C-arm cone-beam computed tomography (CBCT) needle path overlay for percutaneous biopsy of pulmonary nodules

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Purpose

Image-guided percutaneous trans-thoracic needle biopsy is a recognized, safe and accurate diagnostic technique for the evaluation of benignity or malignancy of pulmonary nodules [1;2].

However, its success is dependant on nodule characteristics and operator technique and imaging. Conventional computed tomography (CT) guidance has several limitations: radiation to the patient lack of three dimensional imaging and lack of real-time visualization unless CT fluoroscopy is used [3]. CT fluoroscopy is associated with significant operator exposure and dose not completely resolve the limitations of real time 3D image reconstruction [4].

Recently, Cone-Beam CT (CBCT) imaging was developed. CBCT offers more flexibility than conventional CT, characterized by closed CT gantries, in the orientation of the detector system around the patient. Cone-Beam CT is available in C-arm systems with a flat-panel detector integrated with a cone beam X-ray tube integrated in the C-arm enabling the operator to obtain CT-like images and fluoroscopy from the same machine. CBCT navigation system overlays pre-acquired CBCT images on real-time fluoroscopy thus enabling the operator to navigate needle based on 3D data set with real-time fluoroscopy.

The aim of this study is to evaluate the feasibility of percutaneous transthoracic needle biopsy of pulmonary nodules under XperGuide-CBCT navigation guidance.
Methods and Materials

Patients characteristics

This was a retrospective review of the biopsies performed in our institution between February 2010 to July 2011. This study was approved by internal board review of our Hospital.

From February 2010 to July 2011, 70 percutaneous transthoracic needle biopsies of pulmonary nodules were performed in 70 patients (40 males, 30 females, mean age 65.6 years, range 26-82 years). All patients had a diagnostic conventional chest CT prior to biopsy.

The mean size of the lesion was on average 5.5 cm (range 1 cm -11 cm).

The lesions were divided into two groups according to their transverse diameter: lesions equal or less to 3 cm (34 patients) and lesions larger than 3 cm (36 patients).

The lesion was on average 2.5 cm from the pleura (range 0-5 cm) in the first group of patients (lesion equal or less to 3 cm) and it was on average 1.2 cm from the pleura (range 0 - 4 cm) in the second group.

52 of 70 patients (74.2%) were suffering from chronic obstructive lung disease, 55/70 patients (78.5%) were smokers at the moment of biopsy.

Imaging system and needle path overlay

All examinations were performed in the angiography suite (Philips Allura Xper FD20 system, Philips Best NL) with CBCT navigation (Xperguide, Philips Healthcare, Best, NL).

The C-arm rotates around the patient acquiring CT-like imaging on which the operator plans a virtual needle path choosing the skin entrance point and a target.

In our study we used a 4 s acquisition time for a rotation of 240°, which generates 310 images with a 512 x 512 image matrix and a total reconstruction time of 25s.

Depending on the image matrix and field of view, the highest spatial resolution is 0.4 mm while contrast resolution for the soft tissue is equivalent to 5 HU at a slice thickness of 10 mm.

The reconstructed isotropic soft tissue volume is displayed automatically on the monitor in the examination room; manipulation and viewing of the image volume can be done directly at the tableside as well as in the control room.
Lung biopsies technique

The biopsies were performed by two interventional radiologist (GP.C. and F.F. with 15 and 7 years of experience respectively).

Written informed consent was obtained from each patient before the procedure. During the procedure, heart rate, ECG, oxygen saturation and respiratory rate were continuously monitored, while blood pressure was obtained every 4 minutes.

The patients were placed prone or supine depending on the lesion location.

Once CBCT scan was acquired, the access area was prepped with sterile technique and local anesthesia was given (10 cc of mepivacaine 2%, Angelini, Roma, Italy).

The needle was then advanced according to the virtual path determined by the operator with realtime fluoroscopy. Once the target reached, a confirmation CBCT was obtained.

In all cases, fine needle aspiration was obtained with 20 Gauge bioptic needle (Biopsy Bell, Medical Device, Modena, Italy).

Immediately after FNAB an additional CBCT was performed to evaluate any complications, moreover a follow-up postero-anterior expiratory chest radiograph was also obtained two hours after biopsy. The complications were classified into minor and major complications according to SIR classification [6].

Calculation of Radiation Dose

Doses in Cone-Beam CT were calculated with PCXMC dose Calculations (version 2.0) according to ICRP 103 and considering a hermaphrodite phantom (Rando phantom, model RAN-10, Churcin Associates, Smithtown, NY ) [7].

For fluoroscopy, projection parameters such as source-to-skin distances, field dimensions and positions chosen during the actual procedures were used to calculate dose. An AP projection was chosen for supine patients, PA projection for prone patients and LR or RL projections depending on lesion site and patient position (x-ray tube as close as possible to pulmonary lesion).

The needle is advanced based on two views, one view is parallel to the needle and the other view is perpendicular to the needle. Adjustments are made in the orthogonal view.

Doses were calculated considering the actual Dose Area Product (DAP) imparted in each projection.
A single arc was divided into 43 steps, 5° each, and calculation was done taking into account patient position (supine or prone). Doses were calculated dividing total arc DAP in 43 equal parts and associating one part to each step. This schematization seems adequate because C-arm speed rotation is nearly constant.

**Statistical analysis**

Technical success rate, sensitivity, specificity, positive predictive value, negative predictive value and accuracy were calculated.

Technical success was defined as correct placement of the needle into the lesion.

Accuracy was determined by comparing FNAB with final histopathological diagnose in cases of surgical resection or clinical and radiological outcomes if surgery was not performed.
Fig. 1: CT scan of 78 year old man with 1.7cm central nodule in right upper lobe

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Fig. 2: Preliminary C-arm CBCT scan for path planning and lesion determination.

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Fig. 3: CBCT navigation platform planning in axial and sagittal plane

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**Fig. 4:** CBCT scan obtained during aspiration shows needle positioning in the nodule in axial plane.

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**Fig. 5:** CBCT axial image: control after biopsy, with no evidence of pneumothorax. We observe internal cavitation (white arrow) and mild blood perilesional effusion (small arrow)

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Results

Technical success rate was achieved in 100% of cases.

Accuracy was 94.2%. Forty-six lesions were diagnosed as malignant, 20 were benign, and 4 were indeterminate.

Only 20 of 70 nodules underwent surgical resection and the remaining 50 were followed - up with clinical and CT features.

Of the 20 patients who underwent surgery, final pathological diagnosis was concordant with FNAB diagnosis in 17 cases and discordant with FNAB diagnoses in 3 cases. This discrepancy was likely caused by sampling error during fine needle aspiration of lesion.

Of the 50 of 70 nodules who were followed, 26 were malignant, 20 were benign and 4 were indeterminate.

All malignancies diagnosed by FNAB were confirmed by history and imaging. However of the 20 benign diagnosed by percutaneous biopsy, four were false negatives. In these four cases two patients were diagnosed by FNAB as fibrous tissue and two as non-specific flogoses, however final pathological diagnosis revealed malignancy in all of them. These lesions were heterogeneous with areas of necrosis, which were likely the areas sampled during FNAB explaining the results.

The overall accuracy, sensitivity, specificity, positive predictive value and negative predictive value were 94.2%, 92%, 100%, 100% and 92%, respectively.

The accuracy sensitivity, specificity, positive predictive value and negative predictive value for lesions 3 cm or smaller were 91.2%, 86.9%, 100%, 100% and 78.5%.

The accuracy sensitivity, specificity, positive predictive value and negative predictive value for lesions larger than 3 cm were 97.2%, 96.2%, 100% 100% and 90%.

The overall complication rate in our study was 22.8% (16/70); eight pneumothoraces in each group and only one required chest tube in the small lesion group.

There were no severe complications such as air embolism or procedure-related death. There was no difference between the two groups (lesions < or equal to 3cm and lesions > 3cm) in terms of

complications and radiation dose.
In the 34 patients comprising the first group undergoing XperCT guided lung biopsy the average effective dose was 11.14 mSV (range 1.39-27.29 mSv), while in the 36 patients comprising the second group the average effective dose was 12.10 mSv (range 2.89-49.46 mSv).
Conclusion

CBCT is a technology whereby CT-like images are acquired through the use of a C-arm angiography system that rotates around the patient.

In our study the diagnostic accuracy, safety of CBCT-navigation for percutaneous transthoracic lung biopsy are satisfying, similar to previous publications about this technique [8-13].

CBCT navigation, thus, offers the advantage of CT-like imaging and real-time fluoroscopy as opposed to high radiation of CT fluoroscopy.

Moreover, the use of CBCT to guide percutaneous transthoracic lung biopsy could be useful in Radiology Departments allowing CT just for diagnostic examinations, optimizing resources.
References


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