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COMMENTARY

Photon-counting detector CT: improving interstitial lung disease classification using ultra-high resolution at a fraction of the radiation dose?

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Abbreviations

EID	Energy-integrating detector
ILD	Interstitial lung disease
MTF	Modulation transfer function
PCD	Photon-counting detector
UHR	Ultra-high (spatial) resolution

Interstitial lung disease (ILD) encompasses various chronic inflammatory disorders that often progress to pulmonary fibrosis [1]. Detecting subtle features pertinent to ILD is crucial for disease classification, which ultimately dictates patient management. Computed tomography (CT) allows for such detection and is the imaging modality of choice for comprehensive ILD evaluation and management. Progressive CT technological advancement has potentiated CT-based definitive ILD diagnosis, drastically reducing the need for invasive lung biopsies. The emergence of multi-detector CT and use of advanced iterative reconstruction algorithms have enabled volumetric lung images to be achieved at high spatial resolution and low radiation doses. The next major technological advance in CT imaging is marked by the introduction of clinical photon-counting detector (PCD) CT, which has attracted great attention for high-resolution imaging tasks.

Spatial resolution in CT is influenced by the size of the detector pixel and the focal spot of the X-ray tube. Dedicated "sharp" kernels are required to reconstruct higher spatial frequencies (closer to the limiting resolution) offered by the CT system. Most medical CT systems employ energy-integrating detectors (EID) with a detector pixel size of about 0.5 mm at isocenter [2]. A recent EID-CT system from one vendor offers 0.25-mm detector pixel size to achieve ultra-high-resolution (UHR) imaging [3]. PCDs use direct X-ray conversion [4], which enables the design of small detector pixels previously not possible with EID-CT. The clinical PCD-CT system is equipped with detector pixels of size 0.151 mm × 0.176 mm (isocenter), which results in an in-plane spatial resolution of 125 μm [5]. PCDs do not require interpixel optical reflectors that are used in EIDs, thereby improving the overall geometric dose efficiency. Unlike the comb filter-based UHR approach used in some EID-CT systems [6], the UHR mode on PCD-CT can be extended to all anatomical sites including lungs.

In this issue of *European Radiology*, Gaillandre and colleagues present their results comparing the performance of clinical PCD-CT (NAEOTOM Alpha, Siemens Healthineers) and 3rd-generation dual-source EID-CT (SOMATOM Force, Siemens Healthineers) in 112 patients diagnosed with stable ILD [7]. Patients clinically indicated for non-contrast chest CT were initially scanned on EID-CT and later on PCD-CT, with a median interval of 12.8 months between the two scans. On average, the CT volume dose index (CTDIvol) and dose length product (DLP) values were 25% and 32% lower, respectively, on PCD-CT compared to EID-CT. Statistically significant improvements in image quality were achieved from PCD-CT for visualization of distal bronchial divisions and depiction of bronchial walls based on subjective assessment. Notably, four patients initially classified as non-fibrotic ILD based on their EID-CT exams were later reclassified as fibrotic ILD based on findings from PCD-CT. This change in ILD classification was attributed to the detection of traction bronchiolectasis on PCD-CT UHR images that was not observed in EID-CT images. The subjective image quality improvements from PCD-CT align with the findings from another study [8], where the UHR mode of the clinical PCD-CT system was shown to improve the detection of subtle lung abnormalities in a small cohort of 20 patients with symptomatic COVID-19.

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Gaillandre et al also evaluated ILD features such as micronodules, linear opacities, reticulation, honeycombing, bronchiectasis, and bronchiolectasis [7]. Subjective visualization of the ILD features on PCD-CT was rated superior to EID-CT by two thoracic radiologists with substantially different amounts of experience (6 and 30 years). Given the consensus nature of the CT feature evaluation, decision-making bias (i.e., the radiologist with more experience able to discern features that the other radiologist may have missed) hinders the evaluation of individual reader performance [9]; the authors have acknowledged this as a study limitation. As the technology becomes widely available, it is essential to pursue investigations pertinent to reader performance by including more observers, such that inter-reader variability and reader confidence can be reliably quantified. If the high spatial resolution from PCD-CT enables better detection of subtle ILD features by the less-trained eyes, then perhaps more ILDs can be diagnosed earlier, thus shifting the ILD diagnosis and management paradigms.

When comparing the performance of PCD-CT and EID-CT for a specific clinical task, it is imperative that the acquisition and reconstruction settings of each system be optimally selected to maximize the imaging performance based on their respective technical specifications. While the authors leveraged the large matrix sizes (768^2 and 1024^2) available on PCD-CT for UHR reconstructions, the in-plane resolution of the PCD-CT reconstruction kernel was only slightly higher than that of EID-CT (Bl57/EID-CT versus Bl60/PCD-CT with a 2% MTF difference of 1.5 cm^{-1}). Leveraging the noise reduction capabilities of the quantum iterative reconstruction algorithm, dedicated UHR kernels on the PCD-CT system with spatial resolution exceeding the limiting resolution of EID-CT could provide additional insights into subtle ILD features and patterns. The authors also measured image noise objectively using standard deviation of CT numbers within regions of interest in EID-CT and PCD-CT images. PCD-CT exhibited higher objective image noise relative to EID-CT; however, this can be attributed to the significantly lower radiation dose used in PCD-CT compared to EID-CT (2.7 mGy versus 3.7 mGy, $p < 0.0001$). While the authors focused on non-contrast, UHR PCD-CT for morphologic assessment of lung parenchyma, spectral information which is routinely available on all PCD-CT scans will enable a more quantitative approach to lung imaging [10].

Overall, this study confirms the benefits of UHR from the clinical PCD-CT system for imaging ILD features in a large cohort of 112 patients with fibrosing and non-fibrosing ILD. Additional investigations are warranted to systematically optimize UHR reconstructions and quantify dose reduction factor in PCD-CT. Traditionally, technical advances in CT have often led to revisions in diagnostic criteria and definitions for major forms of ILD [11]; the unprecedented high-spatial resolution offered by PCD-CT may further enhance the diagnosis and prognosis of complex ILDs, offering new clinical insights related to the disease process.

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Methodology
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