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TECHNICAL NOTE

Percutaneous Lung Tumor Biopsy Under CBCT Guidance with PET-CT Fusion Imaging: Preliminary Experience

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Abstract
Purpose The aim of this study is to evaluate the feasibility of percutaneous lung tumor biopsy under cone beam-computed tomography (CBCT) with PET-CT imaging fusion.
Materials and Methods Eleven patients (four women and seven men) underwent C-arm CBCT lung biopsy with PET-CT fusion imaging. A preprocedural PET-CT scan was manually fused with procedural CBCT based on anatomical landmarks; using real-time fluoroscopy, the coregistered PET-CT and CBCT images were overlaid to guide the needle trajectory. Technical success, accuracy, sensibility and specificity were evaluated. Mean total procedure time and time required for image elaboration were recorded.

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Results Technical success, diagnostic accuracy, sensitivity and specificity were 100%. The mean procedure time was 38 min. The average time of PET-CT/CBCT image fusion elaboration was 3.53 min for planning and 3.42 min for needle positioning check.
Conclusion CBCT-guided percutaneous lung biopsy with PET-CT fusion imaging is a feasible and effective procedure, with the potential to further improve diagnostic yield by targeting the most metabolically active portion of a lesion, whether it is morphologically altered or normal.

Keywords Cone beam CT · PET-CT fusion · Percutaneous needle biopsy · Navigation

Introduction

Image-guided percutaneous needle biopsy (PNB) has emerged as the invasive procedure of choice for the diagnosis of lung cancer over the past four decades [1]. In most recent years, we have witnessed the introduction of C-arm cone beam CT (CBCT) [2]; this technology enables the acquisition of cross-sectional imaging with modern angiographic systems and CT images [3]. This, combined with dedicated software planning, has allowed its successful application to guide PNB of pulmonary lesions [4, 5]. On the other hand, functional and metabolic information provided by 18FDG-PET [6] showed the potential to further increase the diagnostic yield by guiding the histological sampling to the most active portion of a lesion, as to guarantee an increase in the molecular information provided by the biopsy [7]. However, until recently biopsy or ablation of FDG-uptake abnormalities have been difficult or impossible to perform, regardless of the presence of a discrete anatomical landmark seen on CT; indeed direct PET imaging during the procedure does not provide real-time navigation and is associated with an increased radiation dose, additional FDG injection and a cumbersome workflow [8].

The aim of this study is to evaluate the feasibility and accuracy of CBCT guidance with PET-CT fusion imaging for lung PNB.

Materials and Methods

This single-center prospective study was approved by the institutional review board, and informed consent was given by all patients.

Patients Characteristics

Eleven patients (four women and seven men; average age 69 years, range 52–81 years) were enrolled in our feasibility study. The unique inclusion criterion was the availability of positive PET-CT scan done until 1 month before the procedure. The PET-CT images were evaluated by a nuclear medicine physician and the interventional radiologist to determine suitability of the biopsy under the new fusion software (Fig. 1). Morphological features (diameter) and metabolic features (SUV-max, SUV intra-lesion heterogeneity) were recorded from CT and PET-CT data.

Procedure Workflow

All procedures were performed in an interventional laboratory equipped with a ceiling-mounted C-arm system with CBCT capabilities (Philips Allura Xper FD20 system, Philips, Best, NL). After patient positioning, the ceiling-mounted C-arm system was positioned such that the field of view was centered around the lesion. CBCT data (XperCT, Philips, Best, NL) were acquired using a 5 s propeller protocol with a tube voltage of 120 kV. CBCT data were reconstructed to total field of view of $251 \times 194 \times 251\ mm^3$ with isotropic voxel size of 0.65 mm using a dedicated workstation and displayed within 5 s from acquisition.

A previously acquired PET-CT scan was imported into the workstation. The PET-CT scan was registered to the geometry of the X-ray imaging system by visually matching its CT series with the CBCT volume using commercially available software (XperGuide, Philips, Best, NL). Registration involved manual identification of homologous landmarks in both data sets, followed by optimization of their alignment by means of translation and/or rotation (Fig. 2). Based on the fused PET-CBCT data, a needle path toward the PET-avid target was planned and visualized in overlay with live fluoroscopy. Based on this planning, a 20-gauge cutting needle with a coaxial system (Biopsy Bell, Medical Device, Modena, Italy) was positioned under real-time feedback in relation to the targeted anatomy and registered metabolic activity. Additional CBCT data were acquired to confirm the needle positioning using the same imaging fusion protocol (Fig. 3). Tissue samples were obtained and sent for pathological examination. At the end, a last CBCT acquisition was obtained to check eventual complications.

Data Analysis

Technical success was defined as the correct placement of the needle within the higher SUV part of the lesion. Diagnostic performance was evaluated by calculating

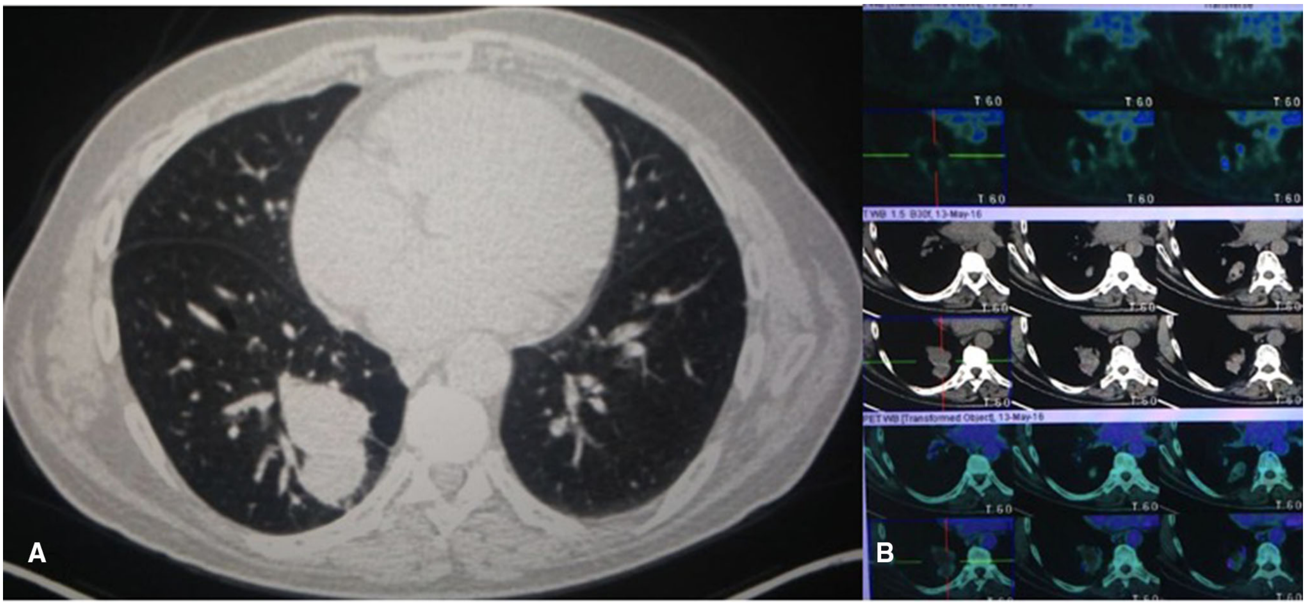

Fig. 1 78-year-old male underwent a PET-CT examination for cough and thorax pain; the CT scan image (left) and PET and PET-CT images (right) show a left low lobe lesion with a FDG-avid tissue only at the periphery of the lesion

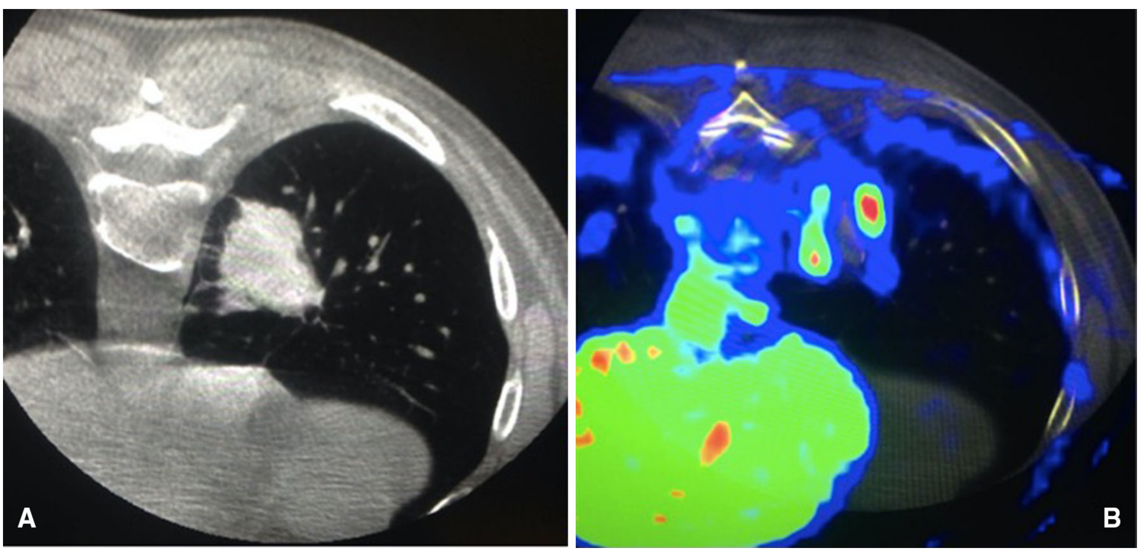

Fig. 2 CBCT image (**A**) obtained with patient prone confirms a left lung lesion; PET-CT and CBCT fusion image (**B**) shows the most FDG-avid tissue to plan the biopsy

sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy. The final diagnosis was confirmed by pathological examination of surgical specimens or by clinical and radiological follow-up.

Mean total procedure time, considered from the first acquired CBCT until the end of the procedure, and time required for image elaboration were recorded.

Complications were classified according to CIRSE classification (Society of Interventional Radiology) [9].

Results

Mean lung lesion diameter was 43.5 mm (range 18–50 mm). The mean SUV-max of the lesions was 13. 8 lesions (72%) demonstrating SUV intra-lesion heterogeneity.

Technical success was achieved in all patients. In a single case, the biopsy specimen was insufficient to establish a diagnosis. Based on surgical and clinical follow-up data, we consider as a false negative the case of insufficient sample; no other false negative or false positive

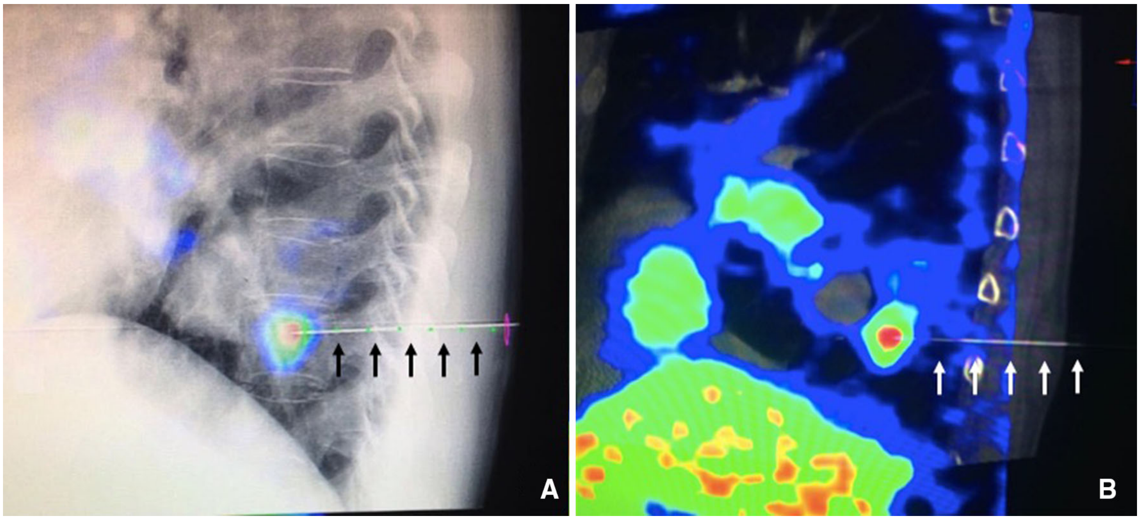

Fig. 3 **A** Fluoroscopy overlaid with CBCT/PET-CT fusion imaging follows real-time needle positioning (black arrows); **B** CBCT sagittal image, acquired after needle positioning, was fused with PET-CT scan and confirms the correct position of needle (white arrows) inside the high FDG-avid tissue of the lesion

cases were observed. Diagnostic accuracy, sensitivity, specificity, PPV and NPV were 90%, 100%, 100% and 50%, respectively.

The mean procedure time was 38 min (range 34–45 min). The average time of registering PET-CT with CBCT was 3 min and 32 s (range 2.45–4.00 min) for planning and 3 min and 25 s (range 2.30–3.45 min) for needle positioning confirmation.

According to CIRSE classification, no complications graded between 3 and 6 were recorded. Two patients (18%) had mild pneumothorax which spontaneously resolved a few hours after the procedure (grade 2).

Discussion

To the best of our knowledge, this is the first case series evaluating the feasibility and efficacy of CBCT guidance with PET-CT fusion imaging for lung tumor PNB. There are only other two previous experiences where CBCT/PET-CT fusion has been used for percutaneous tumor ablation or biopsy [10–12]. A small feasibility study [12] suggested that static off-line registration of PET data with intra-procedural CBCT enables real-time PET-guided navigation without the need for additional hardware or equipment. Recent developments of the used software allow registration of CBCT directly with the CT series of the PET-CT, thereby simplifying the matching of anatomical landmarks and potentially increasing registration accuracy and speed [13]. Our aim was to further substantiate feasibility and accuracy of the technique.

Our results show that the use of PET-CT imaging, which has recently emerged as a new tool for biopsy and ablation guidance [14] with the incremental benefit of targeting the most metabolically active portion of a lesion, whether morphologically altered or normal [8, 15], may also increase the yield of the specimen.

Since direct PET-CT guidance is impractical with critical dose management, interventional procedures have recently been described using retrospective off-line registration, electromagnetic (EM) tracking [8, 16] and CBCT-based fusion [12]. While the first [15, 17] does not offer real-time guidance, EM tracking [8, 18] provides image fusion with real-time feedback. The drawback is the need of additional hardware (EM field generator and tracking workstation), software and disposable equipment (tracked devices and fiducial patches).

CBCT has meanwhile demonstrated to be valuable in lung PNB [2, 13], with these results being consistent with our data; it is widely accessible, whereby PET-CT/CBCT fusion guidance only requires an additional software to the standard equipment, allowing PET data to overlay on live fluoroscopy [12].

This study has several limitations: First, the patient cohort was small; hence, prospective randomized clinical studies are required to define the clinical benefits of this technology compared with conventional techniques in terms of time, radiation dose and accuracy. Although operators were on their first experience, procedural time has not significantly increased compared to CBCT alone, with no need to reposition the needle in any case.

In conclusion, this preliminary experience has showed that CBCT guidance with PET-CT fusion imaging can be a valuable tool to improve accuracy and efficacy of lung tumor biopsies, also proving to be a safe and effective procedure.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institution.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Consent for Publication Consent for publication was obtained for every individual person's data included in the study.

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