
Development of Oncology Protocol Using Fluorine-18-FDG: One Center's Experience

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The major types of cancer studied at the authors' facility were colorectal (107 patients), head and neck (122 patients), gastric/esophageal (57 patients), lung (59 patients) and lymphoma (26 patients). This article presents guidelines and techniques for obtaining optimal PET studies. The authors devised these guidelines through trial and error and hope that by sharing them other facilities can avoid unnecessary mistakes and achieve better quality studies more efficiently.

Key Words: oncology; PET; fluorine-18-FDG

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Oncology is the fastest growing area of PET, which uses the tracer ^{18}F -fluorodeoxyglucose (FDG) to measure tissue metabolism. Glucose metabolic rate, as depicted by FDG uptake, correlates well with a degree of malignancy. We can qualitatively and quantitatively measure the tissue metabolism in detectable tumors. This information can be used in initial staging of cancer patients and for evaluation of therapy and restaging.

CAMERA QUALITY CONTROL

The Center for Positron Emission Tomography is equipped with a 951R ECAT scanner (Siemens Medical Systems Inc., Iselin, NJ) that consists of two rings of detectors with a resultant 10.8-cm field of view. A daily check scan is performed each morning to ensure system integrity. This process produces two reports: one on uniformity of the detectors and the one that compares drift from the original setup, a procedure called normalization. The normalization is used to make the sensitivity more uniform. Sinograms are checked also for artifacts. A blank scan then is obtained, with nothing in the field of view, for reconstructing attenuation files for that day. Figure 1 shows a non-normalized uniform sinogram that is visually checked for artifacts such as streaks.

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PATIENT PREPARATION

Patients undergoing a PET scan should fast for a minimum of 4 hr. This will minimize, but may not eliminate, heart uptake that could interfere with scan interpretation, especially for pulmonary and mediastinal lesion evaluations in lung and breast cancers. A blood sample should be drawn to obtain a glucose level before injection. This value can help explain poor biodistribution and clarify low standardized uptake values. If the glucose value is abnormal, the physician may want to re-evaluate the quantitative data. Patients should also be at least 72 hr post-biopsy because of the possibility of inflammation, which can result in nonspecific FDG uptake.

Before beginning the scan, the technologist and/or physician should explain the entire procedure to the patient and answer questions that may arise. Patient cooperation is essential in achieving an optimal PET scan. In addition, we require negative pregnancy test results before the procedure can begin.

ACQUISITION PARAMETERS

Bed Positions

Before beginning the scan, the patient must be evaluated to determine the area to be scanned, which will vary according to the type of cancer and its pattern of dissemination. Table 1 lists the areas to be scanned for each particular cancer. In certain instances, a thermoplastic mask may be used to minimize patient head motion and help in proper repositioning. The mask is initially stiff, becomes pliable after heating in a water bath of 160-165° F for about 45-60 sec. The pliable mask is then removed and dried. Care must be taken to ensure that the mask has cooled sufficiently before placing it on the patient's face. As the mask cools, it hardens and secures to the patient's head. Once the head region has been imaged, the mask can be removed for added patient comfort.

Every attempt should be made to make the patient as comfortable as possible during image acquisition. A wrap to support the arms, quiet background music, a pillow beneath the knees and a blanket may make the scan time more tolerable for the patient. FDG usually starts to accumulate in the bladder and could interfere with evaluating the pelvic area for tumors.

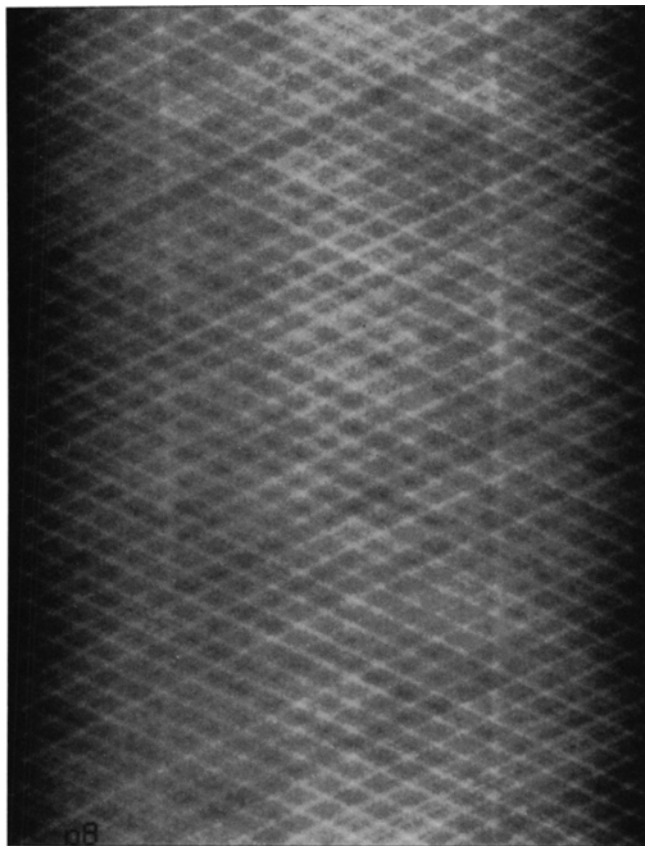


FIGURE 1. All planes of the blank scan should be checked for any intensity abnormalities along the diagonal in both the normalized and non-normalized sinograms.

For patients with colorectal cancer, scanning the pelvic area first can minimize but not totally eliminate bladder interference. Patients should be encouraged to void before the start of each scan.

Depending on the size of the field of view, 10.8 cm for the 951R ECAT Scanner, the correct number of bed positions should be determined. Figure 2 (left) shows a typical head and neck cancer PET scan of four bed positions, while Figure 2 (right) shows a colorectal PET scan which can be up to 10 bed positions.

TABLE 1
Type of Cancer to be Imaged and Starting and Ending Bed Position

Cancer type	Start	Finish
Lymphoma*	Top of ear	Mid-thigh
Melanoma*	Head	Mid-thigh
Lung	Eyebrow	Below umbilicus
Head and Neck*	Eyebrow	Mid-liver
Parathyroid*	Eyebrow	Below heart
Esophageal and Gastric*	Chin	Umbilicus
Breast	Mid-neck	Umbilicus
Colorectal	Below pelvis	Shoulder
Ovarian	Below pelvis	Shoulder

*Thermoplastic face mask used.

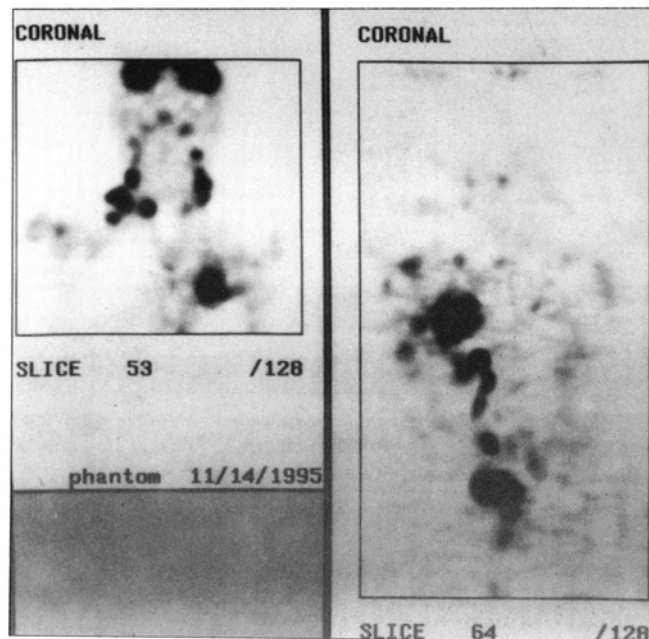


FIGURE 2. Head and neck cancer patients (left) require only four bed positions, while colorectal cancer patients (right) may require up to 10 bed positions.

TRANSMISSION SCAN

We routinely obtain transmission scans on all cancer patients. This scan is obtained for 6 min/bed position, with the exception of head and neck cancer scans which are obtained for 8 min/bed position, because these studies require only four bed positions and the increased time does not usually cause patient discomfort. At the completion of the scan, lasers are used to mark the mask, suprasternal notch, xiphoid process and/or umbilicus and aid in repositioning for the emission scan. Also bed elevation and initial start positions should be noted. There should be no tilt to the gantry for any of these scans.

The patient is then injected with ≤ 10 mCi ^{18}F -FDG and care is taken to flush the syringe two to three times with saline to reduce any residual tracer in the syringe. Residual syringe activity is documented and subtracted from the drawn-up activity to calculate actual activity injected into the patient. Forty-five minutes is allowed for radiotracer uptake. This uptake period may be completed in a separate room where the patient may feel more comfortable. Limited patient movement or exercise will prevent FDG uptake by the muscles. To optimize camera time in a busy PET facility, one patient's transmission scan may be completed during another patient's uptake period.

Emission Scan

When the patient is ready for the emission scan, great care should be taken in repositioning the patient, as incorrect repositioning may introduce artifacts. Use of the markings on the patient and initial bed positions can aid the technologist in repositioning. Emission scans are obtained for 8 min/bed position with the exception of scans performed on patients with head and neck cancers, which are obtained for 10 min per bed position. It should be noted these times may vary according to patient circumstances, such as claustrophobia, sickness and pain.

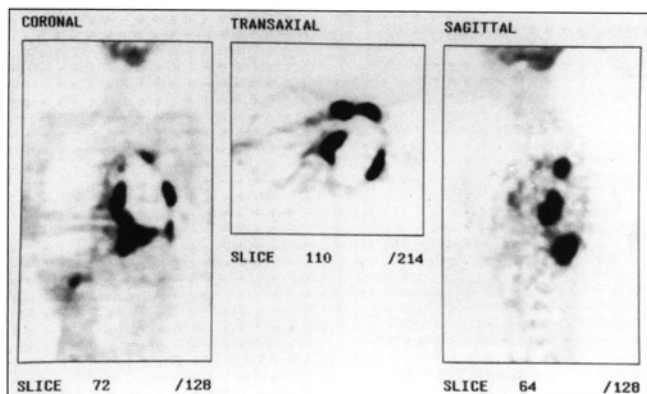


FIGURE 3. By using the whole-body viewer, coronal, transverse and sagittal slices of the scan can be viewed. This is a lung cancer patient who has increased FDG uptake in the left hemithorax.

PROCESSING

Reconstruction

The transmission scan is processed with a Hann filter, cutoff of 0.3 cycles per pixel and a zoom of 1.5. The emission scan is processed using the same parameters. We have found that the cutoff of 0.3 allows for the best balance of resolution, noise, and visual interpretation. Both scans are then processed using the whole-body viewer, included in the 951R ECAT scanner software package. On completion, the intensity may be adjusted for optimal viewing by the physician. Figure 3 shows the PET scan displayed with the whole-body viewer.

If requested by the physician, the emission scan can be processed without the transmission scan when misalignment artifacts are obvious. However, no attenuation correction factors are then applied (1). Figure 4 (left) shows a PET scan using the transmission scan with attenuation correction compared to Figure 4 (right), the emission scan only, which has no attenuation correction.

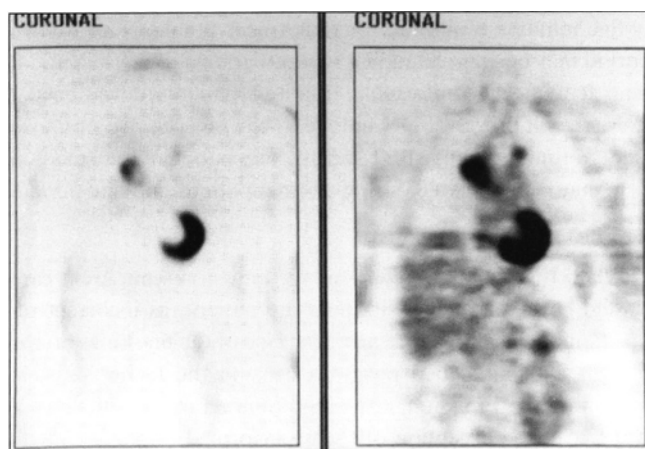


FIGURE 4. Lung cancer patient with attenuation correction (left) and without (right). Metastatic disease involving the mediastinum is more clearly depicted in the attenuation-corrected image.

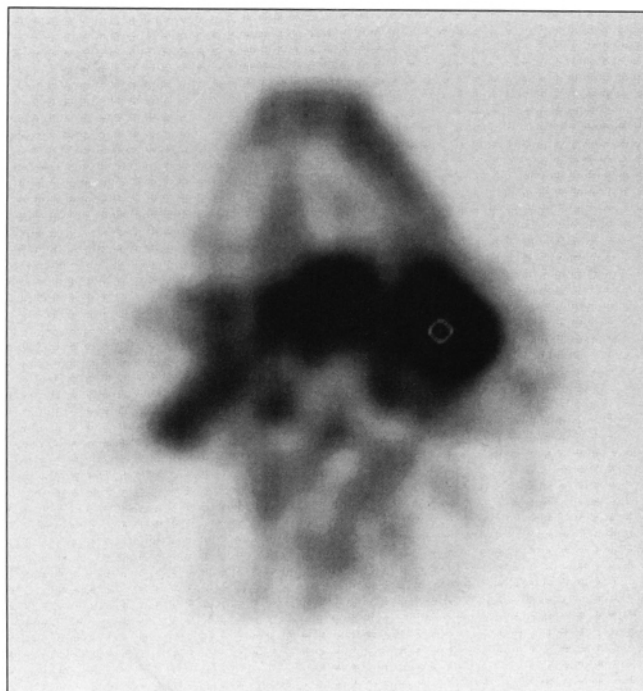


FIGURE 5. ROI is placed within boundaries of the tumor on the transaxial slice that best visualizes the tumor for SUV determination.

Standardized Uptake Values

In certain cases, standardized uptake values (SUVs) may be needed to differentiate between normal and abnormal FDG uptake. These values are a quantitative measurement of tissue uptake taking into account activity injected, patient weight and calibration factors of the camera. The calibration factor converts Ecat counts per pixel per second to microcuries per milliliter per counts per second per pixel. A transmission scan must be acquired to calculate the SUV. Although the clinical utility of SUV has been questioned (2), it may be useful in certain circumstances such as evaluating therapeutic response on a repeat PET scan, evaluating patients with a single pulmonary nodule or differentiating between colonic carcinomas and nonspecific bowel uptake. To calculate the SUV, the image should be reviewed and the bed position which contains the tumor selected. This bed position of 31 planes is then reprocessed using the Retro Recon Tool with a Hann filter, cutoff of 0.4 cycles per pixel and a zoom of 1.5. The cutoff is increased to 0.4 when calculating SUVs because less smoothing is needed. When reviewing the transaxial slices, a plane is selected that best demonstrates the area in question and a region of interest (ROI) is drawn within the tumor's boundaries. Our work in this area has been previously described (3,4). Figure 5 shows the placement of the ROI on the tumor.

The following formula was used in calculating SUVs:

$$SUV = \frac{\mu\text{Ci/g (ROI)}}{\mu\text{Ci/g (Patient)}}$$

Normal SUV values are usually less than 3.5, although some anatomic areas, such as the brain, heart and bladder, will have

significantly higher SUV values since they normally metabolize or take up FDG (5). Tumor type, size, location and differences between primary and metastatic tumors must also be considered when evaluating SUV values.

Archiving

Selected slices on all three views (coronal, sagittal and transaxial) that best visualize the tumor are filmed for the patient's folder. These are available to the referring physician and serve for presentation when no computer is available.

All processed images are archived to optical disks for retrieval at a later date, if necessary. All raw sinograms, including the blank scan and normalization used in the processing, are archived to 8 magnetic tape.

Problem Solving

Throughout our evaluation of (560) patients with various types of cancer, we have encountered several problems, which are presented along with their solutions:

1. Familiarization with abnormal patterns of FDG uptake (6), especially in patients who are tense. This manifested as abnormal uptake in the cervical and supraclavicular regions. Administering a tranquilizer may be beneficial. We also recommend tranquilizing claustrophobic patients. We try to calm and relax the anxious patient the best we can through talking and calming gestures.
2. The bladder can introduce artifacts in the pelvic area, making scan interpretation difficult. We do not use the bladder irrigation protocol used at some institutions. Instead, we have the patient void before scanning and image the pelvic area first. It is more comfortable for the patient and if bladder activity causes an interfering artifact, we use the rotating whole-body projections to delineate the bladder.
3. Glucose levels are determined for all patients before injection. These can help explain any abnormal FDG distribution, especially when a repeat PET scan demonstrates an uptake pattern different from the initial study.
4. Avoid the use of existing intravenous lines, including subcutaneous venous access ports for tracer injection. Residual activity in the line may cause artifacts.
5. Achieve all raw sinograms. If a patient had a repeat PET scan, there may be a need to reprocess the initial study so that both scans are processed identically.
6. Some patients require several bed positions, which require more processing time and disk space. By staggering

technologists, we are able to complete all tasks within one working day.

Reimbursement Issues

This is an area that needs to be addressed in a separate article. We successfully developed a rapport with the insurance companies because our patient population is both veterans and patients from the community. Each case is approved on an individual basis with a greater success rate. The key elements here are open dialog with the key personnel at insurance companies, support from the referring physicians, constant dissemination of the value of PET-FDG and its limitations to the referring physicians.

CONCLUSION

This article summarized our experience in setting up oncology PET protocols. We hope that sharing our experience is helpful, particularly to new PET centers, and will prevent them from repeating some of our early mistakes. PET oncology is a growing field and computer and camera improvements make it a constantly changing one. Although we have a solid base from which to build, we are constantly trying to improve our methods to deliver the best possible PET service for the physician and the patient.

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