学位論文の要旨

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学位論文名	Performance Evaluation of a Direct-Conversion Flat-Panel Detector System in Imaging and Quality Assurance for a High-Dose-Rate ^{192}Ir Source
発表雑誌名 （巻，初頁～終頁，年）	Physics in Medicine & Biology (63, 5, online:055017, 2018)
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論文内容の要旨

INTRODUCTION

In internal irradiation, ^{192}Ir high-dose-rate (HDR) brachytherapy is a well-established cancer treatment. A ^{192}Ir source emits gamma photons, beta-rays and characteristic x-rays from a radioactive solid core which is enclosed in a stainless steel capsule and attached to a stainless steel cable. In order to depict a radioactive ^{192}Ir source by radiography, dual-rays (high-energy gamma-rays from a radioactive source and X-rays from a generator) must be incident on the detector. With conventional devices such as an image intensifier, it was not possible to clearly depict a source image due to image halation. A direct-conversion flat-panel detector (d-FPD) system has made it possible to depict a ^{192}Ir source without image halation. However, the performance evaluation of the d-FPD system has been difficult on depicting a radioactive source due to incident dual-rays simultaneously emitted to the detector. To overcome this problem, we developed a subtraction technique to process raw data obtained from the dual-rays.

The routine quality assurance (QA) procedure for a ^{192}Ir source is an important task to provide appropriate brachytherapy. We conducted QA tests for a source positional accuracy using two different types of clinical applicators and d-FPD. The differences of the 192-Ir source positions between planned and actual positions were evaluated by three dimensional coordinates.

Our purpose was to evaluate the performance of a d-FPD system for the imaging of a source, and to establish a new quality assurance test method to promote source positional accuracy using the d-FPD system.

MATERIALS AND METHODS

The physical imaging characteristics of the d-FPD were evaluated on depicting a ^{192}Ir source, which emits gamma-rays, regarding the modulation transfer functions (MTF) with an edge phantom, noise power spectral (NPS) with an aluminum plate, contrast transfer functions (CTF) with a microchart, and linearity of d-FPD to high-energy gamma-rays. The acquired data included X-rays: [X], gamma-rays: [γ], dual-rays (X+γ): [*D*], and subtracted data for depicting the source ([*D*] - [γ]).

In the quality assurance (QA) test for the positional accuracy of a source core, the coordinates of each dwelling point were compared between planned and actual source core positions using CT/MR-compatible ovoid applicator and Fletcher-Williamson applicators.
Three-dimensional coordinates were constructed by the semi-orthogonal method from the d-FPD images (frontal and lateral views) obtained using a reconstruction jig and an applicator with a radio-opaque catheter (markers).

RESULTS AND DISCUSSION

The profile curves of [X] and ([*D*] - [γ]) matched well on MTF and NPS. Additionally, with NPS measurement, four kinds of data, [X], [γ], [*D*], and ([*D*] - [γ]), could be acquired. The results indicate that d-FPD would identify and differentiate X-rays from gamma-rays as electrical charges, even when these are simultaneously transmitted to the detector. In other words, the data subtraction procedures are considered innovative and potentially a breakthrough technique for the analysis of each spatial frequency characteristic in multi-rays. In CTF measurement, contrast resolutions of [*D*] and [X] were equivalent. Thus, the image quality of d-FPD is considered unaffected by high-energy gamma-rays.

In linearity measurement of d-FPD to high-energy gamma-rays, the d-FPD is considered to have had a wide dynamic range for detection of high-energy gamma-rays, as well as excellent linearity between output values of d-FPD and the ^{192}Ir source strength.

With regard to the accuracy of the source core position, the source cores with two different types of applicators were clearly depicted, and the coordinates of the source core could be identified. In the evaluation of the differences of the source positions, since 1σ of each axis was almost within 0.1 mm (0.17 mm at the maximum), high reproducibility of our measurement, and high precision of the source dwell positions were suggested. The largest coordinate difference (3D-distance) was noted at the maximum curvature of the CT/MR-compatible ovoid and

Fletcher-Williamson applicators showing 1.74 ± 0.02 mm and 1.01 ± 0.01 mm, respectively. This is because the ^{192}Ir capsule-tip moves along the inner-diameter at some angles. The recommendation of the American Association of Physicists in Medicine (AAPM) for source position accuracy is ± 2.0 mm relative to the applicator system. In our study, all positional errors were within the acceptable range.

CONCLUSION

With d-FPD, X-rays for depiction of a ^{192}Ir source are unaffected by high-energy gamma-rays, even though these are simultaneously transmitted with X-rays to the detector. In addition, the source positional accuracy test with clinical applicators we conducted is considered useful for quality assurance of d-FPD, as well as contributing to the accuracy of high-dose-rate brachytherapy.