

CT in PET/CT: Essential Features of Interpretation

Education is not something to prepare you for life; it is a continuous part of life.

Henry Ford

Since its clinical introduction in 2001, PET/CT has quickly made inroads and (where available) has become an essential tool for the work-up of patients with cancer. We now consider this imaging modality an indispensable component of our clinical practice and research endeavors. By many accounts, 80%–90% of all sales of PET scanners are now generated by combined PET/CT machines. How did this happen? Before PET/CT, PET alone, in particular with the radiotracer ^{18}F -FDG, had already become a widely accepted imaging test for the assessment of many malignancies. Like other new imaging modalities (1–3), PET has a learning curve for interpretation; many normal variants and disease- and treatment-specific patterns of tracer uptake need to be recognized. Nevertheless, it is not uncommon to encounter problems in image interpretation that are related solely to the lack of anatomic information in the PET dataset. Combined PET/CT alleviates these shortcomings by improving the anatomic localization of PET findings and reducing the number of equivocal PET interpretations, often translating into improvements in patient management (4–11).

New techniques pose new challenges, and this is also true for the imaging sciences. Accordingly, with the clinical introduction of PET/CT, different philosophical and practical concepts emerged regarding the acquisition and interpretation of the combined study and the use of the CT data. The approach to

reading the PET/CT studies was based primarily on the training of interpreting physicians and was influenced, to some degree, by institutional guidelines and reimbursement policies.

The CT portion of combined PET/CT provides not only anatomic information but also fast, reliable, and accurate attenuation correction of the PET emission data (12,13). Some characteristic artifacts, including those caused by highly concentrated oral or intravenous contrast material, as well as respiration, can also be introduced by this approach; however, these artifacts are easily recognized in most cases (14). Nevertheless, to avoid such pitfalls, some institutions have decided to acquire a low-dose CT scan for attenuation correction of PET data first, followed by PET emission images, followed by a full diagnostic CT scan with intravenous contrast material and breath holding. This approach is perhaps justified when both PET and diagnostic CT are requested by a referring physician and may be particularly useful when dual-phase or dynamic CT data are to be acquired. In this case, the diagnostic CT scan should be interpreted by a sufficiently trained physician, usually a diagnostic radiologist. It is conceivable that slight modifications in intravenous-contrast protocols (e.g., slower injection speed, greater time delay) will still provide a full diagnostic CT scan of good quality, without causing CT or PET/CT artifacts, thereby eliminating 1 step in this 3-step process (15). In that case, breath holding at mid expiration has been recommended (16) but may cause small lung nodules to be missed on CT. Many other institutions, including ours at this time, do not regularly acquire a full diagnostic CT scan as part of the PET/CT study. As a compromise and for

dosimetry reasons, we obtain the CT scan as a low-dose scan (120–140 keV; 40–80 mAs) but administer 2% oral barium sulfate routinely. This approach further improves the anatomic localization of PET abnormalities without causing image artifacts. How about the interpretation of the CT data in this scenario? Should they be used for anatomic localization of PET abnormalities only, or should they be interpreted in their own right? It appears obvious that the CT scan cannot and should not be reduced to an expensive tool for correcting attenuation and finding anatomic landmarks alone. Even low-dose CT can provide important diagnostic information. Regardless of their professional background and training, PET/CT readers should therefore be able to recognize certain characteristic or important abnormalities on CT images. This thesis is addressed in an article by Osman et al. on pages 1352–1355 of this issue of *The Journal of Nuclear Medicine* (17). These authors report their findings on 250 patients undergoing combined PET/CT at Johns Hopkins University Medical Center. CT scans generated as part of the combined study were interpreted by a radiologist. Significant abnormalities on CT were noted in 7 of 250 patients (3%). This 3% prevalence is at the lower end of the 3%–10% range of important incidental abnormalities that have been reported for various CT screening or whole-body PET studies (18–21). Significant CT abnormalities noted in the study of Osman et al. included 3 cases of masses or lesions suggestive of tumor, as well as aortic aneurysm, cirrhosis of the liver, and small lung nodules. Table 1 adds several other abnormalities that we consider important or sufficiently relevant to require reporting and some find-

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TABLE 1
Categories of Potentially Important or Significant CT Findings in a PET/CT Study

Category	Definition	Examples
Major	A finding that may require medical or surgical intervention immediately or within a short time	Abdominal aortic aneurysm, pneumothorax, pneumoperitoneum, tumor invasion/compression of airways, massive pleural/pericardial effusion, large osteolytic lesions with impending fracture, tumor invasion of spinal canal (usually also noted on PET/CT images)
Intermediate	A finding that is potentially important or helpful in PET interpretation	Lung nodules without ¹⁸ F-FDG uptake, pulmonary consolidation, cystic abdominal lesions (renal, hepatic, adnexal), ascites, massive bile duct dilatation, aerobilia, diverticulosis, surgical defects (especially in the head and neck), postsurgical changes (pneumonectomies, percutaneous endoscopic gastrostomy tubes, colostomy, urinary diversions, surgical clips, prosthetic devices, and fluid collections not associated with abnormal ¹⁸ F-FDG uptake)
Minor	A finding that is not seen on PET, does not affect PET interpretation, but may provide relevant medical information	Gallstones and renal stones, vascular calcifications (especially coronary and renal arteries), myomatous uterus, emphysema, prostate enlargement, extremity edema

ings that may not affect the immediate management of the patient but should nevertheless be recognized. Many of these abnormalities we have indeed noted in our clinical practice. Some may have been known from previous imaging studies, whereas others may be new, and some may even be sufficiently advanced to require medical or surgical intervention. The article by Osman et al. does not address how many of their observed CT abnormalities were known before PET/CT (e.g., from another imaging study, either previous or concurrent). Nevertheless, knowledge of abnormalities before the PET/CT study would not necessarily relieve the reader of the responsibility of recording such findings. Although most PET/CT studies today are performed in addition to other imaging tests, such as full diagnostic CT, bone scanning, MRI, or ultrasound of certain body regions, it is conceivable that PET/CT will replace some of these tests in the future. It will then be even more important to provide a comprehensive interpretation of both datasets.

In current practice, some groups have implemented PET/CT readout sessions jointly attended by body radiologists and nuclear medicine physicians. Although these provide a unique learning opportunity for both parties, this approach is clearly not sustainable in the long term unless both parties are rewarded for their time and effort. In recognition of this unique situation, the Society of Nuclear Medicine and the

American College of Radiology have designed guidelines for minimum qualifications for radiologists and nuclear medicine physicians who want to interpret PET/CT studies on their own (22). These proposed training requirements serve as guidelines only, and certificates of competence will be issued at the local level through the credentialing process. Nevertheless, it is likely that hospital administrators and local insurance providers will require proof of expertise at some time in the future. As such, most nuclear medicine physicians who want to interpret PET/CT studies will require additional CT training. Although some may consider this a nuisance, there really is no other solution. Diagnostic radiology and nuclear medicine are imaging sciences in constant flux that have certain aspects in common but differ in many other respects. Limited training in CT or PET/CT interpretation will not qualify radiologists as nuclear medicine physicians or vice versa (although some might think so). It does, however, indicate a certain degree of merging between the 2 disciplines. This will become even more apparent when the number of combined anatomic and functional imaging studies increases, as is expected with the wider clinical introduction of SPECT/CT. Although this modality was originally designed to improve anatomic localization in nuclear medicine studies with highly specific tracers (e.g., antibody studies,

metaiodobenzylguanidine), there is no reason why CT data should not be interpreted in their own right once available, regardless of whether the combined SPECT/CT is done for the assessment of coronary artery disease or the assessment of cancer.

Proper interpretation of a PET/CT scan requires considerably more time and effort than reading a standard PET scan. Unfortunately, this is not reflected in current administrative assessments, such as relative value units, or reimbursement policies. Nevertheless, PET/CT is a new imaging technique that is here to stay. Although some issues, including reimbursement, still need to be worked out, nuclear medicine physicians will have to embrace this new technique if they want to maintain professional expertise and competence. In particular, the additional CT training will require time, patience, and likely also financial resources. What do we gain? More work, yes, but also, we would hope, professional pride and satisfaction from providing better diagnoses (fewer equivocal PET and CT readings) and seeing them eventually translate into improved patient care.

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