

INVESTIGATION OF ON-BOARD PET WITH TOMOTHERAPY

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Positron Emission Tomography (PET) was investigated for imaging onboard TomoTherapy machine for localization of functional and molecular targets. Split PET can be operated in 3D mode imaging and its geometry is naturally suitable for its marriage with the TomoTherapy system. The split PET would allow measurement of both inter and intra-fractional tumor motion variation, reducing treatment uncertainties and improving the delineation of tumor volume at any stage in the radiation treatment delivery process. The objective of this work is to introduce the concept of on-board PET with tomotherapy and evaluate the compatibility of PET integration with the existing TomoTherapy device. An onboard PET scanner can be utilized immediately prior to the radiation delivery for biological based patient alignment, during the treatment for tracking tumor motion, or during the treatment for simply performing PET scanning for investigation of tumor response to radiation. Onboard tumor tracking during the radiation delivery treatment can be accomplished via region of interest imaging and/or low activity PET markers. The intra-fractional PET imaging can be synchronized with the TomoTherapy beam pulsation so that the tumor is imaged and motion tracked while treated simultaneously. The potential of onboard PET can be optimized by combining the biological information obtained using PET with the anatomical information provided by megavoltage computed tomography (MVCT). Furthermore, attenuation correction for PET can be directly formulated from TomoTherapy's MVCT images.

In order to determine the possibility of combining PET with a TomoTherapy, various designs of split PET were simulated and the sensitivity of each PET system design achieved was comparable to conventional PET today. An on-board PET design for TomoTherapy is established that can image in the gap for treatment beam. The scan time for a typical PET activity can be as low as few seconds to achieve an image quality applicable for biological image guidance either for patient setup or intra-fractional image tracking. Ray tracing generated data, Monte Carlo PET with GATE generated data, and real data were all used for the investigation of the image quality of split PET. In all three cases, the generated data is masked to simulate a gap region and reconstructed iteratively with ordered subset expectation maximization (OSEM). Real time tumor tracking with PET markers labeled with low activity PET isotope may also play an important role for onboard PET, allowing a reference frame for PET image tracking intra-fractionally.