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An attempt to measure the linearity of diagnostic flat-panel detectors with monochromatic X-rays

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1 Introduction

At present, diagnostic flat-panel detectors (FPDs) are clinically used on the premise that exposure doses and pixel values form a linear relationship with conventional diagnostic X-ray photography. Radiographs are therefore taken in conditions where X-ray input/output characteristics of FPDs are stable.

In the generation of diagnostic images with FPDs, images are often processed to suit a specific diagnostic purpose. Image processing often involves gradation processing, in which the tone varies, and it is questionable whether the linear input/output relationship between conventional diagnostic X-rays and FPDs is preserved.

To address this question, in this experiment, we attempted to measure the linearity of FPDs to X-rays via monochromatic X-rays using a diagnostic range and an aluminum step wedge.

2 Major equipment used

Experiment station : BL-14C
Monochromatic X-ray energy : 33 keV
FPD：CXDI-80CWireless (Canon)
Pixel size : 125μm×125μm
Aluminum step wedge : 10 stair-steps (Fig.1)
Shutter (Fig.2)
Aluminum plate : 10-mm thick plate

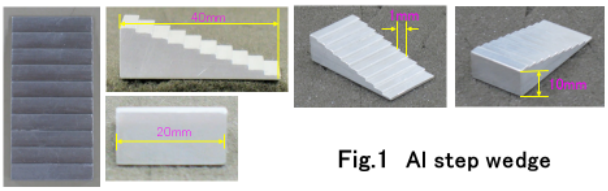


Fig.1 Al step wedge

Fig.2 Shutter

3 Methods

I . Preparation of images for measurement

i Experimental alignment (Fig.3)

- An aluminum plate and a shutter were placed on the radiation port side.
- Distance between the radiation port and the shutter : 38cm
- Distance between the shutter and the diffraction crystal : 77cm
- Distance between the diffraction crystal and the FPD : 100cm
- Radiation field : 40mm×40mm

ii Irradiation method

- Considering the time for afterglow in the FPD to become extinct, 60 s was chosen as the minimum irradiation interval.
- Irradiation time : 1 s
- Application of irradiation : 3 times
- Three images were prepared (Fig. 4).

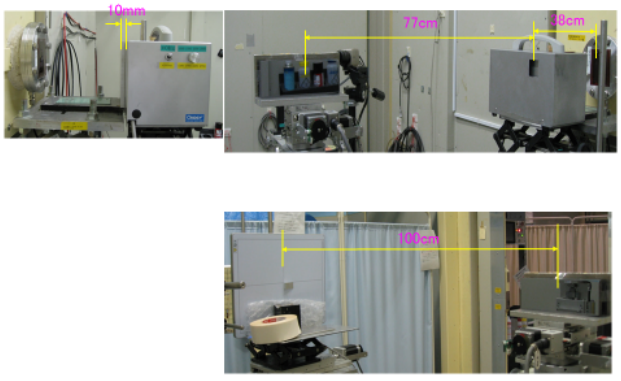
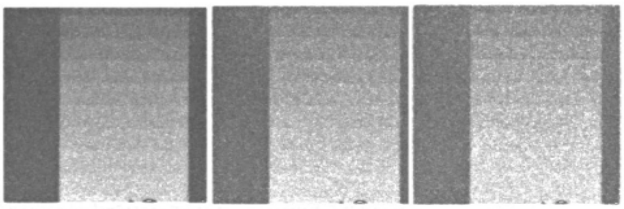


Fig.3 Experimental alignment



〔Image 1〕 〔Image 2〕 〔Image 3〕

Fig.4 Images

Ⅱ. Measurement of pixel values (Fig.5)

- Using ImageJ, regions of interest (ROIs) were set on each stair-step of the aluminum step wedge and in an area outside the aluminum step wedge (referred to as the zeroth stair-step of the aluminum step wedge), and the mean pixel value of the three images was determined for each ROI.
- ROIs on the first and tenth stair-steps of the aluminum step wedge had an area half as large as the ROIs on the other stair-steps as images of the former two stair-steps were narrower than those of the other stair-steps.
- The image of the zeroth stair-step of the aluminum step wedge was wide; thus, the ROI on this step had an area twice as large as ROIs on the second to ninth stair-steps.
- Number of ROIs set
  Aluminum step wedge : 10
  Outside the aluminum step wedge : 1
- Area of ROI (number of pixels)
  First and tenth stair-steps of the aluminum step wedge : 148000 pixels
  Second to ninth stair-steps of the aluminum step wedge : 296000 pixels
  Outside the aluminum step wedge (zeroth stair-step) : 592000 pixels

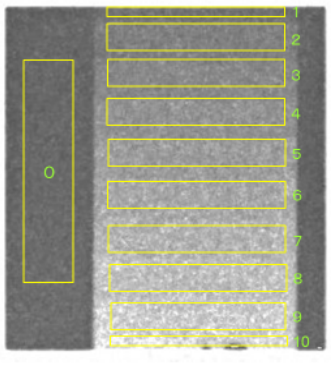


Fig.5 Number of ROIs set

4 Result

Ⅰ. The pixel values (Table.1)

- Pixel values of the three images ranged from approximately 1500 to 3500.

Ⅱ. Relationship between the aluminum step wedge and pixel values (Fig.6, Fig.7)

- The correlation between the stair-step numbers of the aluminum step wedges and pixel values is shown in all three images.
- A correlation was found between the stair-step numbers of the aluminum step wedges and the mean pixel values of the three images (correlation coefficient : 0.997)

Al step wedge	Image 1	Image 2	Image 3	AVERAGE
0	1693	1889	2007	1863
1	1846	2112	2244	2068
2	2065	2313	2460	2279
3	2208	2455	2624	2429
4	2364	2572	2798	2578
5	2513	2726	2912	2717
6	2696	2912	3118	2909
7	2896	3121	3346	3121
8	3074	3335	3457	3289
9	3342	3544	3593	3493
10	3501	3622	3596	3573

Table.1 pixels value

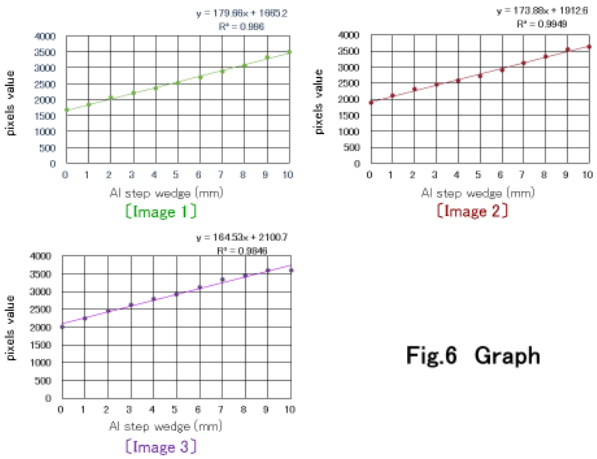


Fig.6 Graph

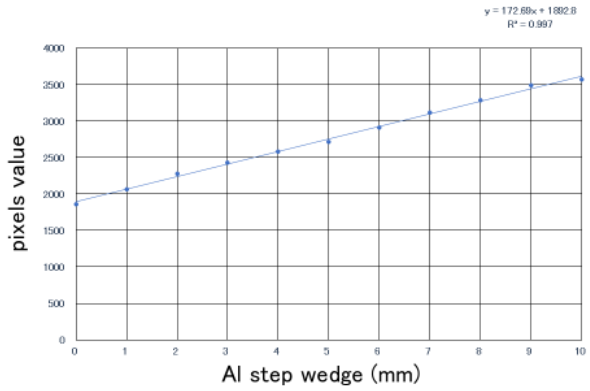


Fig.7 Graph

5 Discussion

- A correlation was found between the stair-step numbers of the aluminum step wedges and pixel values from each of the three images or mean pixel values of the three images. Therefore, it can be concluded that the linearity of FPDs to X-rays is preserved.
- Based on these results, we propose that X-rays need to be monochromatic to generate diagnostic X-ray images. Alternatively, it is desirable to make X-ray spectra as close to monochromatic as possible.
- Although X-ray scattering from aluminum step wedges was not considered in the present experiment, scattered X-rays may need to be measured to improve the measurement accuracy.

6 Conclusion

In this experiment, we attempted to clarify the relationship between incident X-ray doses (exposure doses), which represent the basis of input/output characteristics of FPDs, and pixel values using aluminum step wedges.
Our results showed that the linearity of FPDs was maintained, indicating that FPDs are suitable for the generation of digital images.

7 Future tasks Problem

We propose that (1) measurement of X-ray scattering from aluminum step wedges, which was not considered in the present experiment, and (2) measurement of linearity using diagnostic X-rays (continuous spectrum X-rays) should be performed in studies for obtaining clinical images.

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