Quantitative evaluation method for metal artifact in virtual monochromatic CT image

S. Tanaka[1,2,3], Hiroki Shirato[3,4,5], Takaaki Yoshimura[6], Yuto Matsuo[2,3], Rie Yamazaki[7], Seishin Takao[2,3], Naoki Miyamoto[1,2,5], Shinichi Shimizu[2,3,4,5]

[1]Faculty of Engineering, Hokkaido Univ., [2]Department of Medical Physics, Hokkaido Univ. Hosp., [3]Proton Beam Therapy Center, Hokkaido Univ. Hosp., [4]Faculty of Medicine, Hokkaido Univ., [5]Global Station for Quantum Medical Science and Engineering, Global Institution for Collaborative Research and Education (GI-CoRE), Hokkaido Univ., [6]Faculty of Health Sciences, Hokkaido Univ., [7]Division of Medical Imaging and Technology, Hokkaido Univ. Hosp.

INTRODUCTION

Metal Artifact in CT image for proton therapy

It is important to predict an accurate range of proton in treatment planning of proton therapy. Metal artifact is a serious problem in range calculation. Dual-Energy CT including virtual monochromatic CT is effective for metal artifact[1].

The standard deviation of region of interests (ROI) around metal is often used for evaluation of metal artifact. However, it depends on white noise, which has little effect on range calculation.

Purpose

Development of a quantitative evaluation method of metal artifact which is independent of noise for the optimization of Virtual monochromatic CT

METHODS

Virtual monochromatic CT images

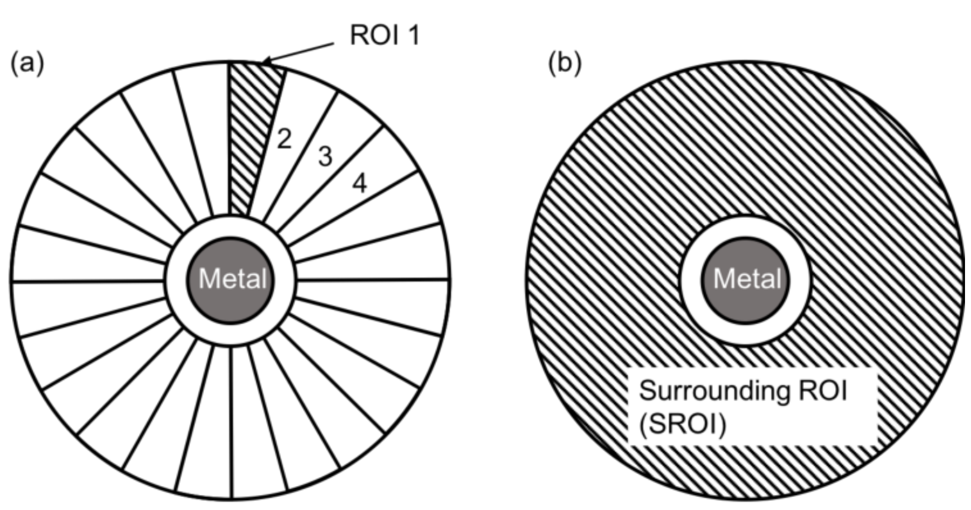
Image-based virtual monochromatic CT image (mono-CT image) can be derived as inter- or extrapolation of of the CT images at low and high energy scan[1]. ω is the weight to determine the mono-CT image.

$$HU_{\mathrm{mono}} = \omega HU_{\mathrm{L}} + (1-\omega) HU_{\mathrm{H}}$$

Evaluation method for metal artifact

We focused on macroscopic distortion around metal. In the method, we assumed the uniform substance around the metal and considered 24 ROIs around the metal (Fig. a). Average pixel values in each ROI represent macroscopic angular distribution (MAD) of metal artifact, which is independent of noise. The standard deviation of MAD (SD-MAD) was regarded as the intensity of metal artifact. The standard deviation of surrounding ROI (SD-SROI) was also calculated for comparison (Fig. b).

(a) SD-MAD	Standard deviation of 24 ROIs
(b) SD-SROI	Standard deviation of pixels in surrounding ROI

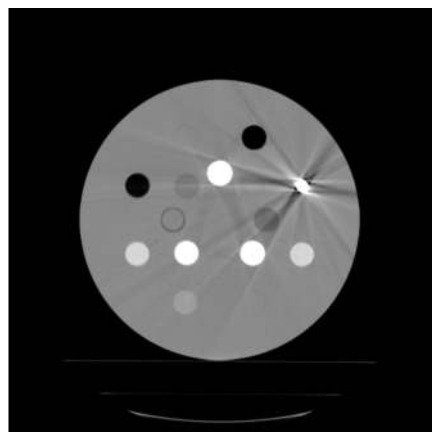


Experiments

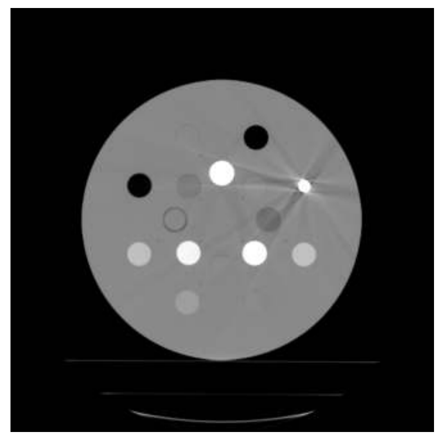
CT images of a GAMMEX phantom (Model 467) with an additional titanium insert were acquired using Optima 580w (GE) with various energies. Virtual monochromatic CT images were calculated as the linear combination of 80 and 140-kV CT images. Virtual monochromatic CT images with intentional noise were also evaluated.

RESULTS/ DISCUSSION

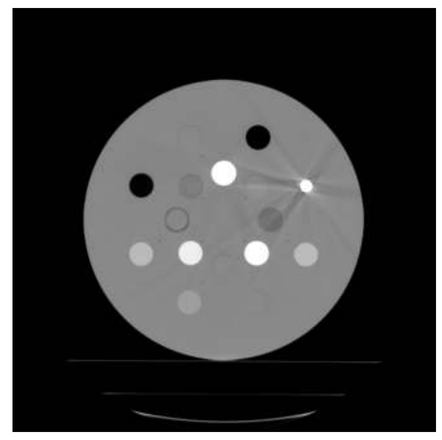
Single-Energy CT images



80-kV CT image
SDMAD: 93.588
SDSROI: 128.286



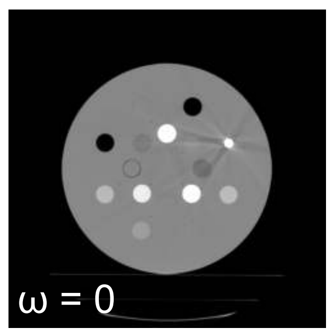
120-kV CT image
SDMAD: 35.357
SDSROI: 50.363

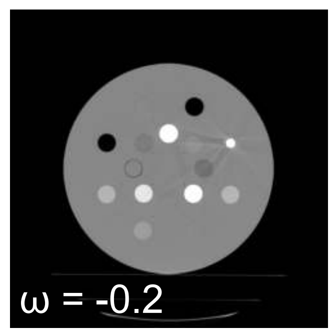


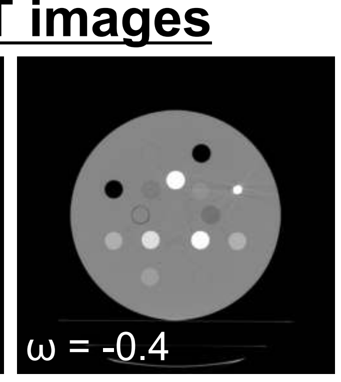
140-kV CT image
SDMAD: 26.579
SDSROI: 37.643

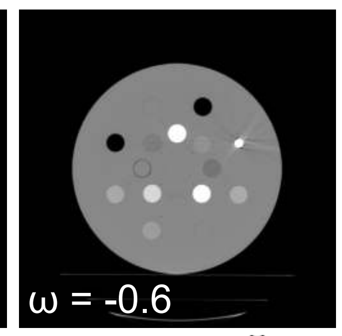
SDMAD and SDSROI agree with subjective evaluations.

Virtual Monochromatic CT images







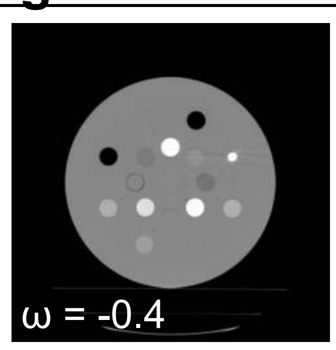


Intensity of metal artifact can be reduced in mono-CT images derived from extrapolation of two CT images.
By three evaluation methods (SD-SROI, SD-MAD, subjective evaluation), weight was optimized as -0.35 or -0.40 in terms of metal artifact.
SD-SROI and SD-MAD represent intensity of metal artifact quantitatively.

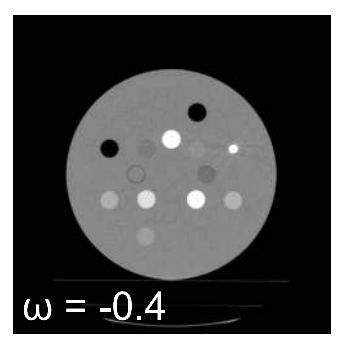
Weight (ω)	SDSROI	SDMAD
0.00	26.579	37.643
-0.05	23.334	33.634
-0.10	20.135	29.831
-0.15	17.008	26.323
-0.20	14.002	23.246
-0.25	11.214	20.791
-0.30	8.853	19.197
-0.35	7.343	18.687
-0.40	7.236	19.347
-0.45	8.587	21.066
-0.50	10.864	23.615
-0.55	13.610	26.758
-0.60	16.594	30.310
-0.65	19.708	34.144

Virtual Monochromatic images with noise

In mono-CT image with intentional noise, same weight was derived as optimized mono-CT image. SD-MAD was almost constant in the case of noised CT image, which differs from SD-SROI.



Mono-CT image
SDMAD: 7.343
SDSROI: 18.687



Mono-CT image with noise
SDMAD: 7.597
SDSROI: 30.961

SD-MAD is the quantitative evaluation method of metal artifact which is independent of noise.

CONCLUSION

We established a quantitative evaluation method for metal artifact which is independent of noise.
We derived an optimized monochromatic CT image with the index for metal artifact.

[1] Yu L, et al, Med. Phys. **38**, 6371-6379 (2011)

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