CT Protocol Selection in PET-CT Imaging

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Computed tomography (CT) acquisition during positron emission tomography (PET)-CT imaging is often performed for a variety of purposes. In whole body PET-CT imaging, the CT portion can be used for:

1. Diagnosis
2. Anatomic localization of PET images
3. Attenuation correction of the PET images

The CT acquisition techniques should be tailored for their intended purposes. As a brief summary, CT imaging prescribed for diagnostic assessment (with contrast enhancement or otherwise) typically requires higher techniques and imparts more radiation dose than the other two types of studies. If the CT scan is performed for anatomic localization of the PET image only, the acquisition technique can be reduced substantially from diagnostic levels, often by 50-80%[1,2,3]. Furthermore, if the CT study is only necessary for attenuation correction of the PET image, the technique can be reduced even further leading to techniques with a 10-100 fold reduction from diagnostic CT levels[4,5]. For the purpose of PET attenuation correction, the CT image is used to generate a low-resolution attenuation map. Thus CT images used for attenuation correction can be many times more noisy than diagnostic quality images because they will be smoothed to match the PET resolution prior to generation of PET attenuation correction factors. Table 1 summarizes the typical ranges of techniques and dosimetry for these three categories of CT imaging for adult whole body 18F-2-fluoro-2-deoxy-D-glucose (FDG) PET-CT for a scan range from the eye to mid-thigh.

Table 1-Typical acquisition techniques used for whole-body FDG-PET-CT imaging

Study	Injected Activity	Effective Dose Estimate
PET[6, 7]	[5-15] mCi ^{18}F-FDG Injected (185-555 MBq)	3.5-10.5 mSv
CT for diagnostic purposes[8]	[110-200] mAs[1] CTDIvol = [8-14] mGy	11-20 mSv
CT for anatomic localization[8]	[30-60] mAs[3] CTDIvol = [2-4] mGy	3-6 mSv
CT for attenuation correction only[8]	[5-10] mAs[4] CTDIvol = [0.3-1.0] mGy	0.5-1.0 mSv

For ease of comparison, all CT studies presented are performed with 120 kVp, pitch 1.375, 40 mm collimation, 900 mm scan range, average tube current-time product.

Special Considerations

When diagnostic CT studies are prescribed in addition to a whole-body FDG-PET-CT exam, the diagnostic CT region of interest may differ from the conventional PET "skull base-to-mid-thigh" tumor imaging. Often the diagnostic CT study requires a limited field-of-view (for example chest only), which is a subset of the PET study. In these situations, the higher technique CT study could be performed over only the diagnostic region of interest, and then a low-dose attenuation correction study could be performed over the remaining regions to provide attenuation correction throughout the PET study. Some PET-CT scanners offer this flexibility for axially varied, low-high-low CT acquisitions to lower exposure in appropriate regions. If a system does not support different acquisition techniques axially, it may still be advantageous to acquire the diagnostic CT only over the appropriate region of interest and acquire a separate CT for attenuation correction over the entire PET scan region. This is particularly true if there is patient motion, or the potential for patient motion, between the diagnostic CT scan and the PET scan. Misalignment between the CT scan used for attenuation correction and the PET scan can lead to substantial attenuation and/or scatter correction artifacts.[9,10,11]

Contrast-enhanced CT can lead to errors in attenuation correction for the PET images. This is a result of the quantitative limitations of CT and the multilinear scaling method for deriving attenuation maps from CT images.[9] For the purpose of detecting lesions, these errors are arguably minor.[12,13] When quantitation is of concern, particularly for therapy assessment and clinical trials, correction steps are needed to account for contrast.[14] Many commercial systems offer corrections to reduce these errors, although they can lead to increased errors in other highly attenuating regions, such as bone, and at lower kVp settings.[15]

When the CT is acquired for the sole purpose of attenuation correction, the technique can be very low as presented in Table 1. Often, these studies can be performed with the lowest available settings on the CT system. It should be stressed that these images have a very low signal-to-noise ratio. While these images may not be visually interpretable, they provide more than sufficient information for attenuation correction of the PET images. Individual sites should test these low dose settings to ensure that other CT processing corrections do not fail for these low settings. For example, some systems provide truncation correction of the CT image to effectively enlarge the image to match the PET field of view (i.e., the 50 cm CT FOV is enlarged to the 60-90 cm PET FOV). These truncation algorithms can fail in the case of extremely low dose CT technique settings. Future development of PET-CT systems will lead to CT data processing methods designed specifically for low-dose attenuation correction acquisitions.[5]

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