Prone 18F-FDG PET/CT changes diagnostic and surgical intervention in a breast cancer patient: some considerations about PET/CT imaging acquisition protocol

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A B S T R A C T

We report a case study demonstrating the value of prone positioning in positron emission tomography (PET) of a woman with diagnosed breast cancer (BC) addressed to lumpectomy. Surgeon required 18F-fluorodeoxiglucose (18F-FDG) PET study for staging and assessment of lymphnode involvement/metastasis prior to lumpectomy: a whole-body supine study and a prone acquisition of breast. Supine study revealed one lesion, while prone study revealed two lesions. Prone PET findings changed diagnosis and therapeutic intervention for patient who was subsequently subjected to quadrantectomy.

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1. Introduction

The diagnosis of breast cancer (BC) is performed with the support of a multimodal imaging approach, including X-ray mammography and ultrasound [1]. A preoperative diagnosis can be confirmed by cytology and histology. The staging of BC is completed by the evaluation of lymph nodes and distant metastases using other imaging methods including 18F-fluorodeoxiglucose (18F-FDG) positron emission tomography (PET) combined with computed tomography (CT) (18F-FDG PET/CT) and magnetic resonance imaging (MRI) [2–4].

The role of 18F-FDG PET/CT as a staging procedure in primary BC is not completely established, although promising results have been reported [5,6]. Many 18F-FDG PET/CT studies have been performed in large and/or locally advanced BC, and lower PET sensitivities have been reported for small and node-negative BC [5,7,8], mainly due to the partial volume effect (PVC) [9]. Recent studies have shown the prognostic role of 18F-FDG PET/CT in BC when accurate semiquantification of 18F-FDG uptake within the lesion is provided [10]. Clinical guidelines for BC patients have recommended the use of PET/CT as an additional examination tool when standard staging examinations are equivocal or suspicious [11].

Standard 18F-FDG PET/CT imaging protocols for BC staging are based on whole-body studies with the patient in supine position [4]. However, some studies have suggested that PET acquisition with the patient in prone position can provide better visualization of the uptaking lesions in comparison with the standard supine procedure [12]. To our knowledge, the value of prone positioning in 18F-FDG PET/CT in the management of BC patients for both the diagnosis and development of a therapeutic intervention has not been proven, and PET whole-body studies with the patient in supine position still comprise the adopted acquisition procedure for both the staging of breast primary tumors and the assessment of lymph nodes and distant metastases.

Here, we report a case study of a patient with newly diagnosed BC who was a candidate for a lumpectomy; her diagnostic and surgical program changed following new findings that were obtained from an 18F-FDG PET/CT presurgical evaluation with the patient in prone position. These findings allow important considerations to be derived regarding the optimal PET/CT imaging acquisition protocol in BC patients.

2. Materials and methods

2.1. Patient management

A 57-year-old woman went to San Raffaele Hospital (OSR), Milan, Italy, after BC was discovered via mammography, ultrasound, and fine-needle aspiration cytology (FNAC) at another hospital. In the upper outer quadrant of the left breast, mammography and ultrasound...
showed a small, irregular mass in the axillary tail, and medially, an oval hypoechoic nodule in the prepectoral region was also found. FNAC on the first finding revealed an invasive ductal carcinoma, while indicated fibroadenoma for the other nodule. A breast surgeon visited the patient and clinically confirmed the external nodule in the outer equatorial region of the left breast. Prior to the planned lumpectomy, and considering that the patient had not performed diagnostic examinations that could be used for staging (e.g., liver ultrasonography, bone scan, and chest radiography X-ray), the surgeon prescribed a whole-body 18F-FDG PET examination due to the possibility that the surgeon could evaluate, in an easier and faster way (in a single-session study), both the stage of the primary tumor and the involvement of the lymph nodes, as well as to determine the presence of distant metastases [13].

The patient was also evaluated by axillary ultrasound for correct planning of the sentinel lymph node biopsy. The patient signed informed consent forms before each diagnostic procedure was conducted.

2.2. PET/CT study

The patient fasted for at least 6 h and received an intravenous dose of 18F-FDG (314 MBq) following normal blood glucose level measurement (81 mg/dl), and 18F-FDG PET/CT acquisition was performed 60 min after the radiotracer injection. The PET/CT system, Discovery-STE (General Electric Medical System) [14], was used, and it was cross calibrated with a dose measurement system. Discovery-STE is a threedimensional (3D) hybrid system that combines a 16-multislice helical CT scanner with a PET scanner consisting of 280 bismuth oxygen germi crystals (4.7 mm × 6.3 mm × 30 mm) arranged in 24 rings. The transaxial field of view is 60 cm and 50 cm for PET and CT, respectively. The axial field of view is 15.7 cm for PET. A dedicated, two-phase 18F-FDG PET/CT imaging protocol was performed. In the first phase, a whole-body, multiple-bed 18F-FDG PET/CT study was acquired, and a scan was performed from the patient’s head to her upper thighs, with the patient in supine position. This study included a scout scan at 40 mA, followed by a CT scan at 140 mA, and 3D PET scans were performed for adjacent bed positions in the cranio-caudal direction (2.5 mm/scan). In the second phase, a single-bed 18F-FDG PET/CT study was performed on the breast region alone, with the patient repositioned in the prone position by the use of a dedicated breast-positioning device designed and realized by IBFM-CNR (Milan, Italy). The device was specifically conceived in order to allow for full breast extension during PET/CT breast acquisition, so as to reduce respiratory movement and, at the same time, to achieve maximum comfort for the patient (e.g., avoiding breast compression and respiratory impairment).

For both supine (first phase) and prone (second phase) scans, the acquisition parameters for the CT and PET studies were the same. For each bed position, CT data were reconstructed into a 512×512×47 matrix with a voxel size of 0.97 mm × 0.97 mm × 3.27 mm [15]. For each bed position, PET data were sampled into a 128×128×47 matrix with a voxel size of 4.7 mm × 4.7 mm × 3.27 mm and reconstructed using a 3D-ordered subset expectation maximization algorithm, with corrections for random, scatter, and attenuation incorporated into the iterative process.

2.3. Qualitative and quantitative evaluation of the images

Image readout was performed on an Xeleris Workstation (GE Healthcare), which allowed for the visualization of PET, CT, and PET/CT fused images in the transverse, coronal, and sagittal planes. An expert nuclear medicine physician performed the qualitative and quantitative evaluations.

The presence of abnormal 18F-FDG uptake, excluding the areas of physiologically increased uptake, was considered suspicious for malignancy, and its anatomical site was indicated on the basis of CT anatomy. The interpretation of pathologic lymph nodes was based on the presence of focal increased tracer uptake on 18F-FDG PET images corresponding to lymph nodal chains on the CT images, independent of their size on CT. Conversely, lymph nodes with no detectable tracer uptake were reported as benign, without considering their size on CT images.

PET quantification of focal increased uptake was performed using the mean standardized uptake value (SUV), which was corrected for the PVC (SUVmean) [16,17]. The metabolic target volume (MTV) was evaluated using a manual contour, and total lesion glycolysis (PVC-TLG) was calculated as the product between the PVC-SUVmean and the MTV.

3. Results

In terms of lesion detectability, only one uptake lesion was detected by the 18F-FDG PET/CT images when the patient was in supine position (Fig. 1, Panel A) while two uptake lesions were visualized by the 18F-FDG PET/CT images when the patient was in prone position (Fig. 1, Panel B), thus revealing that one uptake lesion was confounded with the other lesion upon visual inspection. For both supine and prone 18F-FDG PET/CT images, no abnormal increase in glucose uptake was detected in the other investigated body segments.

Concerning prone PET acquisition, the lesion in the outer quadrant showed PVC-SUVmean = 2.69 g/cc, MTV = 1.09 cc, and PVC-TLG = 2.93 g while the other lesion showed PVC-SUVmean = 5.18 g/cc, MTV = 1.01 cc, and PVC-TLG = 5.25 g. The quantitative results confirmed the confounding effect that occurred on the PET images when the images were acquired with the patient in supine position. The use of prone image acquisition during the PET/CT study yielded images that could better visualize the breasts and regional lymph node areas without tissue compression or breathing motion. Indeed, prone patient positioning caused less lung movement during respiration than did supine positioning, thus limiting imaging artifacts. The visible surface of the breast was increased, and better definition of the lesion and lymph nodes (in particular, the axillary lymph nodes) was obtained.

Following the results of the 18F-FDG PET/CT study with the patient in prone position, the surgeon decided to refer the patient for further diagnostic evaluations. A subsequent bilateral contrast-enhanced MRI examination of the breast was performed, and it confirmed two hypervascular lesions with highly suspicious rim enhancement (see Fig. 2). FNAC was also repeated on both nodules. The two lesions, one (1 cm diameter) in the axillary tail and another (1 cm diameter) in upper outer quadrant (distance between the lesions: 2.5 cm), were cytologically proven to be ductal carcinomas.

Based on these new findings, the surgeon planned a quadrantectomy instead of the previously planned lumpectomy, so as to include both lesions.

Final histopathology of the two lesions following the surgical intervention revealed two foci of invasive ductal carcinoma, with a negative sentinel node biopsy.

All of the findings that were observed in this case study of a single patient with BC revealed that an 18F-FDG PET/CT study performed with the patient in prone position was crucial for the therapeutic management of that patient.

4. Discussion

There are several reasons for suggesting PET image acquisition when performing a breast study with the breast in a fixed and undeformed position [12,18,19]. First, it offers the possibility of avoiding potential deformities and compression of the mammary gland; it also limits chest wall movement. In addition, it offers excellent separation of the
deep breast structures from the myocardium in the left breast, and the relaxation of the pectoralis muscle. All of these conditions can enhance the qualitative evaluation of PET images.

Kaida et al. [18] showed improvements in the detection rate of BC in a protocol of cancer screening with 18F-FDG PET/CT. A total of 7 out of 660 patients were diagnosed with BC during the screening, and among these patients, three were diagnosed only when dedicated breast acquisition with the patient in prone position was performed. In a more advanced study, Kaida et al. [18] qualitatively analyzed a large pool of 118 patients diagnosed with BC, which showed a significant increase of 18F-FDG sensitivity and accuracy, and it also featured a negative predictive value for prone acquisition with respect to supine acquisition.

Recently, Koolen et al. [20] demonstrated that the use of optimal imaging acquisition protocols for imaging of the breast region with dedicated prone positioning allowed the majority of T1 breast carcinomas to be visualized with PET/CT; this did not include the limited specificity of PET reported in BC studies.

With respect to PET images acquired with BC patients in the prone position, only Vidal-Sicart et al. [12] performed an analysis of quantitative parameters; their study showed a significant increase of SUVmax when the images were acquired in prone position. Despite this, the impact of SUV quantification on patient management in terms of the possibility to optimize therapeutic approach in BC has not been clearly defined.

At present, despite these findings, supine whole-body scanning is still the acquisition procedure that is adopted for both the staging of primary breast tumors and for the assessment of lymph nodes and distant metastases. However, this case study provides supportive evidence that image acquisition with patients in the prone position is recommended when evaluating BC patients by 18F-FDG PET/CT imaging. Indeed, we reported a case study of a patient for which the standard imaging diagnostic assessment for BC (mammography and ultrasound) indicated the presence of a single BC lesion, while dedicated prone 18F-FDG PET/CT image acquisition revealed a multifocal disease, thus requiring changes to the diagnostic program (an additional breast bilateral contrast-enhanced breast MRI examination and the repetition of ultrasound and FNAC studies were performed) and the therapeutic program for the patient (a quadrantectomy including the two diagnosed lesions was performed, rather than a lumpectomy on a single lesion). 18F-FDG PET/CT imaging and prone positioning might also be useful when planning to scan a patient who cannot be subjected to an MRI study (e.g., for patients with claustrophobia, when pacemakers and ferromagnetic metal implants or prosthetic devices are present, or in cases of patients with impaired renal function).

5. Conclusions

In conclusion, this case thus demonstrated that an 18F-FDG PET/CT study with the patient in prone position should be recommended when evaluating BC, as it allows for better detectability of both the breast and axilla regions. This method also plays a role in the diagnosis and surgical intervention development for BC patients.
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