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Feasibility Study for dual-energy X-ray computed tomography system

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Introduction

Dual-energy X-ray computed tomography (CT) can provide distribution of electron density which is important in treatment planning for particle radiotherapy. The electron densities, which obtained from CT scanning by monochromatic X-rays of two different energies, were in agreement with theoretical values within ±1 %[1,2]. For the next step, we have been developing a mixed dual-energy X-ray CT system which is more efficient for clinical applications.

Mixed dual-energy X-ray CT system

Experiments and System Setup

Experiments of the mixed dual-energy X-ray CT were carried out at NE5A beamline in AR. In the CT scanning, X-rays reflected by a Si(220) double crystal monochromator fully tuned to Bragg reflection angle of 40 keV were used [3]. They include the second order harmonics (80 keV X-rays)with a few percent in photon flux as well as the fundamental (40keV X-rays). The mixing-ratio of the photon flux of 80 keV X-ray to that of 40 keV can be changed by inserting a metallic filter in front of the monochromator. Two projection images taken by two kinds of X-rays with different mixing-rations were converted to two equivalent images taken by monochromatic X-rays of 40 keV and 80 in consideration of the detection efficiencies of the detector and the mixing-ratios. The mixing-ratio was derived from the energy spectrum of Compton scattering X-rays scattered from a thin Al sheet measured using CdTe detector during the CT scanning. A metal filter was Cu plate of thickness 1.0 mm. The ratio of 80 keV to 40 keV was 2.04 with a filter and was 0.015 without a filter. The CT scanning of a transfer-rotation method using a plastic scintillation detector was used in these experiments. The size of scanning beam was 1 mm × 1 mm, and the diameter of a collimator covering a detector was 5 mm. The sliding step was 1 mm, the rotation step was 0.8 ° and total 180 ° scanning was carried out.

Samples

Samples for the experiments were a lung phantom (Kyoto Kagaku), a sausage, and a raw egg, and liquid samples: solutions of dipotassium hydrophosphate (K2HPO4), water, and ethyl alcohol. The measured electron densities of liquid samples were compared with theoretical values. Since it is difficult to theoretically calculate the electron densities of the solid samples, they were evaluated by measuring the range of high-energy carbon ions in water [4] except for the raw egg.

Result

The preliminary results are summarized in Table 1. They are compared with the theoretical values or the values measured with the range-method (reference value). The electron densities of the solid samples agree with the reference values within about 1 %. While those of the liquid samples except Ethyl alcohol agree with the theoretical values about 2 %. The causes of the worse agreement in the liquid samples are under consideration. Not only the image based on the electron density but also the image based on an effective atomic number are reconstructed. The effective atomic number is obtained in the process of analyzing the electron density. Both the images show different aspects of a sample.

Table 1 Preliminary results of electron density

Sample	Electron density $\times 10^{23}$ cm^{3}	Theo./Ref. Value $\times 10^{23}$ cm^{3}	Difference %
Water	3.41±0.023	3.34	2.1
K2HPO4 1 %	3.42±0.026	3.36	1.8
K2HPO4 2 %	3.47±0.021	3.38	2.7
K2HPO4 3 %	3.49±0.018	3.41	2.3
K2HPO4 4 %	3.52±0.031	3.44	2.3
K2HPO4 5 %	3.56±0.025	3.45	3.2
Ethyl Alcohol	2.69±0.031	2.68	0.2
Lung Phantom	1.16	1.15	0.8
Sausage	3.51	3.51	0.1

Summary

We carried out the experiments of the mixed dual-energy X-ray CT system. The preliminary results proved that the accuracy of this method was about 1~2 %. In addition, the images of the electron density and the effective atomic number may be useful for to diagnosis because both the images are expressed different characteristics of an object.

Reference

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