Total-Body PET: A Desire or Need?

In current era positron imaging tomography (PET) with computerized tomography (CT) or magnetic resonance imaging (MRI) are the most widely used hybrid imaging modalities in clinical arena. In fact, it has revolutionized the staging, restaging, selection of therapy and response assessment in various malignancies. However, we must be cognizant of PET s journey which started from a research laboratory of Massachusetts General Hospital, USA in 1951 to 1999 when first commercial hybrid PET/CT was introduced by Townsend and team in USA and *Time Magazine* called it medical invention of the year in 2000.[1] PET with CT and MRI is believed the most sensitive hybrid technique available to study physiology, metabolism, and various molecular pathways in human being. However, one must not forget the limitations of PET imaging like extremely poor sensitivity (<1%), limited resolution due to low signal to noise ratio (SNR), long acquisition times and concerns about radiation exposure. Two major factors which govern the poor sensitivity of existing PET scanners are (1) 85-90% of body is outside of field of view (FOV) and no signal is from these regions is collected; (2) only 3-5% of signals emitted from body within FOV are collected as rest of events being emitted isotopically do not hit detector rings.[2] Both these factors can be addressed by adding detectors rings to cover total body (TB-PET). This concept paved the path of journey from *Whole-Body PET to Total-Body PET*.

Existing whole body PET (WB-PET) scanners have an axial field of view (AFOV) of 20-30-cm to image whole body (like in melanoma) or more common eyes-to-thighs which needs 6-8 beds positions or greater for total body. Due to this fact clinical PET imaging has trade-offs between the number of detected positron annihilation coincidence events (sensitivity <1%), scanning time, and administered dose of PET tracers. Due to low SNR, current PET scanners usually produce noisy images which cannot generate high-resolution dynamic imaging studies with tracer kinetic modeling.[3] Both of these limitations can be addressed by increasing AFOV from 30-cm to 200-cm (TB-PET) and thus increasing the effective sensitivity to approximately 40-fold (total body imaging like in melanoma).[3] But for eyes-to-thighs coverage, sensitivity gain with TB-PET scanners is about 24-fold but gains for single organ like brain and heart will be modest as these are already accommodated in FOV of existing WB-scanners. The said increase in sensitivity can be achieved with 6-fold higher SNR or 1/40 scanning time or administered PET tracers while maintaining existing SNR. Two major constraints in developing the TB-PET are cost and physical problems due to geometry. About 40-60% of cost of TB-PET is related to volume of scintillators which lutetium-yttrium-oxyorthosilicate (LYSO) due to its higher energy resolution and light yield.[4] Cheaper crystal like Bismuth Germanite (BGO) is high density but has slower decay time resulting in prolong scanning time and incompatibility for Time-of-Flight technology (TOF).[3] Physical challenges include electronics to handle and process the large volume of real time data (list mode datasets) and tightly packed detector modules together to reduce sensitivity loss caused by gaps between modules. In addition, design of a proper cooling system to provide stable environment to detectors which certainly ensures their performance.[3]

In 2018 two TB-PET scanners were introduced for clinical imaging. United Imaging installed its uEXPLORER scanners (AFOV 194 cm) at Shenzhen Hospital China and University of California Davis, USA and PennPET Explorer (AFOV 64-142 cm) built and installed at University of Pennsylvania, USA.[5] In 2020, Siemen healthcare installed its Biograph Quadra scanner (AFOV 106 cm) at Bern Hospital Switzerland.[6]

TB-PET scanners due to their ultrahigh system sensitivity, excellent spatial resolution, and long 1940-mm scan range, they can acquire scans with lower administered activity or short acquisition

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time, total-body dynamic acquisition at a longer delayed time point, and higher lesion detectability. Lowering the radiation exposure by virtue of smaller quantity of isotope administered is important not only for pediatric but also for adults due to better survival in some malignancies. Dynamic TB-PET will allow precise analysis of tracer kinetic in human body for better understanding of physiology, biochemistry and pharmacology which is not practical with WB-PET as it requires frequent arterial blood sampling. Due to exceedingly high SNR, good quality images are acquired with short acquisition time which is convenient for patient and mitigate the impact of external (patient) and internal (breathing or cardiac) movements on image quality. Similarly, longer acquisition delay will improve the target to background ratio and better lesion detectability.[3]

Clinical results of first generation TB-PET are very promising and expected to have surge with wider use in future. However, its cost and spectrum of clinical need in routine practice are major obstacles. But it is expected that ongoing efforts on technical and clinical frontiers, will transform this gadget into a sustainable option for most of nuclear medicine facilities.

Conflict of Interest: None

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