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Review

Advances in low-dose spectral computed tomography imaging for colorectal cancer

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ABSTRACT

This systematic review examines the technological principles and clinical applications of low-dose spectral computed tomography (CT) in colorectal cancer (CRC). Although spectral CT provides significant functional and quantitative insights beyond conventional anatomical imaging, the associated high radiation exposure necessitates the development of low-dose imaging protocols. This review synthesizes the current evidence on methods used to achieve acceptable image quality with reduced radiation dose, using techniques such as automatic tube current modulation and high-pitch scanning. A summary of the reviewed studies indicates that these low-dose protocols can maintain adequate diagnostic performance for key clinical tasks in CRC, including vascular visualization, tumor delineation, and the development of radiomics and deep learning-based diagnostic models. The emerging use of advanced reconstruction techniques—particularly artificial intelligence-based iterative reconstruction and deep learning image reconstruction algorithms—shows promise in supporting substantial dose reduction without compromising diagnostic confidence. In addition to advances in reconstruction algorithms, photon-counting CT represents a promising future direction owing to its inherently higher dose efficiency and spatial resolution. Continued research in radiomics and deep learning models is also pivotal to the future of medical imaging, as these approaches hold strong potential to enhance diagnostic accuracy, support individualized treatment planning, and advance precision medicine in CRC imaging.

1. Introduction

Colorectal cancer (CRC) is one of the most common malignant tumors of the digestive system.[1] Globally, it exhibits a high incidence and mortality rate, ranking as the third most lethal cancer.[1,2] In China, shifts in dietary patterns and lifestyles have contributed to an increasing number of younger patients being diagnosed with CRC, which poses a significant public health concern.[3,4] Therefore, early detection and precise diagnosis of CRC are crucial for improving survival rates and the quality of life of affected patients.

Contrast-enhanced abdominal computed tomography (CT) remains the primary imaging modality for CRC diagnosis and regular follow-up.[5] Conventional CT enables accurate assessment of tumor location, size, infiltration into surrounding tissues, and distant metastasis.[5] Compared to conventional CT, spectral CT, also known as dual-energy CT, provides significant clinical value in the diagnosis and management of CRC by moving beyond conventional anatomical imaging to functional and quantitative analysis. Spectral CT not only generates virtual monoenergetic images (VMIs) and material decomposition images but also provides spectral curves and effective atomic number, significantly expanding the clinical application of conventional CT.[6] These multi-parametric datasets enhance image quality and support robust quantitative analysis, thereby improving the diagnostic accuracy for colorectal diseases and guiding more personalized patient management.[7,8]

However, both conventional and spectral contrast-enhanced abdominal CT scans involve multiple phases and a large scan range, resulting in increased radiation exposure to patients.[9] As patients with CRC require frequent follow-up imaging to monitor possible tumor recurrence, the cumulative radiation dose may negatively affect their long-term health. Thus, developing personalized low-dose imaging strategies for these patients has become an area of growing clinical interest. This systematic review comprehensively summarizes recent advances in low-dose spectral CT applications in the context of CRC.

2. Principles of spectral CT imaging

Spectral CT imaging is fundamentally based on the principle that

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