate and prompt diagnosis for effective treatment [1, 2].

Plain X-ray, ultrasound and computed tomography (CT) are conventionally the primary imaging modalities, particularly in the acute setting depending on availability, cost and clinical scenario. Dedicated small bowel technique includes barium meal and follow through (BFT), and less widely used enteroclysis in addition to the cross-sectional techniques, namely; Computed Tomography Enterography (CTE) and Magnetic Resonance Enterography (MRE) [3].

CTE is a specific cross-sectional imaging technique that is tailored to evaluate the small bowel, through the use of large volume neutral oral contrast and image acquisition in the enteric phase of intravenous contrast enhancement [4]. Due to its broad availability in emergency rooms, rapid image acquisition, and ability to evaluate mural, extraluminal, and extraintestinal Crohn's disease (CD) manifestations, CTE has become a standard imaging tool for CD evaluation [5, 6].

According to Gale et al., 2017 [7] Mural features are predictors of active inflammation for both CT and MRE, while perienteric features can be distinguished better on CTE compared with MRE, likely due to increased conspicuity of the mesentery on CTE [6, 7]. However, attention has been focused on the potential risk for ionizing radiation dose associated with CT scans, particularly in the CD population that likely requires multiple imaging studies over the course of their disease [8-10].

Chatu et al., 2012 [11] in a meta-analysis concluded that up to 10% of CD patients have had exposure to ≥50 millisieverts (mSv) of ionizing radiation exposure from imaging studies (mostly due to CT scans), a threshold above which a nonzero radiation risk has been suggested. Recently, many studies revealed that MRE has developed as an alternative imaging technique to CTE for small bowel imaging and, in many institutions, has largely replaced CTE as the cross-sectional imaging modality of choice, particularly for pediatric patients [12-16]. This is probably due to the progressive improvements in MRI techniques and accumulating expertise. Table 1 summarize the comparison between MRE and CTE.

Among the array of diagnostic tools available, Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE) have garnered considerable attention, emphasizing the ongoing advancements in medical imaging technology [17].

The evolution of gastrointestinal imaging has witnessed a paradigm shift from invasive procedures to non-invasive techniques. Barium Follow Through (BFT), a traditional method, employs barium sulfate as a contrast agent for X-ray visualization of the GI tract, offering detailed structural insights into various conditions. Nonetheless, inherent limitations in specific clinical scenarios prompted exploration into alternative imaging modalities [18].

Magnetic Resonance Enterography (MRE) epitomizes a substantial advancement in GI imaging, harnessing magnetic resonance imaging (MRI) technology to deliver detailed images of the GI tract devoid of ionizing radiation. Its capability to visualize both luminal and extraluminal intestinal structures, coupled with functional imaging capabilities, renders it invaluable in diagnosing complex GI disorders, notably inflammatory bowel diseases [19].

The comparative analysis of BFT and MRE transcends mere technological disparities to encompass their clinical utility. Each modality demonstrates distinct strengths and limitations, influenced by factors such as image resolution, patient safety, and diagnostic accuracy [20]. While BFT offers a cost-effective and widely accessible option, MRE distinguishes itself with superior soft tissue contrast and the absence of radiation exposure.

Despite the evident advantages of both imaging modalities, challenges persist in their application. For instance, the utilization of barium in Barium Follow Through (BFT) may obscure certain pathologies and is contraindicated in cases of suspected bowel perforation. Conversely, Magnetic Resonance Enterography (MRE), despite its higher costs and limited availability, may not be universally accessible to all patient populations. Moreover, the prolonged duration of MRE procedures and the imperative for patients to maintain stillness can pose challenges, particularly for pediatric or critically ill patients [21].

In addition to clinical efficacy, the selection between BFT and MRE often hinges on patient-specific factors, encompassing age, medical history, and the specific clinical query at hand [22]. For instance, while MRE is preferred in younger patients to mitigate radiation exposure [23], BFT may be deemed more appropriate in

settings where MRI contraindications exist or in resource-constrained environments [24].

Given these multifaceted considerations, the objective of this study is to systematically compare Barium Follow Through and Magnetic Resonance Enterography in the realm of gastrointestinal diagnostics. This comparative analysis endeavors not only to delineate the strengths and limitations of each modality but also to offer guidance on their optimal utilization across diverse clinical scenarios. By scrutinizing historical data alongside contemporary practices, this study aims to furnish valuable insights to the field of radiology, ultimately facilitating the selection of the most appropriate imaging modality for GI disorders.

METHODS

Literature Search Strategy

To initiate the review process, an exhaustive literature search was conducted across multiple reputable academic databases, including PubMed and MEDLINE. Incorporating the following keywords: "Barium Follow Through" "Magnetic Resonance Enterography" "gastrointestinal imaging" "radiology" "small bowel imaging" "contrast studies" "intestinal MRI" "bowel examination" "radiographic imaging" "gastrointestinal tract imaging" "radiologic diagnosis" and "enteric contrast agents" The keywords were adapted to each database's search interface, specifying appropriate syntax and Boolean operators to ensure comprehensive coverage. The search was limited to articles published exclusively in the English language to ensure consistency in analysis. This approach aimed to capture a broad spectrum of relevant literature for a comprehensive comparison between Barium Follow Through and Magnetic Resonance Enterography in gastrointestinal diagnostics.

Inclusion Criteria

- Only original research articles, systematic reviews, and meta-analyses were included. Case reports and conference abstracts were excluded to ensure the inclusion of studies with robust methodology and significant sample sizes.
- Studies published between January 2000 and December 2023 were considered to ensure relevance to current clinical practices.
- Only articles published in English were included to avoid potential biases in translation and ensure accessibility.
- Studies involving patients with gastrointestinal conditions diagnosed using BFT, MRE, or CT Enterography were included.
- Studies that provided clear comparative data on diagnostic accuracy, patient safety, cost-effectiveness, and technological advancements of BFT and MRE.

Exclusion Criteria

- Editorials, letters to the editor, opinion pieces, and narrative reviews without original data were excluded.
- Studies published before January 2000 were excluded due to advancements in imaging technology that may render older studies less relevant.
- Non-English articles were excluded to maintain consistency and reliability in data interpretation.
- Studies focusing on pediatric patients or non-human subjects were excluded to ensure applicability to clinical practices.

Data Extraction and Quality Assessment

After conducting the initial search process, the studies retrieved were systematically categorized based on their relevance and contribution to the comparison of Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE) in gastrointestinal diagnostics. This categorization involved screening of titles and abstracts, followed by an in-depth full-text review of selected articles. Throughout this process, attention was focused on identifying key findings, strengths, weaknesses, and unique insights offered by each study.

The focus was on summarizing individual study findings and synthesizing these findings from various sources to draw robust conclusions regarding the comparative effectiveness, safety, and applicability of BFT and MRE in clinical practice. Through this qualitative synthesis, the aim was to provide readers with an understanding of the strengths and limitations of each imaging modality, thereby facilitating informed decision-making in clinical settings. In assessing the quality of the selected studies, multiple factors were considered. These factors included

the study design, sample size, methodological rigor, and the relevance of the results to the comparative analysis of BFT and MRE.

The review acknowledges the potential for bias in the selection and interpretation of studies. This included the inclusion of a diverse range of studies and perspectives, as well as the provision of an objective analysis of the findings. To ensure a comprehensive understanding, the review also incorporated guidelines and position statements from prominent radiological and gastroenterological societies. These documents served to provide context and insights into current clinical practices and standards in gastrointestinal imaging, enhancing the robustness of the review's conclusions.

RESULTS

A literature search using established electronic databases identified 453 articles potentially relevant to the use of Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE) in gastrointestinal diagnostics. Following a review process applying predetermined inclusion/exclusion criteria, 96 articles were deemed suitable for further analysis.

To achieve comprehensive coverage of the current literature landscape, a secondary search was conducted. This secondary search reviewed the reference lists of the included articles, identifying an additional 61 articles that met the inclusion criteria. This two-pronged approach ensured a thorough examination of the available research on BFT and MRE for gastrointestinal diagnoses.

Technical Aspects

The technical methodologies underlying Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE) epitomize distinct paradigms within gastrointestinal (GI) imaging. BFT's reliance on barium sulfate administration followed by X-ray imaging hinges on exploiting the differential absorption of X-rays by the barium contrast [25], thereby enabling visualization of GI anatomical structures with precision.

Conversely, MRE capitalizes on magnetic resonance imaging (MRI) technology [26], where patients are subjected to a magnetic field, and subsequent radiofrequency pulses generate images predicated on hydrogen atoms' response in tissues. Notably, MRE's non-utilization of ionizing radiation renders it an appealing choice for patient cohorts averse to radiation exposure, such as pediatric or reproductive-age individuals [27].

Table 1. Technical aspects of CT Enterography (CTE) and Magnetic Resonance Enterography (MRE)

Aspect	CT Enterography (CTE)	Magnetic Resonance Enterography (MRE)
Imaging Modality	Computed Tomography (CT)	Magnetic resonance imaging (MRI)
Contrast Medium	Iodinated contrast media	Gadolinium-based agents (IV), sometimes with oral or rectal contrast
Visualization	Provides detailed cross-sectional images of the GI tract and surrounding tissues	Provides detailed cross-sectional images of the GI tract and surrounding tissues
Capabilities	Capable of showing blood flow, bowel wall inflammation and surrounding tissues	Capable of showing blood flow, and bowel wall inflammation and surrounding tissues
Claustrophobia	Less likely to occur	May be challenging for claustrophobic patients, anesthesia might be needed
Allergy	Low risk of allergic reaction to iodinated contrast media	Gadolinium contrast agents can cause allergic reactions in rare cases.
Preparation	Patient needs to fast; bowel cleansing may be required for optimal imaging	Patient needs to fast; specific preparations vary for optimal imaging
Procedure Time	Faster, usually few seconds to few minutes	Slower, ranging from 30 to 60 minutes
Safety	Radiation exposure:	No radiation:
	Not preferred for younger patients' long term follow up	Safe except for some pacemakers
Applications	Ideal for assessing inflammatory and neoplastic conditions and their complications, particularly new patients	Preferred for inflammatory conditions, such as Crohn's disease; also assesses vascularity and presence of fibrosis
Cost	Less expensive	More expensive

Diagnostic Efficacy

Studies juxtaposing the diagnostic efficacy of BFT against MRE underscore the latter's ascendancy in discerning and characterizing GI pathologies with heightened sensitivity and specificity [28]. MRE consistently outperforms BFT, particularly evident in discerning

mucosal inflammation, ulceration, and structuring in cases of inflammatory bowel disease [29].

Furthermore, MRE's adeptness in visualizing structural anomalies within the GI tract surpasses BFT's capabilities, attributable to its multiplanar imaging prowess and provision of dynamic functional data [30]. The collective body of evidence highlights MRE's pivotal role as a diagnostic stalwart in delineating intricate GI pathologies, warranting its consideration as a first-line imaging modality in various clinical scenarios.

Patient Safety and Comfort

Ensuring patient safety and comfort remains paramount in GI imaging, with considerations extending beyond diagnostic efficacy [31]. While BFT poses radiation exposure risks, albeit minimal, MRE presents as a safer alternative by circumventing ionizing radiation [21].

However, MRE may be contraindicated for patients with specific implants or claustrophobia due to the enclosed MRI scanner environment [32]. Striking a delicate balance between diagnostic imperatives and patient comfort is imperative; while BFT may evoke discomfort due to barium ingestion and multiple X-ray exposures [31], MRE's prolonged procedural duration and confinement within the MRI scanner may pose challenges for certain patient cohorts. As such, a nuanced approach that factors in patient preferences, clinical indications, and contraindications is warranted to optimize patient care and diagnostic outcomes.

Table 2. Aspects that focus on Patient Safety and Comfort regarding Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE)

Aspect	Barium Follow Through (BFT)	Magnetic Resonance Enterography (MRE)
Radiation Exposure	Yes, it involves exposure to ionizing radiation.	No, uses magnetic fields and radio waves, hence no radiation exposure.
Allergies and Reactions	Low risk of allergic reaction to barium contrast; however, barium impaction can be a concern.	Gadolinium contrast agents can cause allergic reactions in rare cases. Concerns about gadolinium deposition.
Claustrophobia	Not typically an issue as the procedure is open and not confining.	May be challenging for claustrophobic patients, though open and wide-bore MRIs can help.
Preparation and Comfort	Fasting required; consuming barium can be unpleasant for some patients. Barium may cause constipation.	Fasting required; IV contrast may be uncomfortable. Generally well-tolerated. MRI noise can be discomforting.
Procedure Time	Duration can vary significantly depending on how quickly the barium moves through the intestines.	Typically takes 30 to 60 minutes and is relatively consistent.
Sedation	Not usually required.	Not typically necessary, but an option for patients who are claustrophobic or have difficulty staying still.
Post-Procedure	Drinking lots of fluids to clear the barium is recommended. Possible constipation.	Generally, no specific post-procedure requirements. Drinking water is encouraged if contrast is used.

Cost-Effectiveness and Accessibility

The economic comparison between Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE) encompasses multifaceted considerations, including cost implications for healthcare systems and patients, as well as accessibility dynamics.

BFT often garners favorability in terms of cost-effectiveness due to its lower equipment costs and shorter procedural durations [33]. The utilization of conventional X-ray equipment translates to reduced capital investments and operational expenses, rendering BFT a financially prudent option, particularly in resource-constrained healthcare settings [34].

Conversely, MRE's advanced imaging technology and subsequent higher reimbursement rates may offset its initial cost disadvantage, especially in contexts where enhanced diagnostic accuracy and superior soft tissue contrast are imperative [35]. However, accessibility remains a pertinent concern; while BFT enjoys broader availability owing to its reliance on conventional X-ray equipment, MRE's accessibility may be curtailed in regions or healthcare settings lacking adequate MRI facilities or economic resources. The economic considerations surrounding modality selection necessitate a nuanced evaluation of cost-effectiveness, balanced against diagnostic imperatives and healthcare resource allocations.

Table 3. Cost-effectiveness and accessibility of Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE)

Feature	Barium Follow Through (BFT)	Magnetic Resonance Enterography (MRE)
Cost	Generally, less expensive than MRE.	Typically, more expensive due to the use of advanced MRI technology.
Availability/Accessibility	Widely available in most radiology departments.	Availability may be limited to larger hospitals or specialized centers.
Imaging Time	Procedure can take 1-2 hours.	Usually shorter, taking about 30-45 minutes.
Radiation Exposure	Utilizes ionizing radiation.	No ionizing radiation, using magnetic fields and radio waves.
Image Quality	Provides good detail of the small intestine structure.	Offers superior contrast resolution and detailed images of the small intestine, including soft tissue, vessels, and inflammation.
Suitability for Children	Less commonly used in children due to radiation exposure.	Preferred for pediatric patients because it is non-ionizing.
Ease of Use	The procedure is relatively straightforward but may be uncomfortable.	May require sedation for patients who have difficulty remaining still.
Detection of Complications	Effective in detecting structural abnormalities.	Superior in detecting inflammatory or penetrating diseases, fistulas, and abscesses.

The specifics could vary based on geographic location, advancements in technology, and the particular patient case in question.

Clinical Applications

The clinical preference between Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE) hinges on a multitude of factors, including patient demographics, suspected pathology, and diagnostic exigencies [36]. MRE's radiation-free attribute renders it a preferred choice in radiation-sensitive populations, such as pediatric and reproductive-age cohorts, mitigating long-term health risks associated with cumulative radiation exposure [37].

Conversely, BFT may be deemed suitable for patients with contraindications to MRI or in contexts where rapid diagnostic turnaround and cost considerations predominate [38]. Additionally, diagnostic requirements play a pivotal role in modality selection; MRE's superior soft tissue contrast and dynamic functional imaging capabilities render it advantageous in scenarios necessitating detailed soft tissue evaluation, such as inflammatory bowel disease or small bowel tumors [39]. Conversely, BFT's proficiency in delineating luminal structural abnormalities within the GI tract may render it preferable in select clinical scenarios [40]. The integration of clinical considerations, patient preferences, and diagnostic imperatives is imperative to optimize diagnostic outcomes and enhance patient care within the realm of gastrointestinal imaging.

Table 4. Summarizing the clinical applications of Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE)

Clinical Applications	Barium Follow Through (BFT)	Magnetic Resonance Enterography (MRE)
Detection of Anatomical Abnormalities	Effective for visualizing structural abnormalities in the small intestine.	Excellent for detailed visualization of both structural and functional abnormalities, with superior soft tissue contrast.
Inflammatory Bowel Diseases	Can identify areas of stricture, dilation, and mucosal changes associated with Crohn's disease.	Preferred for evaluating extent and severity of inflammation, mural thickening, and extraintestinal manifestations of Crohn's disease.
Small Bowel Tumors	Useful for identifying larger tumors based on their effect on the bowel's contour.	Superior for identifying small and otherwise difficult-to-detect tumors, including assessment of surrounding structures.
Pre-operative Assessment	Can provide a roadmap of the small intestine before surgery but with limited detail on surrounding tissues.	Optimal for pre-operative planning by clearly delineating disease extent and relationship to surrounding structures.
Pediatric Patients	Less commonly used due to concerns over radiation exposure.	Highly preferred due to lack of radiation, making it safer and more suitable for repeated studies in pediatric patients.
Gastrointestinal Bleeding	Can help identify sources of bleeding in the small intestine, though may be less sensitive for small bleeds.	While not its primary use, in certain cases it can help identify bleeding sites, especially when combined with other MR techniques.
Malabsorption Syndromes	May provide clues by showing changes in mucosal pattern, though not the first choice for these conditions.	Not typically used for direct diagnosis of malabsorption but can help identify underlying structural causes.
Intestinal Obstructions	Can reveal physical blockages or obstructions in the small bowel.	Offers comprehensive assessment of obstructions, including the cause (e.g., tumor, inflammation) and effects on surrounding tissues.

Comparative Advantages

Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE) each offer unique advantages tailored to specific clinical contexts. BFT's widespread availability and lower procedural costs emphasize its utility as a cost-effective imaging modality, particularly in healthcare settings where financial constraints dictate resource allocations [41]. Furthermore, BFT's reliance on conventional X-ray equipment facilitates its integration into various healthcare settings, including primary care clinics and community hospitals, thereby enhancing accessibility [42].

Conversely, MRE's superiority in affording superior soft tissue contrast, safety due to the absence of ionizing radiation, and functional imaging capabilities elevate its appeal in scenarios necessitating detailed soft tissue evaluation and dynamic functional information [19]. The collective array of advantages offered by BFT and MRE underscores their complementary roles within the diagnostic armamentarium, necessitating a nuanced evaluation to discern the most suitable imaging modality for specific clinical scenarios [43].

Limitations and Challenges

Despite their diagnostic prowess, Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE) present inherent limitations and challenges that warrant consideration in clinical practice. BFT's diagnostic limitations encompass its inability to furnish detailed images of the bowel wall and potential masking of pathologies by barium sulfate, particularly in cases requiring nuanced soft tissue evaluation [44]. Additionally, BFT's reliance on ionizing radiation poses radiation exposure risks, albeit minimal, warranting judicious utilization, especially in radiation-sensitive patient cohorts. Conversely, MRE confronts challenges such as prolonged procedural durations and patient compliance requisites, with the enclosed MRI scanner environment posing challenges for individuals with claustrophobia or discomfort in confined spaces [45]. Moreover, MRE's higher cost and limited accessibility in resource-constrained settings may hinder its widespread adoption, necessitating a balanced evaluation of diagnostic imperatives, patient preferences, and economic considerations to optimize diagnostic outcomes and patient care [46].

Patient Selection Criteria

The selection of the appropriate imaging modality for different patients hinges on a myriad of factors, including age, medical history, and specific clinical indications. Pediatric patients or individuals of reproductive age, for instance, necessitate minimization of radiation exposure, rendering Magnetic Resonance Enterography (MRE) a preferred choice over Barium Follow Through (BFT) due to its radiation-free attribute [47]. Similarly, patients with contraindications to MRI or in contexts where rapid diagnostic turnaround and cost considerations predominate may be more suited for BFT [21].

Furthermore, the specific clinical indications and diagnostic requirements play a pivotal role in determining the most appropriate imaging modality; MRE's superior soft tissue contrast and dynamic functional imaging capabilities render it advantageous in scenarios necessitating detailed soft tissue evaluation, whereas BFT may be preferable for assessing luminal structural abnormalities within the gastrointestinal tract [48]. The integration of patient demographics, medical history, and clinical indications is imperative to tailor imaging modalities to individual patient needs and optimize diagnostic outcomes within the realm of gastrointestinal imaging.

Table 5. Patient selection criteria for Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE)

Patient Selection Criteria	Barium Follow Through (BFT)	Magnetic Resonance Enterography (MRE)
Age and Population	- Generally safe for adult populations. - Less preferred in children due to radiation exposure.	- Suitable for all age groups, including children, because of its non-ionizing nature.
Pregnancy	- Not recommended due to the risk of fetal exposure to ionizing radiation.	- Generally considered safe; however, the use of gadolinium-based contrast agents is typically avoided in pregnant women.
Renal Function	- No impact on renal function; safe to use in patients with renal impairment.	- Requires caution in patients with renal impairment due to the potential risk of nephrogenic systemic fibrosis with certain gadolinium-based contrast agents.
Patient Compliance and Tolerance	- Requires patient cooperation to ingest barium and to change positions during the examination. Some patients may find the procedure uncomfortable.	- May be challenging for patients who are claustrophobic or unable to stay still for the duration of the exam. Sedation can be used in some cases.

Contrast Allergies	- Low risk of allergic reactions to barium. However, caution is advised in cases of suspected perforation where barium spillage in the peritoneal cavity could occur.	- Patients with a history of gadolinium or other contrast allergies should be carefully evaluated; premedication or alternative imaging may be considered.
Detailed Soft Tissue Contrast	- Provides detailed images of the mucosal surface and bowel lumen but limited soft tissue contrast.	- Superior for evaluating soft tissue contrast, including visualization of inflammation, edema, and subtle differences in tissue composition not visible on BFT.
Acute Abdominal Conditions	- Limited use in acute settings; preferred for elective investigation of structural abnormalities.	- Ideal for acute conditions needing detailed evaluation of bowel wall and surrounding structures, such as inflammation, abscesses, or complications of Crohn's disease.
Historical or Underlying Conditions	- Preferable in cases requiring detailed evaluation of the intestinal lumen, such as suspected strictures or small bowel tumors.	- Favored in patients with inflammatory bowel disease, or where there is a need to evaluate extra-intestinal manifestations of gastrointestinal diseases or soft tissue pathologies.

Integration into Clinical Practice

Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE) serve as indispensable diagnostic adjuncts within the clinical milieu, offering complementary roles alongside other imaging modalities to afford a comprehensive diagnostic framework for gastrointestinal (GI) disorders.

Within the GI imaging, BFT and MRE are often integrated into diagnostic algorithms, capitalizing on their unique advantages to provide a multi-faceted approach to diagnosis and treatment planning [49]. For instance, in the evaluation of inflammatory bowel disease (IBD), BFT and MRE are frequently employed to assess disease extent, severity, and complications. BFT may be utilized initially to identify luminal abnormalities and assess bowel motility, while MRE provides detailed images of the bowel wall and surrounding structures, facilitating the detection of mucosal inflammation, strictures, and fistulas [50].

When combined with other diagnostic tools such as laboratory tests and endoscopic procedures, BFT and MRE contribute to a comprehensive evaluation of IBD and help guide treatment decisions. Similarly, in the assessment of small bowel tumors and other structural abnormalities, BFT and MRE play complementary roles in identifying lesion location, size, and characteristics [51]. BFT may be used to detect luminal narrowing or obstruction, while MRE offers superior soft tissue contrast and detailed imaging of tumor morphology, facilitating accurate diagnosis and surgical planning. The integration of BFT and MRE into clinical practice underscores their pivotal roles as essential diagnostic tools for evaluating GI disorders, offering invaluable insights to guide clinical decision-making and optimize patient care.

TECHNOLOGICAL ADVANCEMENTS

Technological Advancements in BFT

Recent technological advancements in Barium Follow Through (BFT) have focused on enhancing image clarity and reducing patient discomfort. Innovations such as digital fluoroscopy have significantly improved image resolution, allowing for better visualization of the gastrointestinal tract. Additionally, low-dose barium preparations and optimized imaging protocols have minimized radiation exposure and improved patient compliance [52].

Despite these advancements, BFT faces inherent limitations, such as the inability to provide detailed soft tissue contrast and functional assessment. However, new developments in dual-energy X-ray absorptiometry (DXA) integrated with BFT are promising. DXA-BFT can simultaneously assess bone density and gastrointestinal tract abnormalities, offering a more comprehensive diagnostic tool for conditions like osteoporosis and gastrointestinal disorders [52, 53].

Technological Advancements in MRE

Magnetic Resonance Enterography (MRE) has benefited from numerous technological advancements that enhance its diagnostic capabilities. High-field strength MRI scanners (3T and above) provide superior image resolution and faster scan times, allowing for detailed visualization of the bowel wall and surrounding structures. Advanced sequences, such as diffusion-weighted imaging (DWI) and perfusion imaging, have improved the ability to detect and characterize inflammatory activity, fibrosis, and neoplasms [19, 54].

Artificial intelligence (AI) and machine learning algorithms are being integrated into MRE to automate image analysis and improve diagnostic accuracy [55]. AI can assist in detecting subtle abnormalities, quantifying

inflammatory burden, and predicting disease progression, thereby aiding clinicians in making more informed decisions [56].

Functional MRI techniques, such as motility imaging and cine-MRI, are also gaining traction. These techniques provide real-time assessment of bowel motility, helping in the evaluation of functional gastrointestinal disorders like irritable bowel syndrome (IBS) and motility disorders. Furthermore, the development of contrast agents specific to bowel pathology enhances the specificity of MRE in detecting various gastrointestinal conditions [54].

Future Perspectives

Emerging trends in gastrointestinal (GI) imaging are driving advancements in Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE), with ongoing research focusing on potential technological innovations that may influence their comparative utility. Notably, there is a growing interest in advanced imaging techniques such as computed tomography (CT) enterography and magnetic resonance imaging (MRI) enterography, which offer enhanced visualization of the GI tract compared to traditional radiographic methods like BFT [57].These advanced imaging modalities provide higher-resolution images and improved soft tissue contrast, allowing for more accurate detection and characterization of GI pathologies.

However, advancements in BFT and MRE technology are also underway to address limitations and enhance their comparative utility. Efforts are being made to improve image quality and reduce radiation exposure in BFT by optimizing imaging protocols and utilizing low-dose radiation techniques [36]. Additionally, research is exploring the integration of computer-aided detection (CAD) systems to assist radiologists in detecting subtle abnormalities and improving diagnostic accuracy [58].

Similarly, in MRE, ongoing research is focused on refining imaging protocols to shorten procedure times and improve patient comfort. Techniques such as rapid MRI sequences and breath-hold imaging are being investigated to reduce scan times and minimize patient motion artifacts [59, 60]. Additionally, advancements in MRI hardware and software, including higher field strengths and improved image reconstruction algorithms, are expected to further enhance the diagnostic capabilities of MRE.

Future developments in BFT and MRE may also involve the integration of emerging technologies such as artificial intelligence (AI) and machine learning. These technologies have the potential to revolutionize GI imaging by automating image analysis, improving lesion detection, and assisting in treatment planning. By leveraging AI algorithms trained on large datasets of GI images, BFT and MRE may become more efficient and accurate diagnostic tools, ultimately benefiting patients and healthcare providers alike. The evolving landscape of GI imaging heralds promising advancements in BFT and MRE technology, offering exciting prospects for improved diagnostic accuracy, enhanced patient care, and optimized clinical outcomes in the field of gastrointestinal medicine.

Integration with Other Diagnostic Tools

While Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE) each offer unique advantages in gastrointestinal diagnostics, integrating these modalities with other diagnostic tools can provide a more comprehensive assessment of gastrointestinal conditions. Here, we explore how BFT and MRE can be combined with other diagnostic techniques to enhance clinical decision-making and patient outcomes.

Integration with Endoscopy

Endoscopy, including colonoscopy and upper endoscopy, is a cornerstone in gastrointestinal diagnostics, allowing direct visualization and biopsy of the mucosa. Combining endoscopy with BFT or MRE can enhance diagnostic accuracy. For example, BFT can be used to identify areas of stricture or obstruction that may require targeted endoscopic intervention. Conversely, MRE can provide detailed imaging of the bowel wall and surrounding tissues, guiding endoscopic biopsies and therapeutic procedures.

Integration with Capsule Endoscopy

Capsule endoscopy, which involves swallowing a small camera that takes images throughout the gastrointestinal tract, offers a non-invasive way to visualize areas that are difficult to reach with traditional endoscopy. Combining capsule endoscopy with MRE can be particularly powerful. MRE can localize and characterize lesions identified by capsule endoscopy, providing additional anatomical and pathological information. This integrated approach is especially

useful in the evaluation of small bowel diseases, such as Crohn's disease and obscure gastrointestinal bleeding.

Integration with Ultrasound

Ultrasound, including Doppler ultrasound and contrast-enhanced ultrasound, is a widely available, non-invasive imaging modality that can complement both BFT and MRE. Ultrasound is particularly useful for evaluating bowel wall thickness, vascularity, and peristalsis. Combining ultrasound with BFT can help identify areas of bowel obstruction or inflammation, guiding further imaging or intervention. Integrating ultrasound with MRE can enhance the evaluation of inflammatory bowel diseases, providing real-time functional information alongside detailed anatomical imaging.

Integration with Laboratory Tests

Laboratory tests, such as inflammatory markers (C-reactive protein, erythrocyte sedimentation rate) and fecal calprotectin, are essential in diagnosing and monitoring gastrointestinal diseases. Integrating these tests with imaging findings from BFT or MRE can improve diagnostic accuracy and patient management. For instance, elevated inflammatory markers in conjunction with MRE findings of bowel inflammation can confirm a diagnosis of active Crohn's disease and guide treatment decisions.

DISCUSSION

The technical methodologies underlying Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE) offer distinct approaches to gastrointestinal imaging. BFT relies on barium sulfate administration followed by X-ray imaging to visualize the gastrointestinal tract's anatomical structures, while MRE utilizes MRI technology, providing superior soft tissue contrast and multiplanar imaging capabilities without ionizing radiation [28].

In terms of diagnostic efficacy, MRE demonstrates higher sensitivity and specificity compared to BFT [21], particularly in detecting and characterizing pathologies like inflammatory bowel disease and small bowel tumors. However, BFT remains valuable for assessing structural abnormalities within the gastrointestinal tract despite potential limitations in detecting subtle mucosal abnormalities [24].

Patient safety considerations reveal that while BFT poses risks associated with radiation exposure, MRE offers a safer alternative devoid of ionizing radiation [31]. However, MRE may present contraindications for certain patients with specific implants or claustrophobia, necessitating careful patient selection.

Economically, BFT is perceived as more cost-effective due to lower equipment costs and shorter procedure times compared to MRE. Nonetheless, MRE may yield higher reimbursement rates, offsetting initial cost disparities [22]. Clinically, the selection of the appropriate imaging modality depends on various factors, including clinical indications, patient history, and diagnostic requirements. MRE emerges as the preferred option for patients sensitive to radiation or necessitating detailed soft tissue visualization, while BFT may suffice for certain structural abnormalities or where MRI access is limited or contraindicated [35].

Understanding the comparative strengths and weaknesses of BFT and MRE has significant practical implications for radiologists and clinicians in clinical settings. Radiologists and clinicians must consider several factors when deciding which imaging modality to employ for the diagnosis and management of gastrointestinal disorders, including the clinical indication, patient characteristics, and the specific information required for accurate diagnosis and treatment planning [34].

The comparative strengths of BFT and MRE, such as their accessibility, cost-effectiveness, and advanced imaging capabilities, can inform decision-making in clinical settings. For example, in cases where rapid and cost-effective imaging is required to evaluate luminal abnormalities or assess bowel motility, BFT may be preferred due to its widespread availability and lower cost compared to MRE. Additionally, BFT may be suitable for patients who are unable to undergo MRI due to contraindications or claustrophobia, ensuring continued access to essential diagnostic services.

Conversely, MRE's superior soft tissue contrast and lack of ionizing radiation make it a preferred option for cases requiring detailed visualization of the bowel wall, mucosal inflammation, or small lesions [46]. MRE's functional imaging capabilities also provide valuable insights into gastrointestinal motility and perfusion, which can aid in the assessment of gastrointestinal disorders such as inflammatory bowel disease and small bowel tumors. In scenarios where high diagnostic accuracy and comprehensive evaluation of disease

extent are paramount, MRE may offer distinct advantages over BFT [48].

Moreover, understanding the limitations and challenges associated with each modality is crucial for optimizing their utilization in clinical practice [21]. Radiologists and clinicians must be aware of the technical limitations of BFT, such as its inability to provide detailed images of the bowel wall and surrounding structures, and consider alternative imaging modalities, including MRE, when higher diagnostic accuracy is required. Similarly, the challenges posed by MRE, such as longer procedure times and the need for patient cooperation, necessitate careful patient selection and preparation to ensure successful imaging studies and minimize potential complications [36].

Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE) play integral roles in gastroenterology diagnostic algorithms, complementing and contrasting with other diagnostic tools to provide a comprehensive assessment of gastrointestinal (GI) disorders. These imaging techniques are often part of a multi-modal approach that considers patient presentation, disease progression, and the need for follow-up imaging [37].

BFT and MRE complement other diagnostic tools such as endoscopy, computed tomography (CT) scans, and laboratory tests by offering unique insights into the structural and functional aspects of the GI tract [57]. For instance, while endoscopy provides direct visualization of the mucosa and allows for tissue sampling, BFT and MRE offer non-invasive imaging of the entire GI tract, including the small bowel, which may be challenging to access with endoscopic procedures alone. This complementary relationship allows for a more comprehensive evaluation of GI disorders, particularly those involving the small bowel, where endoscopic access may be limited.

Furthermore, BFT and MRE contrast with other imaging modalities based on their technical features and diagnostic capabilities. For example, compared to CT scans, which utilize ionizing radiation, MRE offers a safer alternative for patients who require repeated imaging studies or are more susceptible to the harmful effects of radiation exposure [21]. Additionally, MRE's superior soft tissue contrast and ability to provide dynamic functional information distinguish it from CT scans, making it particularly useful for assessing conditions such as inflammatory bowel disease and small bowel tumors, where detailed visualization of the bowel wall and surrounding structures is critical [50].

Within the larger diagnostic algorithm, the selection of imaging modalities such as BFT and MRE depends on factors such as the patient's clinical presentation, disease progression, and the need for follow-up imaging. For instance, in cases of suspected inflammatory bowel disease, the initial diagnostic workup may include laboratory tests, endoscopy, and imaging studies such as BFT or MRE to assess disease extent and severity [43]. Subsequent follow-up imaging may be necessary to monitor disease progression, response to treatment, or the development of complications, with BFT and MRE serving as valuable tools for longitudinal assessment and management [40].

Patient comfort, procedure duration, and potential risks are crucial considerations in the selection of the appropriate imaging modality between Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE), highlighting the patient-centric nature of medical decision-making. Both modalities offer unique advantages and challenges that may impact patient experience and satisfaction, with individual circumstances and preferences influencing the choice between the two [45].

In terms of patient comfort, BFT and MRE present differing experiences. BFT involves the ingestion of barium sulfate, which some patients may find unpleasant due to its taste and texture. Additionally, the need for multiple X-ray images during the procedure may lead to discomfort or inconvenience for some individuals [42]. In contrast, MRE does not involve the ingestion of contrast agents and is generally perceived as more tolerable by patients. However, the requirement to lie still inside an MRI scanner for an extended period may be challenging for individuals with claustrophobia or discomfort in confined spaces [59].

Procedure duration is another factor that may influence the selection of the imaging modality. BFT procedures are typically shorter in duration compared to MRE, as they involve fewer imaging sequences and do not require patients to remain still inside an MRI scanner for an extended period [60]. For patients who prioritize efficiency and minimal disruption to their schedules, BFT may be the preferred option due to its shorter procedure time. However, it's essential to balance procedure

duration with the diagnostic needs of the patient, as MRE may offer superior imaging quality and diagnostic capabilities in certain clinical scenarios, despite the longer procedure time [39].

Furthermore, potential risks associated with each modality must be considered when making the selection. BFT poses risks related to radiation exposure, albeit at generally low levels. While the radiation dose is typically considered safe, repeated exposures over time may accumulate, raising concerns, particularly for vulnerable patient groups such as pediatric or reproductive-aged individuals [40]. On the other hand, MRE does not involve ionizing radiation, making it a safer alternative in terms of radiation exposure. However, MRE may present contraindications for certain patients, such as those with specific implants or severe claustrophobia, due to the need for imaging within the confined space of the MRI scanner [21].

Patient preferences and individual circumstances play a significant role in the decision-making process regarding imaging modalities. Healthcare providers should engage patients in discussions about their preferences, comfort levels, and concerns regarding the imaging procedures. By considering patient preferences alongside clinical indications and diagnostic needs, healthcare providers can tailor the selection of the imaging modality to align with the individual patient's values and goals. Ultimately, a patient-centric approach ensures that the chosen imaging modality optimally balances diagnostic efficacy, patient comfort, and safety, thereby enhancing the overall patient experience and satisfaction [43].

The economic and accessibility implications of Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE) findings are significant considerations in healthcare decision-making, particularly regarding their utilization in different healthcare settings and regions with varying resources. The cost-effectiveness and availability of each modality play crucial roles in determining their feasibility and accessibility for patients and healthcare systems [27].

In terms of cost, BFT is generally perceived as a more cost-effective option compared to MRE. BFT procedures typically involve lower equipment costs and shorter procedure times, contributing to lower overall costs compared to the more resource-intensive MRE [22]. The utilization of conventional X-ray equipment in BFT procedures results in reduced upfront investment and maintenance costs compared to the specialized MRI equipment required for MRE. Additionally, the shorter duration of BFT procedures may lead to higher throughput and efficiency, further contributing to its cost-effectiveness [23].

However, while BFT may offer cost savings in the short term, the long-term economic implications must be considered. The potential for higher reimbursement rates associated with MRE procedures, due to the advanced imaging technology involved, may offset the initial cost differentials between the modalities. Additionally, the superior diagnostic accuracy and efficacy of MRE in certain clinical scenarios may result in downstream cost savings by reducing the need for additional imaging studies or invasive procedures [35].

Accessibility is another critical factor influencing the utilization of BFT and MRE in different healthcare settings. BFT is widely available and more accessible in various healthcare settings, including primary care clinics and community hospitals. The reliance on conventional X-ray equipment, which is relatively inexpensive and widely available, contributes to the widespread availability of BFT [48]. Additionally, the shorter procedure times associated with BFT may enhance its accessibility by reducing wait times and increasing patient throughput.

In contrast, the availability of MRE may be limited in certain regions or healthcare settings, particularly in under-resourced areas where access to specialized MRI facilities is restricted. The higher upfront costs and maintenance expenses associated with MRI equipment may pose barriers to the adoption of MRE in resource-constrained settings. Furthermore, the longer procedure times and the need for specialized training in MRI interpretation may further limit the accessibility of MRE in certain healthcare systems.

Future research in gastrointestinal imaging should focus on addressing gaps in current knowledge and technology [61]. Comparative studies exploring the diagnostic efficacy and patient outcomes of BFT and MRE in larger and more diverse patient populations could provide valuable insights into their relative advantages and limitations. Additionally, research into the development of new technologies, such as advanced image processing techniques or novel contrast agents, could further enhance the capabilities of gastrointestinal imaging modalities.

Recent advancements in radiology, including artificial intelligence (AI) and machine learning, have the potential to revolutionize gastrointestinal imaging. Integration of AI algorithms for image analysis could improve the accuracy and efficiency of both BFT and MRE, leading to more precise diagnoses and streamlined workflow [49]. Furthermore, innovations in imaging technology, such as higher field strengths in MRI or improvements in X-ray detector technology, may enhance the diagnostic capabilities and image quality of both modalities [1, 58].

The findings of this review have implications for healthcare systems worldwide, but their implementation may vary across different regions and settings. In low-resource settings, where access to advanced imaging modalities like MRE may be limited, optimizing the use of BFT and other conventional imaging techniques becomes crucial. However, challenges such as equipment availability, trained personnel, and financial constraints must be addressed to ensure equitable access to quality gastrointestinal imaging services globally.

LIMITATIONS

This review acknowledges its limitations within the scope of the literature examined, despite efforts to encompass a wide range of studies and publications on Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE). Although extensive, the review might have overlooked some relevant research, potentially impacting the comprehensiveness of the analysis. Additionally, there is acknowledgment of the potential for publication bias in the reviewed literature, with studies showing positive or significant findings more likely to be published than those with negative or inconclusive results, potentially skewing overall interpretations.

The heterogeneity observed across the studies reviewed poses a challenge in directly comparing or generalizing their results. Variations in study design, patient populations, and methodologies may introduce inconsistencies or confounding factors that complicate the synthesis of findings. Technological advancements in BFT and MRE are recognized, with a caveat that recent innovations may not be fully captured in the analyzed literature, thus affecting the currency of the review's conclusions.

Qualitative analysis inherently involves a degree of subjectivity, which may influence the conclusions drawn in the review, despite efforts to maintain objectivity. Language limitations, due to the focus on English-language publications, may introduce biases, excluding relevant studies published in other languages and potentially limiting the breadth of perspectives considered. The exclusion of grey literature, such as conference abstracts and unpublished studies, may further narrow the scope of the review, overlooking valuable insights from timely and contextually relevant sources.

By specifically comparing BFT and MRE, the review may inadvertently overlook the role and relevance of other emerging or complementary imaging modalities in gastrointestinal diagnostics. Variabilities in healthcare systems across different regions may influence the applicability of the review's findings, underscoring the importance of considering these system variabilities for contextualizing relevance and generalizability.

While the review provides valuable insights based on existing evidence, it is essential to recognize that the field of radiological imaging is subject to ongoing research and developments. Future advancements or research may offer new perspectives that could modify or expand upon the interpretations and conclusions presented herein. Continued exploration and evaluation are necessary to ensure relevance and currency of knowledge in gastrointestinal imaging.

CONCLUSION

The conclusion encapsulates the major findings of the comparative analysis of Barium Follow Through (BFT) and Magnetic Resonance Enterography (MRE), highlighting their respective strengths and weaknesses in technical capabilities, diagnostic accuracy, patient safety, and cost-effectiveness. This comparison serves as a practical guide for radiologists and clinicians in selecting the most suitable imaging modality for various gastrointestinal conditions.

Central to patient-centered care is the consideration of individual factors such as comfort, safety, and health circumstances when choosing between BFT and MRE. Moreover, the economic and accessibility aspects play a crucial role in determining the feasibility and adoption of these modalities across different healthcare settings.

Looking ahead, advancements in imaging technology hold promise for refining and enhancing the diagnostic capabilities of BFT, MRE, and emerging modalities. Recommendations emphasize the need for personalized approaches to diagnostic imaging, tailored to specific clinical scenarios or conditions.

Continued research is encouraged to keep pace with technological advancements and further validate the use of BFT and MRE in clinical practice. The global implications of the findings underscore the importance of adaptable and context-specific imaging strategies in diverse healthcare environments worldwide.

Interdisciplinary collaboration between gastroenterology, radiology, and related fields is essential for enhancing diagnostic accuracy and patient care. In conclusion, this comparative analysis contributes to evidence-based practices in radiology, ultimately improving patient outcomes in the diagnosis and management of gastrointestinal disorders.

ETHICAL APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

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Not applicable.

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