

Pitfalls and Pearls of Wisdom in ^{18}F -FDG PET Imaging of Tumors

Tracey Britton, CNMT, PET, RT(N)(CT)¹, and Nicholas Robinson, CNMT, PET, RT(N)(CT)²

¹Nuclear Medicine Service, Birmingham Veterans Administration Medical Center, Birmingham, Alabama; and ²Department of Nuclear Medicine, Memorial Health University Medical Center, Savannah, Georgia

CE credit: For CE credit, you can access the test for this article, as well as additional *JNMT* CE tests, online at <https://www.snmlearningcenter.org>. Complete the test online no later than June 2019. Your online test will be scored immediately. You may make 3 attempts to pass the test and must answer 80% of the questions correctly to receive 1.0 CEH (Continuing Education Hour) credit. SNMMI members will have their CEH credit added to their VOICE transcript automatically; nonmembers will be able to print out a CE certificate upon successfully completing the test. The online test is free to SNMMI members; nonmembers must pay \$15.00 by credit card when logging onto the website to take the test.

^{18}F -FDG PET imaging of tumors has pitfalls and pearls of wisdom that begin at the point of scheduling and continue through the patient interview, the resting phase, the scan itself, and the image review. Interviewing the patient at the time of scheduling, followed by placing a reminder phone call shortly before the appointment, can save a nuclear medicine department the financial loss of wasted doses and missed appointment slots in the schedule. The pitfalls and pearls of wisdom in tumor imaging are ever changing, and the technologist is in a constant state of inquiry about the patient's disease process and ability to comply. Consideration of each item on the worksheets in this article affects every scan. On completing this article, the reader will be able to identify questions that should be asked in the scheduling and preinjection patient interviews, interpret the answers to those questions, determine how the images may be affected, and adapt the scan.

Key Words: interview; question; review; adapt; assess

J Nucl Med Technol 2016; 44:59–64

DOI: 10.2967/jnmt.115.170803

PET imaging of tumors using ^{18}F -FDG has pitfalls and pearls of wisdom that begin at the point of scheduling and continue through the patient interview, the resting phase, the scan itself, and the image review. Interviewing the patient at the time of scheduling, followed by placing a reminder phone call shortly before the appointment, can save a nuclear medicine department the financial loss of wasted doses and missed appointment slots in the sched-

ule. The patient may also be spared the anxiety and expense of taking a day off from work and traveling to the facility, only to be disappointed that the scan cannot be completed. The interview provides important information in addition to the ordering physician's indication for the PET scan. After the scan, the image review process also provides information about whether additional limited scans or potential emergent patient care is needed. This article is not intended as a guideline for imaging but as a discussion of a few pitfalls and pearls of wisdom that may assist the technologist and nuclear medicine department in reaching the goal of completing PET scans of diagnostic quality within a reasonable time frame. An added goal is to accomplish the scan in a manner that reduces stress on the patient and strain on the imaging facility's resources.

^{18}F -FDG, a glucose analog used in PET, can be transported and phosphorylated in the cell but cannot be metabolized rapidly and is trapped in the cell in the same proportion as glucose. Because many malignancies present with increased glucose use, PET imaging can provide a sensitive method of staging various cancers and monitoring the effects of therapies (1,2).

THE SCHEDULING INTERVIEW

After a physician has ordered a PET scan and its indication has been found to be appropriate both for the patient's condition and for insurance reimbursement, the technologist or another member of the staff contacts the patient to schedule an appointment. Because there are many considerations in determining an appropriate date and time for the appointment, as well as many factors that can affect the quality of the scan, the scheduler uses a worksheet to record the patient's answers to a series of questions. An example worksheet is presented in Figure 1 and discussed in Table 1.

These questions are a valuable tool for screening and scheduling and can help reach the goal of completing PET scans of diagnostic quality within a reasonable time frame.

Received Dec. 3, 2015; revision accepted Feb. 22, 2016.

For correspondence or reprints contact: Tracey Britton, Birmingham Veterans Administration Medical Center, 700 19th Street S., Birmingham, AL 35233.

E-mail: tbritton87@yahoo.com

Published online Apr. 21, 2016.

COPYRIGHT © 2016 by the Society of Nuclear Medicine and Molecular Imaging, Inc.

Surgeries/Biopsies/Procedures			
within 6 Weeks	Yes <input type="checkbox"/>	No <input type="checkbox"/>	Procedures and Dates _____
Diabetic	Yes <input type="checkbox"/>	No <input type="checkbox"/>	Insulin Yes <input type="checkbox"/> No <input type="checkbox"/>
Claustrophobic?	Yes <input type="checkbox"/>	No <input type="checkbox"/>	Antibiotics? Yes <input type="checkbox"/> No <input type="checkbox"/>
Lie Flat 30 Min?	Yes <input type="checkbox"/>	No <input type="checkbox"/>	Steroids? Yes <input type="checkbox"/> No <input type="checkbox"/>
Pregnant?	Yes <input type="checkbox"/>	No <input type="checkbox"/>	Breastfeeding? Yes <input type="checkbox"/> No <input type="checkbox"/>
No exercise 24-48 hours prior _____			
This test involves the use of radioactive material. Pregnant females and children should not come with the patient on the day of the PET scan. If the patient requires an escort or driver, only adults (non-pregnant) should accompany the patient to and from the medical center for this test.			
Letter sent _____	Nuc Med Clerk _____	Date: _____	
Confirmation Call _____	Nuc Med Clerk _____	Date: _____	
PET Before any CT _____	Allow 2 hours _____		
NPO incl. caffeine, sugar, mints, gum _____	No Exercise 24 hr _____		

FIGURE 1. Scheduling interview.

Efficiency in scheduling also reduces patient stress and improves management of disease. Although each physician and facility may have slightly differing procedures and protocols for the issues addressed by these questions, all the answers should be considered in scheduling the appointment.

THE CONFIRMATION LETTER AND REMINDER PHONE CALL

Many PET patients are feeling the burden of their disease on their energy level and alertness, and pain medications may increase forgetfulness. It is a good practice to send a confirmation letter immediately after scheduling and to place a reminder phone call within a few days before the appointment. The latter allows for screening for new developments, maintenance of scheduling, reinforcement of instructions, and avoidance of wasted doses. The preexam phone call is also critical if the examination is scheduled by a centralized center whose staff may not be familiar with the importance of patient preparation for PET scans.

THE PREINJECTION INTERVIEW

After arriving for the appointment and before receiving the injection, the patient is asked another series of questions that may assist the technologist in completing the scan and the physician in interpreting the images. An example worksheet for recording the answers is presented in Figure 2 and discussed in Table 2. Screening questions about pregnancy and breastfeeding are also always necessary.

TABLE 1
Questions to Ask at Scheduling

Questions about...	Relevance
Recent surgeries or biopsies	After surgery or biopsy, healing may increase ¹⁸ F-FDG uptake. Negative or unknown biopsy result may prompt physician to postpone imaging of area of interest. Positive result may prompt physician to proceed with imaging to look for distant metastasis (4).
Diabetes	Diabetic patients are best scheduled for earliest available appointment because they cannot eat or drink beforehand. Blood glucose should be <150–200 mg/dL, depending on facility's protocol. Use of insulin degrades scans; insulin may need to be withheld or diabetes management temporarily changed (1,2).
Claustrophobia	Claustrophobic patients may need anxiolytic medication and a driver.
Ability to lie supine for 30 min	Patients need to know that scanning may take 30 min and that they will need to lie supine during it. To comply, many may require pain medication and a driver. In extreme cases, prone or on-the-side positioning may be needed.
Exercise	Exercise tears down and rebuilds muscle, causing ¹⁸ F-FDG uptake. Scheduling scan 24–48 h after strenuous exercise allows uptake in muscles to dissipate (2,4).
Antibiotics	If patient is taking antibiotics because of infection, physician may postpone scan to avoid uptake by infected tissue.
Steroids	Learning that patient is taking steroids may reveal a current medical condition that will affect scan (5). Also, physician needs to know of steroid use because it can elevate blood glucose and decrease tumor metabolism, reducing SUVs.
Pregnancy or breastfeeding	Scanning is usually contraindicated in pregnant or breastfeeding patients. Some facilities may require pregnancy test on day of scan or written informed consent to scanning. Breastfeeding is withheld for 18–24 h after scan; ¹⁸ F-FDG secretion into breast milk is minimal, but close contact exposes child to radiation. Also, there may be increased uptake in erector spinae muscles of mother (6).
Travel to home after exam	If patient lives far from exam site, traveling from exam with a pregnant woman or small child is not advisable because they will be exposed to radiation from patient.
Duration of scan	Patients who do not know that scanning takes 2 h may make other appointments for same day and choose to reschedule without giving advanced notice.
Other scanning before PET scan	If patient is scheduled for scan requiring contrast agent before PET scan, the agent may attenuate the PET signal.
Nothing-by-mouth instructions	Patients must not eat or drink for 4–6 h before undergoing scan. Need for any special dietary or medication arrangements should be determined (2), as well as patient's willingness to comply with instructions.

Patient Name: _____		Case # _____	
Weight: _____ lbs. Height: _____ ft _____ inches		Room # _____	
Glucose Level: _____		NPO: Yes <input type="checkbox"/> No <input type="checkbox"/>	
Diabetic: Yes <input type="checkbox"/> No <input type="checkbox"/>		Insulin dependent: Yes <input type="checkbox"/> No <input type="checkbox"/>	
Usual glucose level _____		Time last dose: _____	
mCi @ _____		Residual mCi @ _____	
Injected @ _____		Rx: _____	
Injected By: _____		Vol. _____ mL	
Inj. Site: _____			
Prior PET scan date: _____		Prior CT scan date: _____	
Staging:			
Chemotherapy: _____			
Radiation/Irradiation: _____			
Surgery: _____			
Prior malignancies: _____			
Other surgeries/biopsies: _____			
Implants, IV lines/tubes/ports/ostomy site(s): Yes <input type="checkbox"/> No <input type="checkbox"/>			
CAD:	Yes <input type="checkbox"/> No <input type="checkbox"/>	Infections:	Yes <input type="checkbox"/> No <input type="checkbox"/>
Pacemaker:	Yes <input type="checkbox"/> No <input type="checkbox"/>	Recent Trauma:	Yes <input type="checkbox"/> No <input type="checkbox"/>
Artificial Joint:	Yes <input type="checkbox"/> No <input type="checkbox"/>	Pain/Joint Pain:	Yes <input type="checkbox"/> No <input type="checkbox"/>
Shrapnel/Metal:	Yes <input type="checkbox"/> No <input type="checkbox"/>	Incontinence:	Yes <input type="checkbox"/> No <input type="checkbox"/>
Claustrophobic:	Yes <input type="checkbox"/> No <input type="checkbox"/>	Renal Failure:	Yes <input type="checkbox"/> No <input type="checkbox"/>
Lie Flat 30 min:	Yes <input type="checkbox"/> No <input type="checkbox"/>	COPD:	Yes <input type="checkbox"/> No <input type="checkbox"/>
Exercise:	Yes <input type="checkbox"/> No <input type="checkbox"/>	Allergies:	Yes <input type="checkbox"/> No <input type="checkbox"/>
IntramuscularInj:	Yes <input type="checkbox"/> No <input type="checkbox"/>	Contrast React:	Yes <input type="checkbox"/> No <input type="checkbox"/>

FIGURE 2. Preinjection interview.

These questions can be added to the main worksheet or maintained on a separate sheet, and it is wise to have the patient sign a statement about her pregnancy status. Likewise, questions about previous contrast reactions may be added to the main sheet or maintained separately and the patient's signature again obtained. For easy reference, the worksheet can be divided into sections such as demographics, glucose information, injection information, and staging and screening questions.

The worksheet can be printed in half-sheet size and clipped to the order, helping the interview stay on track if the technologist is temporarily pulled away from it or has to transfer the patient's care to another technologist.

The worksheet can also help with decisions on how to scan the patient. For instance, a facility's protocol may dictate that patients be scanned from the middle of the thigh to the base of the skull ("thigh to eye") to allow for scanning of the bladder before it has a chance to fill. However, for a claustrophobic patient or a patient with dementia, scanning in the opposite direction may be beneficial. When scanned from thigh to eye, the patient is taken through the gantry to the thigh and slowly brought back into the scanner. Claustrophobic patients may panic when nearing the enclosed space and may move or refuse to complete the scan. Patients with dementia may have trouble remembering to keep their head still for the entire duration of a lengthy scan. Scanning the head first so that it exits the gantry first helps claustrophobic patients to complete what is, to them, the worst part of exam early and lie still for the remainder; likewise, head movement in patients with dementia will have a lower impact if the head is scanned first. Another example of how the preinjection interview can help decide the direction of scanning is a patient who requires PET for lung cancer but, on questioning, reveals previous melanoma. The technologist

might then ask the interpreting physician whether to scan from the top of the head to the bottom of the feet because melanoma can metastasize not only to organs but to other areas on the skin (3).

The patient history recorded on the worksheet can also alert the physician to factors that may affect interpretation of the scan.

THE CASE OF INACCURATE ANSWERS

Patients who feel burdened by illness or take medications that increase forgetfulness may not answer a question truthfully or even fully understand it or remember the correct answer. For example, a patient who claims not to have done any strenuous exercise within the last 24–48 h may have images indicating otherwise. After being scanned and then questioned further, the patient in Figure 3A admitted that he had actually "pulled a fence" the day before.

If a patient denies taking insulin but actually did, images such as Figure 3B may reveal the truth. In this example, the patient denied taking insulin before injection, testing showed his glucose to be within the desired range, and the scan was performed. After imaging and on further questioning by both the technologist and the radiologist, the patient continued to deny taking insulin until finally admitting to taking it on the morning of the scan to lower his glucose level to below the facility limit.

Some patients may be receiving granulocyte-colony-stimulating factor, which may increase bone marrow activity on an ¹⁸F-FDG scan, resulting in images such as Figure 3C. Activity in the spleen can be increased as well. Additionally, both increased bone marrow activity and increased splenic activity can be seen in anemic patients (2).

It is important to check non-attenuation-corrected images for false-negative findings, especially in the base of the lung and dome of the liver, where breathing motion occurs. For example, the attenuation-corrected image in Figure 4A and the maximum-intensity-pixel image in Figure 4C do not seem to reveal a lesion, whereas the non-attenuation-corrected image in Figure 4B clearly indicates a positive site. A follow-up limited scan with additional time to allow for more counts can reveal the lesion, as seen in Figure 4D, or can reveal that a positive site is actually false-positive, as seen in Figure 5.

During the image review process, it is also important to check for the possibility of a pneumothorax (Fig. 6), especially in lung cancer patients. Likewise, the aorta should be checked from the arch through the bifurcation for an abdominal aortic aneurysm. A physician should be notified if a pneumothorax or an abdominal aortic aneurysm is discovered, to determine whether immediate medical intervention is required (Fig. 7).

The importance of the patient interview can again be illustrated by the multiple incidental findings in the melanoma patient shown in Figure 8. Findings that at first

TABLE 2
Question to Ask Before Injection of ¹⁸F-FDG

Questions about...	Relevance
Diabetes	
Current glucose level	Scanning is contraindicated when blood glucose is >150–200 mg/dL. Facility reschedules scan in most cases (1) or may apply wait-period protocol.
Usual glucose level	If blood glucose is higher or lower than usual for individual patient, physician may reschedule scan.
Time of last insulin dose*	Use of insulin degrades scans; insulin may need to be withheld, its timing altered, or diabetes management temporarily changed (1,2).
Injection	Injection questions are asked for use by technologist and as quick reference for interpreting physician but do not substitute for entering dose on scan order or in medical record. For computerized dose tracking and SUV computation, dose is input before scanning.
Staging	
Prior PET scan date	Physician may want to compare current scan with prior scan. Patient can confirm any scans found in medical records. Technologist will scan patient in same position as before unless new information dictates otherwise.
Prior CT scan date	Physician may want to refer to most current CT scan when interpreting PET scan. Contrast agent from recent scan may attenuate PET signal and cause facility to apply its wait-period protocol (7).
Chemotherapy and radiation therapy	Chemotherapy or radiation therapy may change physiology and thus uptake; questions on therapy are asked for use by technologist and for interpreting physician's reference (8,9).
Date of recent surgeries or biopsies	If scanning takes place too soon after surgery for cancer, increased uptake from healing may interfere with image interpretation (9).
Prior malignancies	Although patients are scanned per indication on order, knowledge of prior cancers such as melanoma may require that scan range be changed (3).
Prior surgeries or biopsies	Questions about whether patient has ever had surgery may elicit a problem the patient has with lying flat or still and may be helpful for physician when viewing altered physiology or anatomy.
Prior experience with medical devices	Information gained by asking if patient has prior experience with implants, intravenous lines, or ostomy sites may help in determining placement of bags on imaging table (after emptying, if involving urine) and patient's ability to lie flat with such devices in place.
Screening	
Coronary artery disease and pacemakers	Questions about coronary artery disease may elicit a problem the patient has with lying flat or still. Coronary artery disease can affect clearance of intravenous contrast agents. It is helpful to know in advance that scout scan will show a pacemaker, and technologist can ensure that its implantation date was at sufficient interval before scan, in accord with facility's protocol (10).
Metallic objects	Artificial joints, shrapnel, and other metallic objects may cause CT attenuation and star artifact, which, depending on type of scanner software, may affect SUV. Physician should be aware of such objects in case patient departs, and thus cannot be questioned, before images are ready for interpretation (11).
Claustrophobia and lying supine for 30 min	Even if patient denied, at scheduling, being claustrophobic or unable to lie supine, the question should be asked again before injection. Simply showing scanner to patient may reveal need for anxiolytic medication and rescheduling. Questioning also allows technologist to confirm that medicated patients have driver.
Exercise	Questioning about exercise allows technologist to confirm compliance with prior instruction not to engage in strenuous exercise for 24–48 h before scan (2,4).
Intramuscular injections	Intramuscular injections such as flu or other vaccinations can cause increased uptake. Awareness of any such injections is important in image interpretation, especially for melanoma patients (3).
Infections	Infection can cause increased uptake, especially in chemotherapy patients. Awareness of current infection allows scan to be rescheduled, if necessary, to prevent difficulty with differentiating between infection uptake and cancer uptake (12).
Recent trauma	If patient has sustained recent trauma, such as car accident or fall, uptake from healing may interfere with image interpretation (12). Type of trauma may also affect patient's ability to lie flat and still during scanning.
Pain	Tensing muscles near site of pain can cause increased muscle uptake, just as occurs during exercise. Inquiring about pain can also elicit whether patient can lie still and flat.
Renal failure	In facilities that use intravenous contrast agents, knowledge of patient's renal function is important. Also, dialysis patients requiring PET may need to be scheduled for nondialysis day, depending on facility's protocol.
Chronic obstructive pulmonary disease	Answers to questions about chronic obstructive pulmonary disease can be another indicator of whether patient can lie flat.
Allergies	Use of intravenous contrast may be contraindicated in patients allergic to iodine or seafood. Also, in emergencies, medical responders need to be aware of any known allergies (13).
Contrast reactions	If intravenous contrast is to be given, patient must be questioned not only about renal function and allergies but about any prior contrast reaction, no matter how minor. In such cases, supervising physician must approve administration, facility's intervention protocol must be followed, and patient may need to sign statement about past reaction (13).

*For insulin-dependent diabetic patients.

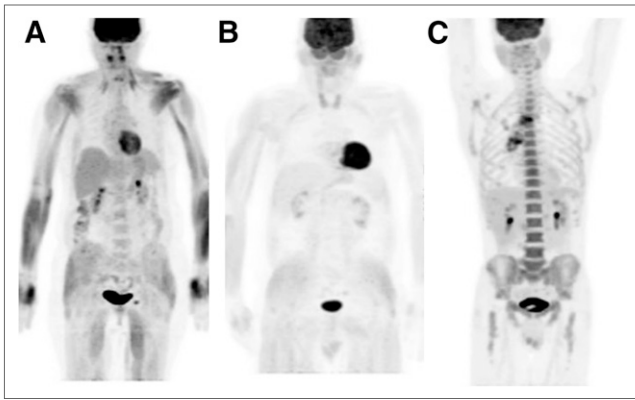


FIGURE 3. Maximum-intensity-pixel ^{18}F -FDG PET images of patient who exercised strenuously 24 h before the scan (A), patient who took insulin the morning of the scan (B), and patient who was receiving granulocyte-colony-stimulating factor (C).

seemed to be positive matched the history given by the patient and were instead determined to be incidental. The patient indicated that the fifth finger on the left hand had been jammed playing basketball, the left heel had been broken and was sore from a cast, the right second toe was a hammer toe, and the right first toe had a bone spur. There was an area of possible contamination on the right forearm that was confirmed as such after it was cleaned and a limited scan of that area performed.

It is ingrained in us as radiologic science professionals to always screen female patients within a certain age range for the possibility of pregnancy before administering any dose of ionizing radiation. Although some facilities require a pregnancy test of such patients before proceeding with imaging, many facilities require only the patient's

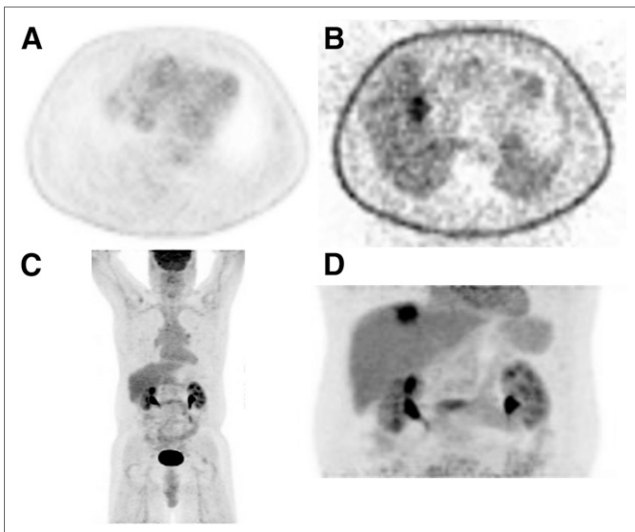


FIGURE 4. False-negative findings on attenuated-corrected axial image (A), non-attenuation-corrected axial image (B), maximum-intensity-pixel image (C), and maximum-intensity-pixel additional limited image with increased time to allow for more counts (D).

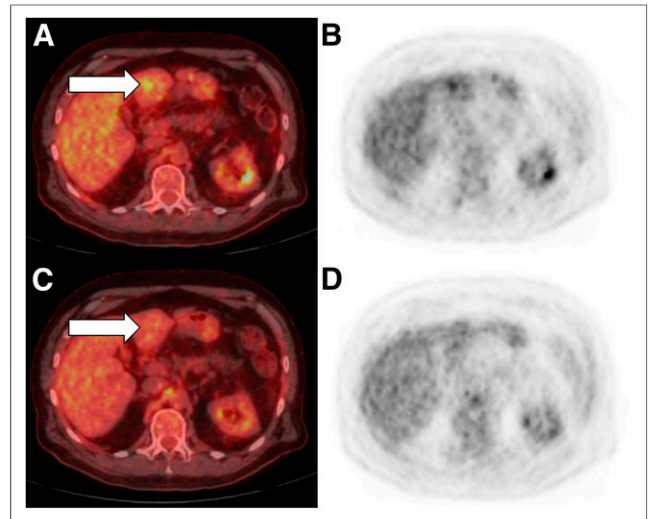


FIGURE 5. False-positive findings on fused axial image (A) and attenuation-corrected axial image (B). Additional limited scan was performed with delay to allow for clearance and for more counts on fused axial image (C) and attenuation-corrected axial image (D).

attestation verbally or in writing. Patients may intentionally lie or may honestly believe there is no possibility they could be pregnant. Many undergoing treatment for cancer, especially cancer of the reproductive organs, are under the impression that they cannot conceive. However, if a patient's reproductive organs are intact and she is sexually active, she might conceive. A urine or serum pregnancy test remains the best way to ensure a patient is not pregnant and protect the facility from legal repercussions. Figure 9 shows a PET scan of a patient who, on being interviewed by the technologist, adamantly swore there was no chance she could be pregnant; she insisted that she was not pregnant and had not been sexually active. After completing the scan, the technologist was quite surprised to see a fully formed fetus on the images. The interpreting radiologist determined through femur

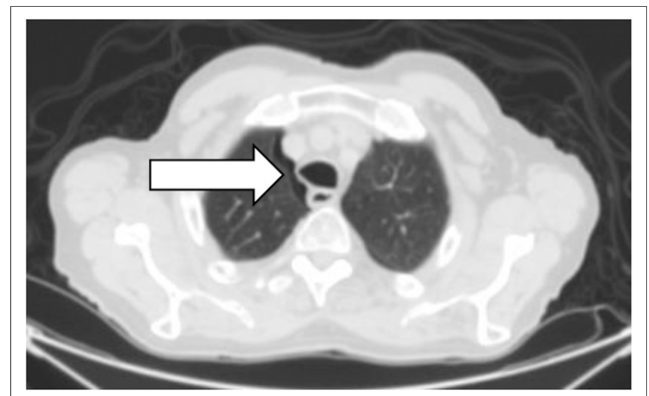


FIGURE 6. Pneumothorax on axial CT image displayed in lung window 1,500 and level -550.

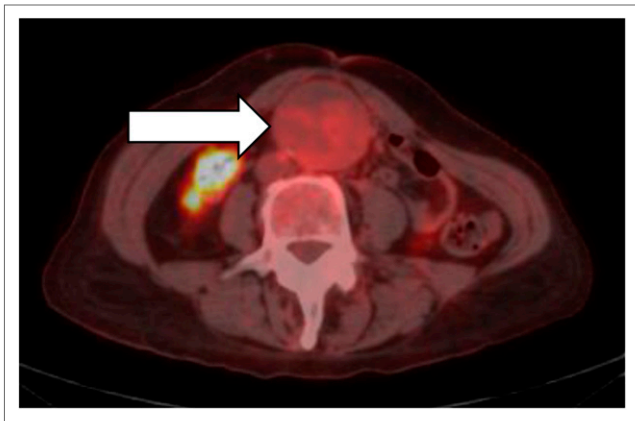


FIGURE 7. Abdominal aortic aneurysm on fused axial image.

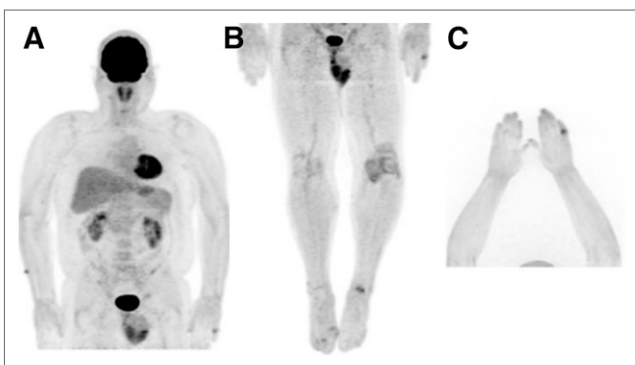


FIGURE 8. Multiple incidental findings in melanoma patient. (A) Fifth finger of left hand was jammed while patient was playing basketball, and contamination of right forearm was suspected. (B) Left heel was broken and sore from cast; hammer toe was seen in right second toe, and bone spur was seen in right first toe. (C) After right forearm had been cleaned and a limited scan performed, contamination was confirmed.

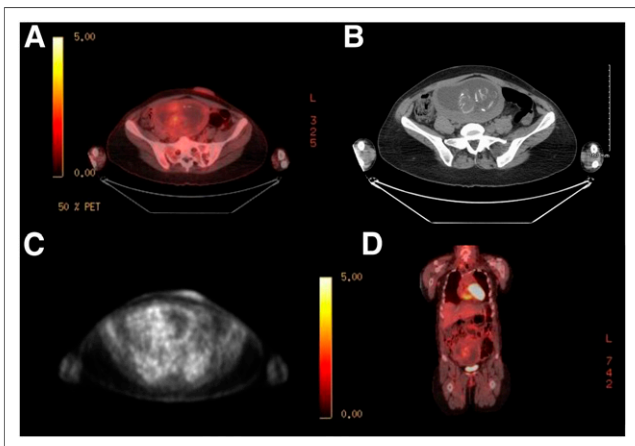


FIGURE 9. Images of pregnant patient: axial fused (A), axial CT (B), axial attenuation-corrected (C), and coronal fused (D).

measurements that the fetus was at a gestational age of approximately 14–15 wk. It was also determined that the patient had undergone a PET scan 3 mo previously, about 2 wk after conception. This example highlights the importance of ensuring without doubt that a patient is not pregnant before proceeding with an examination.

CONCLUSION

From the time of receiving the physician's order until the time of scheduling the appointment, interviewing the patient, injecting the ^{18}F -FDG, performing the scan, and reviewing the images, the technologist is in a constant state of inquiry about the patient's disease process and ability to comply. Consideration of each item on the worksheets in this article affects every scan. Avoiding the ever-changing pitfalls and learning the ever-increasing pearls of wisdom is sometimes a tiring endeavor but can be rewarding even if only by improving future success in obtaining diagnostic-quality scans within a reasonable time and with reduced stress on the patient and strain on the facility's resources.

DISCLOSURE

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGMENT

We thank Lindsay Wendel, RT(CT)(N), for her contributions to the worksheets in this article.

REFERENCES

1. Delbeke D, Coleman RE, Guiberteau MJ, et al. Procedure guideline for tumor imaging with ^{18}F -FDG PET/CT 1.0. Society of Nuclear Medicine and Molecular Imaging website. http://snmmi.files.cms-plus.com/docs/jnm30551_online.pdf. Accessed March 29, 2016
2. Mettler F, Guiberteau M. *Essentials of Nuclear Medicine Imaging*. 5th ed. Philadelphia, PA: Elsevier; 2006:371–372, 379, 382, 387.
3. Wahl R. *Principles and Practice of PET and PET/CT*. 2nd ed. Philadelphia, PA: Lippincott, Williams & Wilkins; 2009:275–286.
4. Christian PE, Waterstram-Rich K. *Nuclear Medicine and PET/CT Technology and Techniques*. St. Louis, MO: Mosby; 2012:395, 404, 418.
5. Raplinger K, Chandler K, Hunt C, Jackson G, Peller P. Effect of steroid use during chemotherapy on SUV levels in PET/CT [abstract]. *J Nucl Med*. 2012;53 (suppl):2718.
6. Christian P, Swanston N. *PET Study Guide*. Reston, VA: Society of Nuclear Medicine and Molecular Imaging; 2010:105–106.
7. Alessio A, Kinahan P. CT protocol selection in PET-CT imaging. Image Wisely website. <http://www.imagewisely.org/imaging-modalities/nuclear-medicine/articles/ct-protocol-selection>. Accessed March 29, 2016
8. Iyer R, Jhingran A. Radiation injury: imaging findings in the chest, abdomen and pelvis after therapeutic radiation. *Cancer Imaging*. 6:S131–S139.
9. Elgazzar A. *The Pathophysiologic Basis of Nuclear Medicine*. New York, NY: Springer; 2006:2d, 294–296.
10. Bae KT. Intravenous contrast medium administration and scan timing at CT: considerations and approaches. *Radiology*. 2010;256:32–61.
11. Sureshbabu W, Mawlawi O. PET/CT imaging artifacts. *J Nucl Med Technol*. 2005;33:156–161.
12. Long NM, Smith C. Causes and imaging features of false positives and false negatives on ^{18}F -PET/CT in oncologic imaging. *Insights Imaging*. 2011;2:679–698.
13. Antoch G, Freudenberg LS, Beyer T, Bockisch A, Debatin JF. To enhance or not to enhance? ^{18}F -FDG and CT contrast agents in dual-modality ^{18}F -FDG PET/CT. *J Nucl Med*. 2004;45(suppl 1):56S–65S.