Postprocessing and Cross Validation

Modeling and Quantification

Basic (Physics) Principles of Quantification Using PET
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Learning Objectives:

- To know the principles of detection
- To know which technical parameters determine the quantitative accuracy of PET measurements
- To know which corrections are necessary in order to obtain quantitative data

The objective of this presentation will be to introduce the audience to the basics of quantitative imaging with positron emission tomography (PET). PET is inherently a quantitative method, not only imaging the distribution of positron emitting isotopes but also measuring their absolute concentration in Bq per ml. However, physical aspects and intrinsic factors in the design of PET scanners affect and limit its quantitative capabilities, and a number of corrections have to be applied to measured data to obtain quantitative images.

Principles of detection: PET is based on the principle of coincidence detection of annihilation photons. The principles of photon detection and scanner design will be discussed.

Limiting factors: A number of physical limits the accuracy of PET images. Spatial resolution, that is, the minimum distance required between two points to distinguish them as separate points in the image, is determined mainly be the energy of the emitted positron, the size of the detector elements, and the non-collinearity of the annihilation photons. Sensitivity of the scanner is defined as the number of measured true coincidences per actual decay, and is mainly affected by the geometry of the scanner and the detector materials. Since a higher sensitivity results in better counts statistics and a higher signal to noise ratio, sensitivity is also of importance for quantitative accuracy.

Correction factors: During image reconstruction, PET data has to be corrected for a number of effects. Firstly, the sensitivity of each individual detector pair, or line of response, is different, and this has to be corrected by a normalization procedure. Correction methods for random coincidences will be discussed. Then, a correction has to be applied for coincidences in which one or both of the annihilation photons have scatter on their path between decay and detectors. Although the choice of a detector material with a high energy resolution can limit the scatter coincidence fraction using energy discrimination, the scatter coincidence fraction is still in the order of several tens of percent. Other correction factors include those for detector dead time.

Quantification and quality control: Once all appropriate corrections are applied and the image reconstructed, the PET images are in units of counts per ml per second. A cross-calibration measurement, generally using a uniform cylindrical phantom containing a solution with a known radioactivity concentration, is used to measure a calibration factor, converting counts per ml per second into Bq/ml. Although an absolute calibration can in principle be obtained, it is mainly important that the PET scanner is properly cross-calibrated with the dose calibrator used to measure syringes prior to patient administration, as well as for example detectors used for measurement of blood radioactivity concentration. In addition to routine daily quality control, the scanner's calibration has to be validated on a regular, e.g. monthly, basis.