Feasibility Study on Pinhole X-ray Fluorescence Imaging for Metal Nanoparticles Using 2D Pixelated CZT Gamma Camera

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1. Introduction

Numerous studies on gold nanoparticle (GNP)-mediated radiation therapy have been conducted [1, 2]. In order to further develop the GNP-mediated radiation therapy, the biological effects and toxicity should be monitored based on *in vivo* biodistributions in the target and normal tissues [1]. X-ray fluorescence (XRF) imaging can be potential imaging modality which can obtain low concentration GNPs. Among several XRF imaging techniques, an imaging system consisted of pinhole collimation and 2D pixelated detector has shown outstanding performances in terms of image acquisition time, spatial resolution and detection limit [3].

2. Methods and Results

2.1 Energy calibration

A commercial Cadmium Zinc Telluride (CZT) gamma camera was chosen to be used in this study (SRE4001-CZT25.4, IDEAS, Oslo, Norway). The gamma camera has 5-mm-thick CZT and offers spectroscopic information of photon counts from ~40 keV to 350 keV. The number of pixels are 1024 with 1.6 mm pixel pitch. Thus, the active area is 5.12 cm x 5. 12 cm. The energy calibration of gamma camera was performed by using several radio-isotopes; Am-241, Ba-133, Cd-109, Co-57. The energy calibration curve was obtained as shown in Fig. 1.

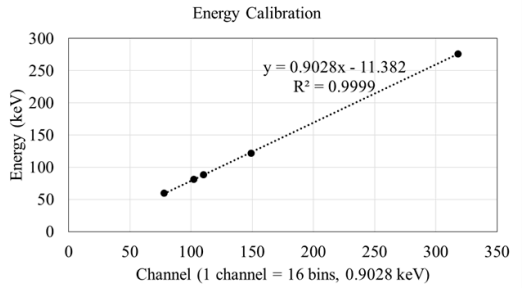

Fig. 1. Energy calibration curve of CZT gamma camera.

2.2 Experimental setup

The experimental setup was shown in Fig. 2. The imaging system was configured with sample stage, pinhole collimator, tungsten collimator, and CZT gamma camera. The design of our imaging system was based on our previous work [3]. The diameter and the thickness of pinhole collimator was 2 mm and 10 mm, respectively. The small part of pinhole was made of tungsten, while the shielding part was made of lead. Tungsten collimator was attached to the front window of gamma camera to block leakage photons originated from X-ray tube. Lead wire was put on the sample stage. The polychromatic X-rays of 140 kVp with aluminium, tin and copper filter was used to stimulate the emission of XRF from the lead wire (X-RAD 320, Precision X-ray, North Branford, CT, USA).

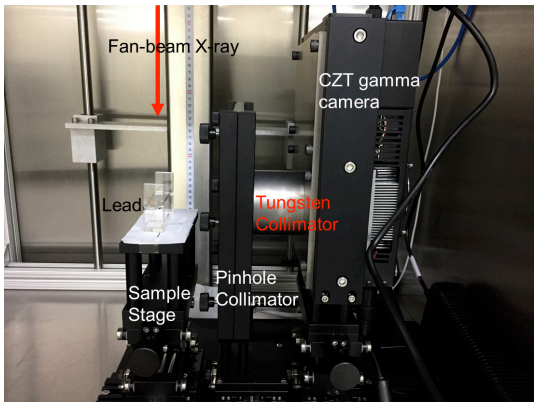

Fig. 2. Experimental setup of pinhole X-ray fluorescence imaging consisted of polychromatic X-rays, lead, CZT gamma camera and pinhole collimator.

2.3 Measurement and signal processing

Fig. 3 shows energy spectra at central pixel of CZT gamma camera measured for lead and without lead. When lead wire was on the sample stage, K-shell XRF signals were observed at 70-80 keV and 80-90 keV. The largest photon counts were K_α peaks. In order to obtain XRF images of lead, photon counts at 70-81 keV were selected.

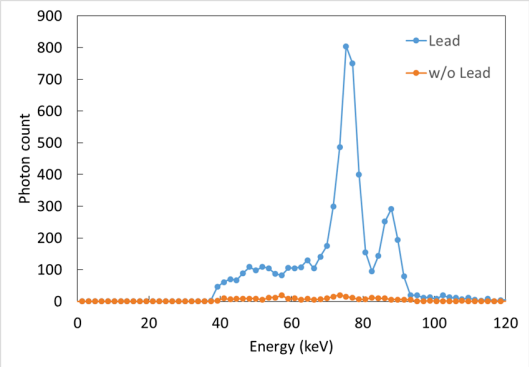

Fig. 3. X-ray spectra at central pixel of CZT gamma camera.

Net fluorescence counts were then calculated by subtracting the signals without lead from the signals with lead as shown in Fig. 4.

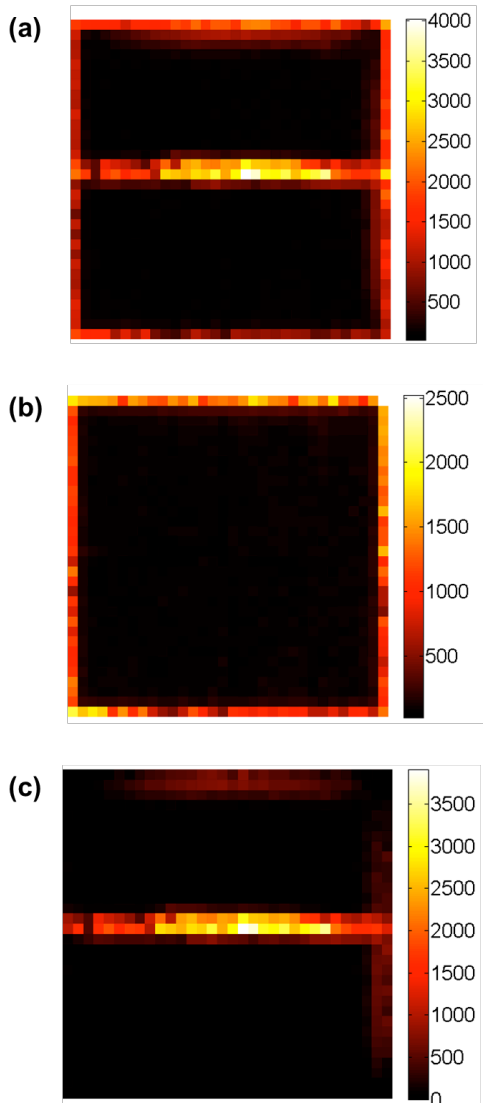

Fig. 4. Images obtained by CZT gamma camera (a) with lead, (b) without lead on the sample stage. (c) Net X-ray fluorescence image of lead.

3. Conclusions and Future Work

Pinhole XRF imaging using polychromatic X-rays and 2D pixelated gamma camera appears to be feasible for imaging and quantification of metal element. Although this study could not guarantee good results for XRF imaging of low concentrated GNPs, but it was observed that XRF peaks from lead could be measured by our developed imaging system. Further investigation of XRF imaging for GNPs is required.

REFERENCES

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