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Cross-sectional image generation and post processing in reconstruction-free direct positron emission imaging (dPEI)

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Coincidence detection of the two 511 keV annihilation photons from positron-emitting radiotracers provides an unrivaled mechanism for sensitive, specific, and quantitative molecular imaging in living objects. In positron emission tomography (PET), a large number of coincident 511 keV photons must be collected with sufficient angular sampling to provide the data needed for tomographic reconstruction algorithms to produce cross-sectional images. Once the timing resolution of gamma-ray detectors becomes adequate to directly localize the source, a cross-sectional image can be directly obtained by measuring the difference in arrival time of the two 511 keV photons of each annihilation event without any reconstruction step. We refer to this imaging technique as direct positron emission imaging (dPEI), as it does not require tomographic reconstruction. We recently demonstrated the first direct cross-sectional imaging of positron-emitting radiotracers without any image reconstruction. The prototype dPEI scanner employed two ultrafast lead-glass integrated microchannel plate PMTs and convolutional neural networks processing, resulting in an average coincidence timing resolution of 32 ps, corresponding to a spatial resolution of 4.8 mm. Different test objects representing pre-clinical and clinical size objects were scanned using the dPEI scanner with different configurations and activity levels. This presentation focuses on 1) details of direct image generation and post-processing methods and 2) development of simulation models to design future dPEI scanners and estimate their performance, and 3) technology roadmap for improving dPEI.

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