RESEARCH ARTICLE

Thinking outside the Scanner: Radiation Exposure from Diagnostic Imaging in Inflammatory Bowel Disease

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Abstract

Abdominal imaging is a vital tool in the diagnosis and management of inflammatory bowel disease (IBD). Patients with IBD, especially Crohn's disease (CD) typically undergo multiple diagnostic imaging tests throughout their disease course. This can result in significant cumulative radiation exposure, which may increase the risk of radiation-induced cancers. In this review, we will explore the risks of radiation exposure from diagnostic imaging, the scope of the problem in IBD, risk factors for higher exposure, and alternative approaches to imaging and treatment of the underlying disease that can reduce an IBD patient's exposure to radiation. Utilization of diagnostic imaging modalities and techniques that minimize radiation exposure and optimal disease management to reduce need for these tests should be considered best practices in the care of patients with IBD.

1. Introduction

Inflammatory bowel disease (IBD) is a chronic inflammatory disorder of the gut that follows a relapsing and remitting course. It is comprised of two main diseases: Crohn's disease (CD) and ulcerative colitis (UC). IBD is more common in Western Europe and North America, with estimated prevalence of 3 million in the United States[1]. Incidence rates of IBD have also been increasing in developing countries[2]. It is most often diagnosed between the ages of 18 and 40, although approximately 15% of cases are diagnosed in childhood[1]. Diagnostic imaging is frequently utilized for diagnosis, assessment of disease activity, evaluation of complications, and monitoring therapeutic response.

2. Effects of Radiation

Ionizing radiation causes injury to DNA in the form of strand breaks and base damage. Misrepair of these points of damage can result in mutations and subsequent development of cancer[3]. Determination of exposure to ionizing radiation from diagnostic imaging requires consideration of both the dose of radiation that is absorbed and the susceptibility of each organ to the effects of radiation. This is quantified as an "effective dose", measured in milliSieverts (mSv). Epidemiological studies suggest an increased risk of solid organ tumors with effective doses >50 mSv. The risk of cancer from repeated exposure to lower doses of radiation, such as with repeated diagnostic imaging, is less well understood, but exposure to even low doses of radiation may predispose to solid organ cancers and leukemia[4]. In the absence of a sufficiently large and long epidemiological study, the linear, no-threshold theory has been proposed by many as the most appropriate basis for extrapolation of risks to lower dose exposure[5]. While the association of repeated low dose radiation exposure with increased cancer risk remains controversial, regulatory bodies like the International Commission on Radiologic Protections and professional societies like the American College of Radiology mandate adherence to the "As Low As Reasonably Achievable" (ALARA) principle when considering radiation exposure from diagnostic imaging[6].

3. Radiation and Diagnostic Imaging in IBD

Diagnostic imaging tests utilized in IBD commonly include x-rays, fluoroscopic exams such as small bowel follow through, computed tomography (CT), as well as radiation-free modalities such as ultrasound (US) and magnetic resonance (MR) imaging. The effective dose of radiation from an abdominal x-ray is 0.7 mSv. The effective dose of ionizing radiation from a single CT scan of the abdomen and pelvis has been estimated to be 10-14 mSv. However, it is notable that the addition of multiple phases in CT (repeated scanning before and after contrast injection) can increase it to 30 mSv or higher. For comparison, the average person is exposed to annual background dose of radiation of 3 mSv[7,8].

Table 1: Average radiation doses of common gastrointestinal imaging studies [7,8]

Imaging procedure	Average effective dose (mSv)
Abdominal x-ray	0.7
Small bowel follow-through	5
Barium enema	8
CT abdomen	8
CT colonography	10
CT abdomen/pelvis	14
Multiphase CT abdomen/pelvis	31

The use of CT has been rapidly increasing for decades, with a 20-fold increase in annual CT scans performed in 2000 when compared to 1980[3]. It has proven to be an accurate, rapid, and readily available imaging modality, but the accessibility of this modality can contribute to overuse or misuse, which can greatly affect radiation exposure. In a retrospective study in 2011 of 500 CT scans, over 50% of CT imaging phases were not supported by American College of Radiology Appropriateness Criteria, which resulted in a mean excess effective dose of 16.8 mSv per patient. Effective doses exceeding 50 mSv were found in over 20% of patients[9]. It is estimated that up to 2% of all cancers in the US are attributable to radiation from CT scans[3]. The use of CT in IBD has also grown significantly, specifically with the use of enterography protocol scans. In a population-based cohort study, the use of CT enterography (CTE) increased by 840% between 2002 and 2007[10]. CTE has been shown to provide better detection of small bowel disease activity than fluoroscopy studies[11]; however, it has 1.6 times the effective dose of radiation than a standard abdominopelvic CT[10]. The role of CT colonography (CTC) in IBD is not yet defined as studies investigating its use in IBD have been small. Given reported cases of CTC-induced bowel perforation, it is generally avoided in active IBD[11].

In a meta-analysis of 6 studies including 1704 IBD patients, 11% of those with CD and 2% of those with UC had CED > 50 mSv from diagnostic medical radiation. This is concerning in a population that already has an increased risk for intraabdominal malignancies such as colorectal cancer and small bowel lymphoma and adenocarcinoma. In a meta-analysis of 6 studies, patients with Crohn's disease were found to have an overall pooled standardized incidence ratio (SIR) of 2.5 (95% CI 1.7-3.5) for colon cancer and 27.1 (95% CI 14.9-49.2) for small bowel cancer[12]. Individual studies have found varied risk factors associated with CED >50 mSv, including age <17 at diagnosis, male gender, penetrating CD phenotype, upper tract involvement, corticosteroid use, infliximab use, and multiple surgeries. A pooled analysis was performed of the 4 risk factors revealed in multiple studies: prior IBD-related surgery, male gender, corticosteroid use, and immunomodulator use. The pooled adjusted odds ratio was 5.4 (95% CI 2.6-11.2) for prior IBD-related surgery, and 2.4 (95% CI 1.7-3.4) for corticosteroid use[13].

4. Optimal Techniques and Modalities to Minimize Radiation

CT enterography (CTE) enhances the sensitivity and specificity of abdominopelvic CT imaging for small bowel pathology by incorporating thinner sections and administering a large volume of neutral oral contrast to distend the small bowel[14]. The main disadvantage of this form of imaging has proven to be the associated radiation dose. Lowering the radiation dose can reduce image quality and sensitivity for detection of small bowel disease; however, reconstruction algorithms such as the model-based iterative reconstruction (MBIR) method have been developed to counteract excessive image noise. In a study of 163 patients undergoing CTE for the evaluation of CD, low-dose CTE using MBIR was non-inferior to standard CTE in its sensitivity and specificity for detection of active inflammatory changes in the small bowel. Importantly, low-dose CTE reduced radiation exposure by more than 50% in comparison to standard CTE[15].

MR enterography (MRE) has been emerging as a leading imaging modality for small bowel CD. A significant advantage is the lack of radiation, but drawbacks include long duration of imaging and degradation of visualization due to motion artifact. In a meta-analysis of 6 studies, MRE was found to have equivalent sensitivity and specificity to CTE for the detection of active small bowel inflammation and detection of stricturing and penetrating complications of CD[16]. MR pelvis is the preferred method of imaging perianal CD[17].

Increasing interest has been shown in intestinal ultrasonography, due to lack of radiation exposure and low expense. Small intestinal contrast-enhanced ultrasound (SICUS) is performed with the addition of oral contrast to bowel ultrasonography (BS), and contrast-enhanced US (CEUS) consists of BS with the intravenous IV administration of a microbubble contrast. The addition of oral contrast has been shown to enhance proximal small bowel assessment and detection of strictures[18]. SICUS has been shown to have similar diagnostic yield for small bowel CD to CT and has good correlation to histologic findings on biopsy or resection[19]. IV microbubble contrast administration enhances assessment of tissue perfusion and detection of active inflammation. A study of 61 patients with CD found that measurements of inflammation by CEUS correlated with the severity grade of inflammation determined during ileocolonoscopy[20].

Table 2: Imaging modalities with reduced radiation exposure [11]

Modality	Indication	Benefits	Disadvantages
Low-dose CT	• Luminal CD • Complications of CD	• Readily available • Rapid acquisition	• Radiation exposure
MRI	• Small bowel CD • Complications of CD • Perianal CD	• Radiation-free	• Higher cost • Limited availability • Lengthier acquisition times
SICUS	• Small bowel CD • Small bowel complications of CD	• Radiation-free • Lower cost • Shorter acquisition times	• Operator-dependent • Optimally requires real-time interpretation • Oral contrast may limit tolerability
CEUS	• Luminal CD • Fibrotic strictures	• Radiation-free • Lower cost • Shorter acquisition times • Well-tolerated	• Operator-dependent • Optimally requires real-time interpretation • Need for specific software

5. Effect of Medical Therapy on Radiation Exposure

Effective medical therapy may further decrease diagnostic imaging by controlling symptoms that could result in non-scheduled medical care, such as emergency department (ED) encounters. In a study of 648 patients with CD who presented to the ED, the use of CT scans greatly increased from 47% in 2001 to 78% in 2009. Despite this increase, there were no significant differences in detection of findings that alter management[21]. Successful healing of mucosa with medical therapy also decreases risk of complications, and secondarily, need for imaging tests. We previously conducted a retrospective review of 99 patients with CD who were initiated on either tumor necrosis factor TNF-alpha antagonist therapy or corticosteroids. The cohort treated with anti-TNF agents experienced a reduction in the number of radiologic tests, primarily CT, and CED of radiation after initiation of therapy. In contrast, the corticosteroid cohort did not see a significant decrease in diagnostic radiation exposure[22]. A similar difference was seen in our subsequent study involving a U.S. claims database. After starting therapy, patients receiving treatment with anti-TNF agents had significantly fewer imaging examinations (2.9 vs. 5.2, $p < 0.0001$) and decreased radiation exposure (7.4 vs. 15.4 millisieverts, $P < 0.0001$) versus corticosteroid-treated patients in the 1-year follow-up period[23].

6. Conclusions

The use of imaging in IBD requires balancing the benefits of effective diagnostic tests with a potential increased cancer risk. It is incumbent upon all providers to consider the true indication for imaging in these patients. Diagnostic imaging may not be required in IBD with symptoms of diarrhea and non-massive gastrointestinal bleeding. In addition, abdominal pain is a frequent symptom of IBD, and imaging should be reserved for suspicion of penetrating complications or bowel obstruction. Outside of small bowel disease above the terminal ileum, colonoscopy is a more effective tool than imaging for assessment of disease activity and response to therapy. When utilizing diagnostic imaging, adherence to the ALARA principle, including the use of modalities without ionizing radiation, is paramount. In addition, periodic estimation of a patient's CED can give providers data that will be vital in consideration of further diagnostic testing. Finally, optimal disease control can reduce the need for imaging tests by reducing symptoms and complications. In addition to educating providers, we should discuss the risk of diagnostic radiation with our patients, so they are empowered to advocate for reduced utilization or alternative modalities when appropriate. We should also consider reduction in radiation exposure as another benefit of effective medical therapy of IBD.

7. References

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