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TOF-PET: from the idea to clinics

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Hal Anger is credited with suggesting the use of time-of-flight (TOF) as far back as 1966 to localize the activity due to positron annihilation, even though his sodium iodide dual Anger camera from that time did not achieve very good timing resolution. Although plastic detectors and fast PMTs were capable of 200 ps timing resolution, it wasn't until the early 1980's that scintillation materials, including cesium fluoride and barium fluoride, became available which had a combination of fast timing and reasonable detection efficiency. These early TOF systems were capable of meeting the high count-rate demands of research brain and heart studies using short-lived isotopes, however, by the late 1980's they could match neither the improvements made in spatial resolution using detector blocks capable of decoding many small crystals, nor the improvements in sensitivity with BGO –even with the effective TOF sensitivity gain. By the early 1990's, these early TOF scanners were all retired just before whole-body FDG oncology studies became prevalent. Renewed interest in TOF after 2000 began once new scintillation materials, in particular LSO and LYSO made it possible to achieve very good timing resolution as well as high sensitivity. Along with better detectors came improved electronics and more powerful computers to meet the practical needs of the clinic and allow the use of sophisticated iterative image reconstruction algorithms which include modeling of the TOF information as well as other physical effects, such as attenuation and spatial resolution. Following a brief summary of development of TOF PET, this presentation will include discussion of how the benefit of TOF is realized with clinical and research studies in terms of image quality and quantitation. Although TOF is now considered to be a key ingredient for high quality clinical whole-body imaging, a better understanding of the gain with TOF and its relevance for clinical practice is needed to optimize the use of TOF instruments and to help guide further development of the technology. All major PET manufacturers now offer TOF PET/CT systems, and TOF is also available for combined PET/MR imaging. In fact, the current spurt of activity and advancements in TOF is likely to accelerate as new scintillation materials and solid-state photo-sensors are incorporated into systems leading to improved timing resolution. The significance of this new technology will be discussed in terms of its potential to expand the range of applications that are enabled by TOF due to improvements in image quality and data quantitation

Presenter: KARP, Joel (University of Pensilvania)

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