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DISCUSSIONS IN PET IMAGING

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Preparing Patients for PET Imaging: The Importance of Prescan Communication

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LEARNING OBJECTIVES

Upon completion of this activity, participants should be able to:

- Explain the importance of patient preparation for FDG-PET oncology studies and cardiac viability studies
- Describe the basic principles of carbohydrate management in preparing patients for FDG-PET oncology and cardiac studies
- Prepare diabetic patients for FDG-PET studies
- Communicate important preparation information to patients prior to their FDG - PET scans.

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Dr. Waxman and Ms. Barondess have no significant financial arrangement or affiliation with any manufacturer of any pharmaceutical or medical device and are not affiliated in any manner with any provider of any commercial medical or healthcare professional service.

The use of whole-body PET scanning has dramatically increased in the past five years as PET as fluorodeoxyglucose (FDG) has begun to play a major role in managing patients with cancer. Increasing applications are emerging in cardiology, as well, especially in determining myocardial viability. PET has also been demonstrated effective in the evaluation of brain disorders, particularly in patients with dementia and epilepsy. Recent studies have shown a high degree of sensitivity and specificity for the detection of Alzheimer's disease, even at early stages, and in some instances before the disease has become manifest. Use of FDG-PET for brain tumor evaluation has also proved useful, especially for differentiating radiation necrosis from recurrent tumor.

To maximize the success of the examination and achieve optimal sensitivity, specificity, and accuracy, it is critical that practitioners follow the correct protocols, tailored to the individual examination.

WHOLE-BODY ONCOLOGY PET SCANS

Prior to the whole-body FDG-PET scan, a set of instructions should be faxed or mailed to the patient. This communication should include a brief introduction that explains the purpose of the study and instructions about diet and exercise limitations before the scan, as well as a description of the procedure. As part of the patient preparation, all healthcare personnel

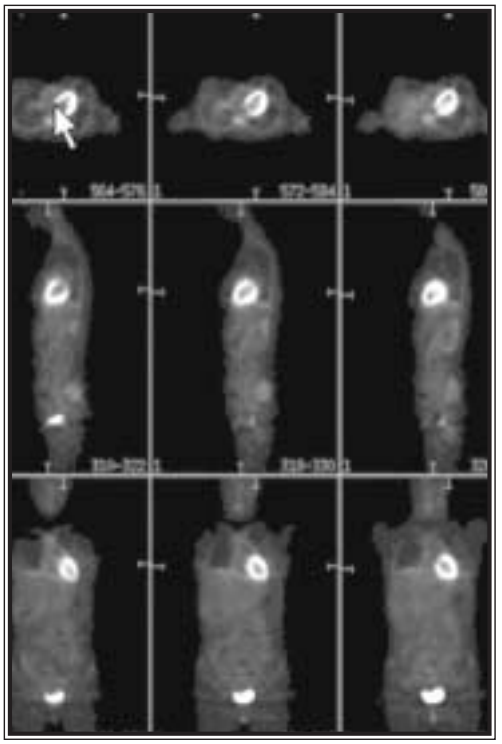

FIGURE 1. *Increased cardiac uptake as a result of elevated glucose causes increased insulin output from the pancreas. Patient drank a large quantity of fruit juice prior to the FDG injection.*

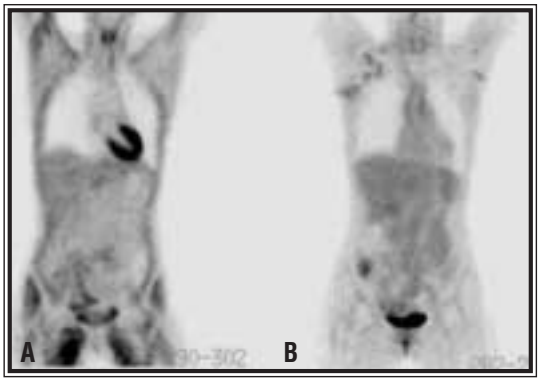

FIGURE 2. *54-year-old woman with recently diagnosed breast cancer, referred for staging with FDG-PET. Despite being informed about minimizing or eliminating carbohydrates prior to her study, she had consumed several glucose-containing soft drinks shortly before the scan was obtained. A: Note the marked increase in muscle (cardiac and skeletal). B: A repeat FDG-PET done 48 hours later demonstrates multiple abnormal axillary foci and markedly reduced muscle and soft-tissue activity. Patient preparation is critical in optimizing lesion detection.*

involved in performing the study should be aware of the guidelines for metabolic studies for oncology, brain, and cardiac studies.

PATIENTS WITH DIABETES

It is important that a nondiabetic patient follows the diet specified. Increasing the carbohydrate load prior to an FDG-PET scan will result in elevation of blood insulin levels. Insulin drives glucose into cells, especially muscle tissue that has recently been exercised. Figure 1 shows marked increase in cardiac activity in a nondiabetic patient who drank fruit juice just before the study.

The following protocol is based on experience at Cedars-Sinai Medical Center. Patients are instructed not to exercise vigorously for at least 24 hours before a PET scan. To minimize FDG activity in the myocardium, it is important that the insulin level be kept at a minimum prior to the injection of FDG. Patients who present with mildly elevated blood sugar who are subsequently given regular human insulin will demonstrate increased activity in the myocardium as well as the body muscle.

Occasionally, a patient who is receiving an intravenous solution requires PET scanning. The technologist should always ensure that the material being given does not contain glucose. Elevation of the glucose levels at the time of FDG injection tends to reduce concentration within normal tissues as well as any neoplasm, which may ordinarily show high concentration.[1-9] This is due to the competitive uptake inhibition of the Glut-1 transporters within the cell membrane, which normally transport glucose into highly metabolic tissue. Figure 2 is a PET scan of a patient who had a markedly elevated glucose level at the time of FDG injection.

Routine sampling of blood glucose levels is controversial. In our hospital, diabetic and cardiac patients are routinely sampled, but nondiabetic oncology patients with no history of diabetes are not.

Standardization of dietary study conditions is essential for obtaining diagnostically adequate and reproducible metabolic images with FDG. Furthermore, in the evaluation of the myocardium, the high incidence of diabetes in patients with coronary artery disease frequently complicates or even precludes adequate imaging of myocardial FDG uptake. The following procedures and precautions will optimize study conditions and imaging results for all patients.

- *At the time of patient scheduling, determine whether the patient has known diabetes mellitus.* Patients without known diabetes should avoid food for six hours before the PET scan appointment. Patients on oral antidiabetic medication should avoid food after midnight but take their oral diabetic medication. Patients with insulin-dependent diabetes should adhere to their normal dietary and insulin schedule.
- *Prepare patients for cardiac FDG-PET.* Upon the patient's arrival in the nuclear medicine department, determine the baseline blood sugar level. Depending on the outcome, proceed as follows:

—If blood sugar <150 mg/dL, give 50 g Glutol orally.

—If blood sugar levels are 150 to 200 mg/dL, give 25 g Glutol orally.

—If blood sugar levels are >200 mg/dL, do not give Glutol.

- *Determine blood glucose levels again 60 minutes after Glutol administration.* Depending on the outcome, proceed as follows:

—If blood sugar is 100 to 150 mg/dL, inject 2 units of regular human insulin. Wait 15 minutes, inject FDG (dose calculated by weight) and begin imaging 45 minutes after FDG injection. Patient must drink 8 oz. of fruit juice immediately before the scan.

—If blood sugar levels are >150 mg/dL, the attending physician or nuclear cardiologist should do the following:

1. Administer regular insulin intravenously, based on the recommended doses in the table below.
2. Fifteen minutes after insulin administration, check whether the glucose level has declined.
3. Repeat steps 1 and 2 until blood sugar levels are <150 mg/dL.
4. Once blood sugar levels are <150 mg/dL, inject FDG (dose calculated by weight) and begin imaging 45 minutes after FDG injection. Patient must drink 8 oz. of fruit juice immediately before the scan.

- *Take the following steps after completion of FDG-PET image acquisition.*

—Check the FDG-PET images before the patient is released. If blood pool activity is high and the image is of nondiagnostic quality, consult with the nuclear cardiologist to determine whether imaging should be repeated or IV insulin administered to clear blood pool activity. If IV insulin is required, check the blood

SUGGESTED SLIDING SCALE OF IV INSULIN DOSES BASED ON BLOOD SUGAR LEVEL

IF BLOOD SUGAR LEVEL IS:	ADMINISTER THE FOLLOWING DOSE OF REGULAR HUMAN INSULIN, IV
>350 mg/dL	6 units
300-350 mg/dL	5-6 units
250-300 mg/dL	4-5 units
150-200 mg/dL	3-4 units
100-150 mg/dL	2 units
<100 mg/dL	Do not give insulin

glucose levels before giving another dose of regular insulin.

—Before the patient is discharged, check blood glucose levels and inform the patient about the possibility of hypoglycemia (if IV insulin was given). The patient may eat a snack or drink more fruit juice at this time. Explain the symptoms associated with hypoglycemia and instruct the patient accordingly. A patient who becomes severely hypoglycemic should receive IV glucose, typically in the form of 20% dextrose.

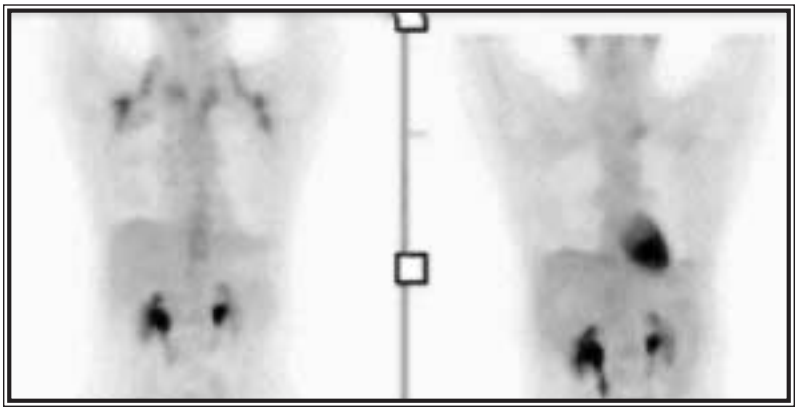

FIGURE 3. *Patient was being evaluated for lymphoma. Initial FDG-PET scan (left) demonstrates increased neck and supraclavicular activity, which may represent muscle uptake or brown fat. These findings disappear in repeat scan after administration of diazepam, possibly related to muscle relaxation or direct effect of diazepam on brown fat.*

—Inform the nuclear cardiologist of the patient's status and insulin administration.

—All metabolic manipulations must be appropriately recorded in the patient's nuclear medicine folder.

AVOIDING ARTIFACTS AND PITFALLS

Proper techniques of patient preparation can help avoid artifacts and the following common problems in PET imaging.

• *Renal and bladder activity*. FDG is not reabsorbed by the renal tubules and is therefore excreted in the collecting system of the kidney, from which it soon passes to the ureter and then into the bladder. Whole-body FDG-PET scans generally show intense bladder activity and at times show pooling of activities within the kidneys and the ureter. To avoid a high concentration of FDG in the collecting system, patients are encouraged to drink large quantities of water prior to the injection of FDG. To minimize bladder activity within the pelvis, the patient is required to void immediately before the scan. The scan is then started from the midthigh region and extended cephalad. While catheterization to evaluate the pelvis is not routinely recommended, it is often helpful in selected cases, especially when pelvic tumor metastases or recurrence is suspected.

Some institutions use furosemide to clear the collecting system of activity in the region of the kidney and ureters. Its use, however, often renders a patient unable to cooperate during the entire whole-body scan. Rapid urine production during the scan may result in distortion of anatomic structures within the pelvis. We normally do not use furosemide for evaluating the abdomen/pelvis because lack of patient cooperation is often problematic.

• *Head and neck studies*. Evaluation of the head and neck region is often complex, as evaluation of multiple anatomic sites is required. Many of these sites are closely related to muscle groups, tonsils, vocal cords, and fatty areas, which can be problematic. Figure 3 is a patient who was being evaluated for lymphoma. The initial FDG-PET image demonstrated increased neck and supraclavicular activity. The findings disappeared in a repeat scan after administration of diazepam.

Patients undergoing head and neck evaluation are instructed not to chew, sip, talk, or in any way exercise the muscles of the head and neck region. Maintaining head and neck comfort during the scan is also critical to avoid excessive muscle uptake in these regions. Some institutions advocate the use of diazepam prior to the FDG scan to minimize uptake in the head and neck region.

• *Bowel activity*. Increased activity in the GI tract, especially the large bowel, is not uncommon. No compelling evidence indicates that bowel preparation is helpful. In the past, patients were often given a bowel preparation to reduce bowel activity before a gallium-67 scan, but it has been determined that this is not helpful, and most institutions have abandoned the practice.

• *Musculoskeletal system*. Exercising muscle causes hypermetabolism, resulting in increased activity of FDG in muscle groups that have recently undergone contraction. Subjects are told to avoid exercise for a minimum of 24 hours prior to their PET scan. Extreme exercise such as weightlifting or competitive sports may result in extended periods of hypermetabolism, so patients are instructed to avoid extreme exercise for 36 to 48 hours before a PET scan. Figure 4 is a patient who had exercised vigorously with body-building equipment 24 hours before his PET study. He had also taken a glucose-containing drink a few hours in advance of his test.

Diabetic patients on insulin may demonstrate increased muscle activity if the insulin is given within two hours prior to the FDG injection. Because insulin drives glucose into muscle, attempting to regulate blood sugar by injecting insulin immediately before the exam often results in a suboptimal study, due to increased activity in the heart and muscles of the axial skeleton.

PET/CT COMBINED STUDY

Many centers are beginning to use a combination imaging system that consists of a high-resolution CT scanner and a dedicated high-resolution PET scanner. Preparation of patients for this exam consists mainly of direct communication: explaining that they will undergo two individual tests done within minutes. The CT is generally completed first and is immediately followed by the PET scan. If no contrast agent is used for the CT portion of the study, no additional patient preparation is required.

Practitioners initially noted that a contrast CT scan often resulted in overcorrection artifacts on the PET scan, and they therefore avoided contrast. It has been demonstrated, however, that while artifacts of overcorrection may occur, a contrast CT scan contains valuable information that can help in the anatomic localization of PET findings. The pitfalls of those artifacts can usually be avoided by looking at the uncorrected PET scan in conjunction with the contrast CT. If con-

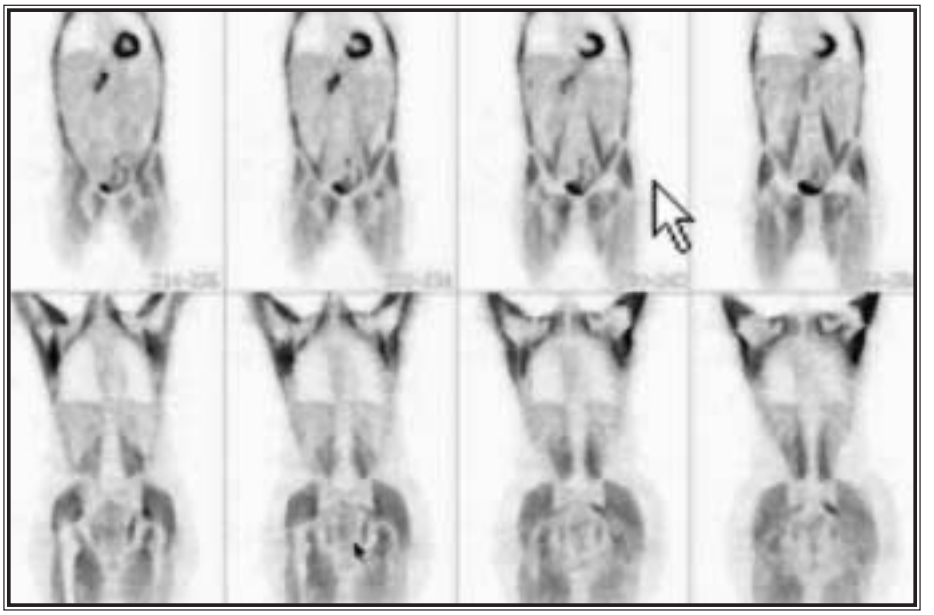

FIGURE 4. *Patient who had exercised vigorously with body-building equipment 24 hours before his PET study. He had also taken a glucose-containing drink a few hours prior to the test. Vigorous exercise should be avoided for at least 24 hours before an FDG-PET scan.*

trast is to be used in the combined study, the preparation is more extensive; precautions normally taken for contrast CT should be observed.

Pretest questions for the contrast CT concern possible allergies. Precautions should be taken if the patient has a history of iodine allergies or intolerance to previous contrast studies. Because the contrast agents are hyperosmolar, a careful evaluation of the patient's potential for renal dysfunction should be explored. Patients should be asked whether they have diabetes, known kidney disease, a single kidney, HIV, or have undergone recent chemotherapy. Patients who are taking diuretics may also be subject to renal dysfunction following contrast administration. A creatinine level should be obtained in a patient with potential for renal dysfunction; the reading should be less than 1.4 mg/dL for the scan to proceed.

Patients taking Glucophage, Glucovance, or Metaglip should discontinue these medications for 48 hours after the contrast study. The patient's creatinine should be monitored for approximately 48 hours.

Because of the high photon absorption of contrast agents containing iodine, the interpretation of a combined PET/CT study should be approached with the understanding that overcorrection artifacts resulting from attenuation correction may be encountered.

SUMMARY

Appropriate patient preparation is essential to optimize the results of an FDG-PET scan. Specific protocols for specific studies need to be implemented. Unnecessary preparation procedures can add to the patient's discomfort, increase the cost of the examination, and result in a study that is no better than a simpler approach. Patient preparation should be as simple as possible but should achieve the goals of improving tumor-to-background ratio, avoiding artifacts and pitfalls, and keeping patient discomfort to a minimum.

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