Metal artifact removal
In c-arm cone-beam ct

Group 4
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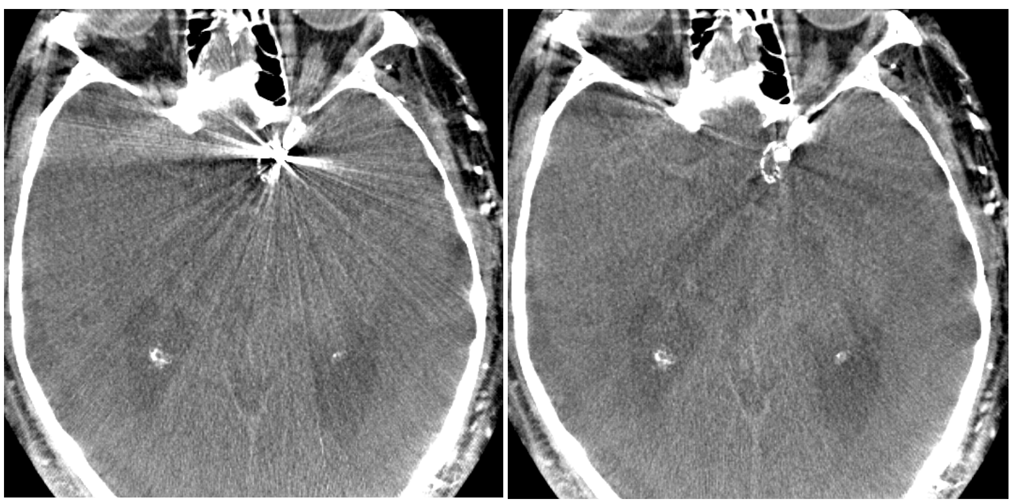
Report #4
MAR application & Data Analysis



CT image of coil before and after MAR algorithm application
Image provided by Radvany, MD

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Metal artifacts introduce systematic discrepancies between the raw data values and the reconstructed image data values in computed tomographic (CT) reconstruction techniques. These discrepancies, which may include streaking artifacts, and visual obstruction of surrounding soft tissue, can seriously degrade the image quality and image fidelity of CT imaging in interventional radiology procedures. Metal artifact removal (MAR) algorithms have been developed and are ready for clinical testing. Prior to clinical trials with such MAR techniques, quantitative analysis of their performance is essential. Data analysis performed in this project will undertake such quantitative assessment of image quality and image fidelity by testing a recently developed MAR technique in an endovascular coiling and clipping intervention guided by CT imaging using custom phantoms designed to emulate the treatment of aortic aneurysms.

I. Introduction

The primary purpose of medical imaging systems is to create accurate images of the internal structure and function of the body for diagnostic purposes or interventional treatment of diseases. The ability of medical professionals to successfully accomplish these tasks strongly depends on the fidelity of the images (the degree to which the image successfully represents the anatomy) and the quality of the images (the degree of degradation or distortion introduced into the image). CT imaging systems introduce some amounts of distortion or artifacts throughout the acquisition of the signal and reconstruction of the image while metal artifact algorithms (MAR) may distort the soft tissue data due to loss of information. Image quality assessments comprise the measurements of contrast, resolution and noise degradation while image fidelity assessments compromise the accuracy of the metal segmentation and the accurate representation of objects and surrounding soft tissue.

The term artifact is applied to any systematic discrepancy between the CT numbers in the reconstructed image and the true attenuation coefficients of the object. Artifacts do not represent valid anatomical objects and can obscure important targets or falsely appear as valid image features. Metal artifacts are caused by *beam hardening, partial volume effects, photon starvation,* and *undersampling;* metal artifacts result in heavy streaking patterns emanating from the metal object.

Image Quality and Fidelity

Contrast refers to the differences between the image intensity of an object and surrounding objects or background. In general terms, resolution is the ability of a medical imaging system to accurately depict two distinct events in time, space or frequency as separate. Therefore, we can talk about *spatial, temporal or spectral resolution*. Noise is a generic term that refers to any type of random fluctuation in an image, and it can have a dramatic impact on image quality. Relevant equations are shown below:

Artifact magnitude: parameter that quantifies the degradation of the background and surrounding structures caused by the presence of a metal artifact.

We define image fidelity as the occlusion or creation of surrounding soft tissue; accuracy of image in representing the correct anatomy

MAR Algorithm

Metal Artifact Removal algorithm is available from Siemens Healthcare and works in conjunction with the *syngo*® InSpace EP available in the Zeego Axiom Artis Zee Leonardo workstation.

Normalized Sinogram Inpainting method with threshold segmentation ? (available documentation?)

problems encountered

An update to the licensing needed to be completed before further application.

Various algorithm-error log files were sent to Siemens

II. Data Analysis for First Phantom: Metal Spheres

MAR Algorithm Application

It was found that after the first image acquisition of 02/28/2013???? the Zeego C-arm was un-calibrated. This produced unwanted geometric artifacts in the images obtained, hindering further data analysis. After C-arm calibration, a new calibration file was obtained and images were reconstructed again. Geometric artifacts were corrected with the acquisition of the new files.

- Include MATLAB generated picture of geometric artifact affected image.

Discuss problem with algorithm and licensing.

Data Analysis Methods

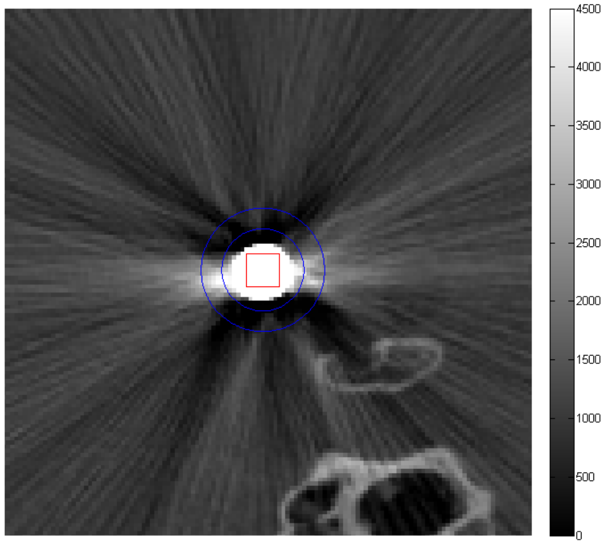
CNR was analyzed for each phantom image acquired. To analyze CNR,

1) For the smallest size metal spheres, 3.2mm, locate the center point coordinates of the sphere in the image.
   a. Select a rectangular box ROI (see Figure 1) of 5x5x4 pixels around this center point to represent the sphere area.
   b. For the background ROI, select the area that is enclosed by the region between two concentric circles of radii 7 and 11 pixels. This combined region in the four z-planes of interest forms the background ROI of a hollow cylinder.
2) For the middle size metal spheres, 6.4mm, locate the center point coordinates of the sphere in the image.
   a. Select a rectangular box ROI of 9x9x8 pixels around this center point to represent the sphere area.
   b. For the background ROI, select the area that is enclosed by the region between two concentric circles of radii 10 and 15 pixels. This combined region in the eight z-planes of interest forms the background ROI of a hollow cylinder.
3) In each of these two ROIs, the sphere and background regions, measure the mean (μ_{sphere} and $\mu_{background}$), and standard deviation (σ_{sphere} and $\sigma_{background}$) of the attenuation in both the original CT reconstruction images and the corresponding MAR corrected images.
4) Calculate $CNR = \frac{C}{\sigma} = \frac{|\mu_{sphere} - \mu_{background}|}{\sigma_{background}}$ for both the original and MAR corrected images.

Image Quality Analysis

High CNR values = better image quality. Data shows that CNR increases after MAR correction.

MAR algorithm Analysis



In order to analyze the distortion created by the metal artifact,

Extra notes:
Mar affecting any other objects
Set standard greyscale for all images, add colorbar to see range
Window – min to max contrast, level – center of window
otes : v

Table 1: Relevant values in images without MAR application

Image Number	Metal	μ_{sphere}	$\mu_{background}$	σ_{sphere}	$\sigma_{background}$
16	3.174mm, titanium	12602	1011.8	2586.7	39.9328
14	3.174mm, steel	32217	1022.5	10366	58.7050
17	6.35mm, steel	25016	1010.1	4197.3	80.6599
15	3.174mm, tungsten	44488	1011.4	15746	92.1705
19	6.35mm, tungsten	24979	1004.3	5186.6	103.9911

Table 2: Relevant values in images after MAR application

Image Number	Metal	μ_{sphere}	$\mu_{background}$	σ_{sphere}	$\sigma_{background}$
16	3.174mm, titanium	9358.2	1072.1	3130.4	32.0886
14	3.174mm, steel	20693	1072.0	3620.4	28.1363
17	6.35mm, steel	14678	1078.1	2310.1	29.3819
15	3.174mm, tungsten	25886	1062.2	3518.0	28.4213
19	6.35mm, tungsten	14586	1075.3	2903.4	29.4137

Table 3: Contrast-to-Noise values in images without MAR application

Image Number	Metal	Contrast = $\lvert\mu_{sphere} - \mu_{background}\rvert$	Noise = $\sigma_{background}$	CNR = Contrast/Noise
16	3.174mm, titanium	11590	39.9328	290.2477
14	3.174mm, steel	31194	58.7050	531.3705
17	6.35mm, steel	24005	80.6599	297.6130
15	3.174mm, tungsten	43477	92.1705	471.6988
19	6.35mm, tungsten	23974	103.9911	230.5433

Table 4: CNR values in images after MAR application

Image Number	Metal	Contrast = $\lvert\mu_{sphere} - \mu_{background}\rvert$	Noise = $\sigma_{background}$	CNR = Contrast/Noise
16	3.174mm, titanium	8286.2	32.0886	258.2277
14	3.174mm, steel	19621	28.1363	697.3541
17	6.35mm, steel	13600	29.3819	462.8566
15	3.174mm, tungsten	24824	28.4213	873.4147
19	6.35mm, tungsten	13511	29.4137	459.3497