Application of an Energy Sensitive CZT Detector to a DXA Type of Bone Densitometer

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ABSTRACT

The accuracy of DXA(Dual Energy X-ray Absorptiometry) highly depends on the detection and separation capability of dual energy X-ray X-ray photons. In addition both of scan time and patient exposure are affected by detection efficiency.

A CZT detector with a good energy resolution and high detection efficiency was evaluated for the application of bone densitometry. Its performance was compared to a photomultiplier tube with a NaI(Tl) scintillator in terms of energy resolution, detection efficiency and the accuracy of bone mineral density measurement.

The comparison study was performed with CZT detector and PM tube using DXA equipments(OSTEO Plus, OSTEO Prima, ISOL Technology). The energy spectrum was acquired using MCA(Multi-Channel Analyzer). The used X-ray energy ranged from 20keV to 86keV.

The MCA result of the CZT detector showed a slightly sharper energy spectrum than that of NaI(Tl). Detection efficiency of the CZT detector at 59.5keV was 1.4 times better. Remarkably the final results of bone mineral density measurements demonstrate only less than 1% difference.

The CZT detector appears to have many benefits for the application of bone densitometry. Its excellent energy resolution can enhance the counting accuracy of dual energy X-ray spectrum. Furthermore its compactness in physical dimension and no cooling requirement will be additional benefits for a more compact and accurate bone densitometer.

Keywords: CZT, bone densitometer, scintillator

INTRODUCTION

The bone densitometry using dual energy X-ray absorptiometry(DXA) has been a standard method for the diagnosis of an osteoporosis. The pencil beam DXA that uses a single detector system requires an energy sensitive detector. A NaI(Tl) scintillator combined with a photomultiplier tube has been widely used for DXA. In spite of its superior detection efficiency of scintillation detector, it has a couple of disadvantages such as large size, performance degradation due to the temperature and humidity changes.

A CZT detector with good energy resolution and high detection efficiency was evaluated for the purpose of bone densitometry applications. Its performance was compared to that of a photomultiplier tube with a NaI(Tl) scintillator in terms of energy resolution, detection efficiency and the accuracy of bone mineral density measurement.

MATERIALS AND METHODS

We applied the CZT detector to commercial DXA products such as OSTEO Plus for forearm scan and OSTEO Prima for spine/femur made by ISOL Technology. The ranges of peak X-ray energies were 57keV for OSTEO Plus and 86keV for OSTEO Prima. In this study dual energy X-ray were generated by K-edge filter.

The CZT detector module(eV PRODUCTS, Saxonburg, USA) is comprised of CZT crystal, preamplifier, pulse shaping amplifier and high voltage unit. The CZT crystal has a diameter of 11.7mm and a thickness of 3mm. The NaI(Tl) scintillation crystal (25 mm diameter, 2.5mm thick) was coupled to 38mm diameter photomultiplier tube(SCIONIX, Holland).

To compare the performance of different detectors, the single energy spectrum was acquired with Am-241 radioisotope. The 59.5keV peak energy of Am-241 is close to the energy range used in bone densitometry. Both detectors were placed 15 cm away from the source. The acquisition time was 30 sec accordingly.

The energy spectra were acquired in each detector with MCA(Amptek, USA) and the spectrum analyzer embedded in OSTEO Prima. Spine phantom scans were performed with the CZT detector installed in the OSTEO Prima. And the precision and accuracy of bone mineral density were evaluated.

RESULTS

The CZT demonstrated 1.4 times better detection efficiency at the peak energy of Am-241 as shown in the figure 1. In Fig. 2 the energy spectra of each detector were shown with a dual energy X-ray source which is used as a source of OSTEO Plus. Though the high energy peak(~52keV) of CZT was higher as expected in the single energy study, unexpectedly, the counting efficiency was decreased at the low energy peak(~27keV). This might be caused by the difference of the detector entrance window. The window of CZT detector is made of brass, which should absorb more low energy X-ray photons than in NaI(Tl) detector with thin Aluminum window.

The energy spectra acquired in OSTEO Prima with both detectors were as shown in Fig. 3. Vertical lines are displayed for the threshold values of low and high energy channels. The measured value of low energy channel was 98% of NaI(Tl) and 88% in high energy. The area and crystal thickness of detector might be the cause of this discrepancy.

Preliminary phantom scan images with CZT detector are as shown in Fig.4. The precision and accuracy of bone mineral density were only within 1% error.

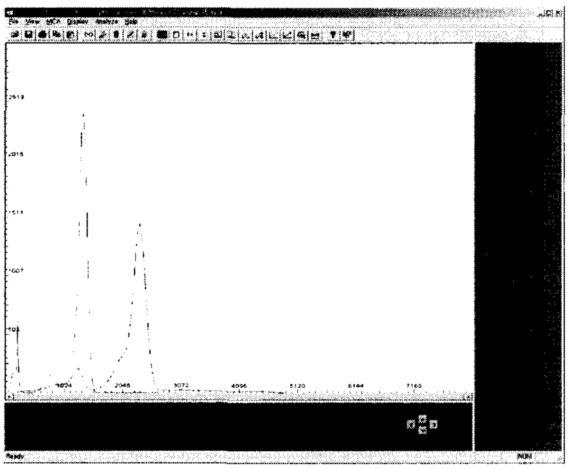

Fig.1 Am-241 spectra (CZT : green, NaI(Tl) : violet)

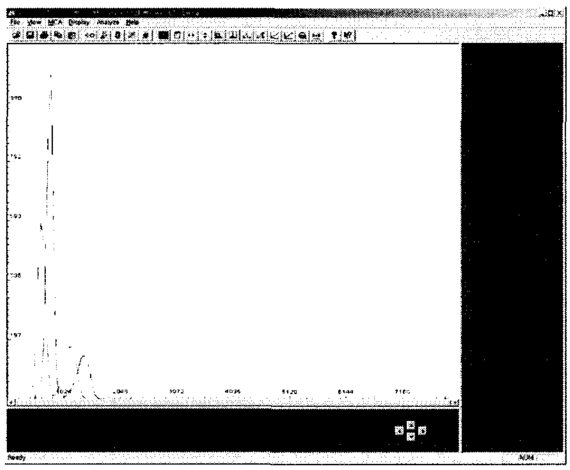

Fig.2 Spectra in OSTEO Plus (CZT : green, NaI(Tl) : violet)

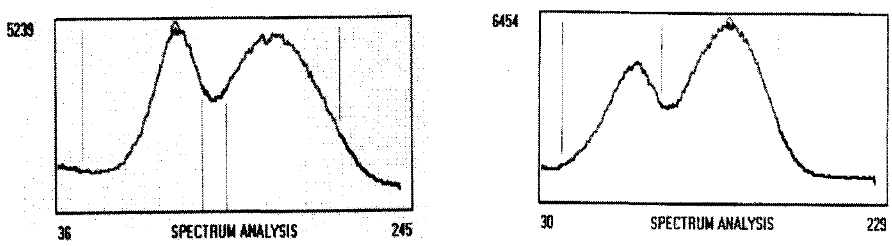

Fig. 3 Spectra in OSTEO Prima (CZT : left , NaI(Tl) : right)

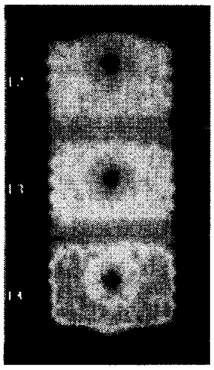

Fig. 4 Spine phantom scan image with CZT detector

CONCLUSION

The modification on a detector window with a low-Z material will enhance the low energy counting efficiency. We could reduce a detector arm size by half with CZT detector.

Considering the detection efficiency and the accuracy of bone mineral density, the CZT detector appears to be an excellent alternative choice for the replacement of the widely used scintillation detector. Its compact size and insensitivity to temperature and humidity will be additional benefits for a more compact and accurate bone densitometer.

REFERENCES

1. R. B. Mazess, J. A. Hanson, R. Payne, R. Nord and M. Wilson, "Axial and Total Body Bone Densitometry Using a Narrow-Angle Fan Beam", Osteoporosis Int. 11, pp 158-166, 2000
2. Glenn F. Knoll, "Radiation Detection and Measurement"