Metal Artifact Reduction in Flat-Detector CT Acquisitions of Stent-Assisted Coiled Intracranial Aneurysms

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Purpose

In recent years the imaging capabilities of flat detector C-arm X-ray systems have been improved. Flat Detector Computed Tomography (FDCT) has become increasingly popular within minimally invasive endovascular interventions [1,2]. Very recently it has become feasible to visualize stents that possess very low radiopacity. The FDCT images offer the possibility to inspect the stent deployment with respect to the vessel lumen and intravascular plaques [3,4]. However, tomographic images of stents that are placed adjacent to aneurysms filled with coils are severely distorted by streaking artifacts caused by the metal coils. In this article, results are reported on reducing these artifacts in a second pass reconstruction.

Methods and Materials

VasoCT - High resolution FDCT of intracranial stents

For the purpose of imaging intracranial stents and their surrounding vasculature a dedicated acquisition protocol and reconstruction settings have been developed (VasoCT; Philips Healthcare, Best, the Netherlands) [3]. The high resolution protocol consists of 620 projection images acquired over a rotational trajectory of 200°, while the imaged detector area is set to a diameter of 22 cm and using a pixel size of 0.154 mm. The X-ray tube voltage is set to 80 kV, the focal spot to 0.4 mm, while no additional copper filter is used. This protocol enables very high spatial resolution 3D reconstructions.

The high resolution protocol can be combined with the injection of iodine contrast medium (either an intravenous injection, or an on-site intra-cranial injection of diluted contrast), in order to inspect the interface between stent and vessel lumen. In this manner it is possible to assess whether the stent has been properly deployed.

Patel et al. [4] have documented the resulting benefits in spatial resolution, as can be seen by comparing Fig. 1 on page 3 (regular soft-tissue FDCT) and Fig. 2 on page 5 (VasoCT reconstruction).

Metal artifact reduction

In the first step of the Metal Artifact Reduction (MAR) algorithm [5] a regular filtered back-projection reconstruction is produced [6]. From this reconstruction the volumetric regions that display high X-ray absorption (such as metal) are identified. These regions are then forward projected [7] on the original X-ray images (see Fig. 3 on page 7 and Fig. 4 on page 7), in order to process the high-absorption areas in the images. These

processed images are then used to create an improved reconstruction in a second pass. The entire process of two passes is performed within about 138 seconds.

Materials

FDCT volumetric reconstructions with endovascularly treated aneurysms were obtained, while diluted iodine contrast (10% contrast medium and 90% normal saline) was selectively injected in the feeding artery to show the vessel lumen. The aneurysms had been filled with coils and stents had been placed to close the neck of the aneurysms. A second pass reconstruction algorithm was used to correct for the streaking artifacts that originate from the coiled volume.

Images for this section:

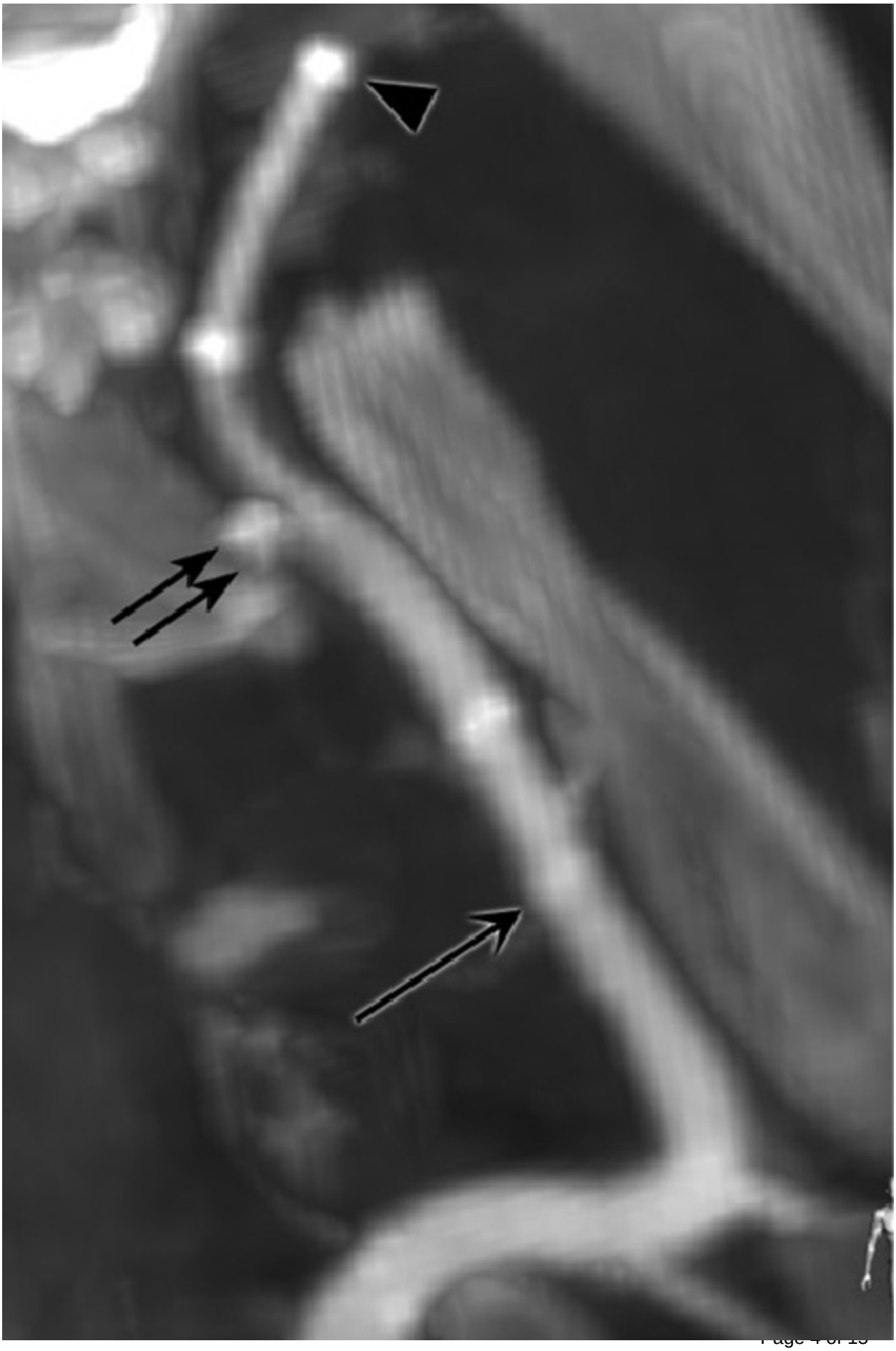

Fig. 1: FDCT reconstruction of stents placed in a swine model obtained with a standard soft-tissue protocol. Adapted from Patel et al. [3].

Fig. 2: High-resolution VasoCT reconstruction of stents placed in a swine model. Adapted from Patel et al. [3].

Fig. 3: Rotational acquisition showing high X-ray absorption in the coiled aneurysm and teeth fillings.

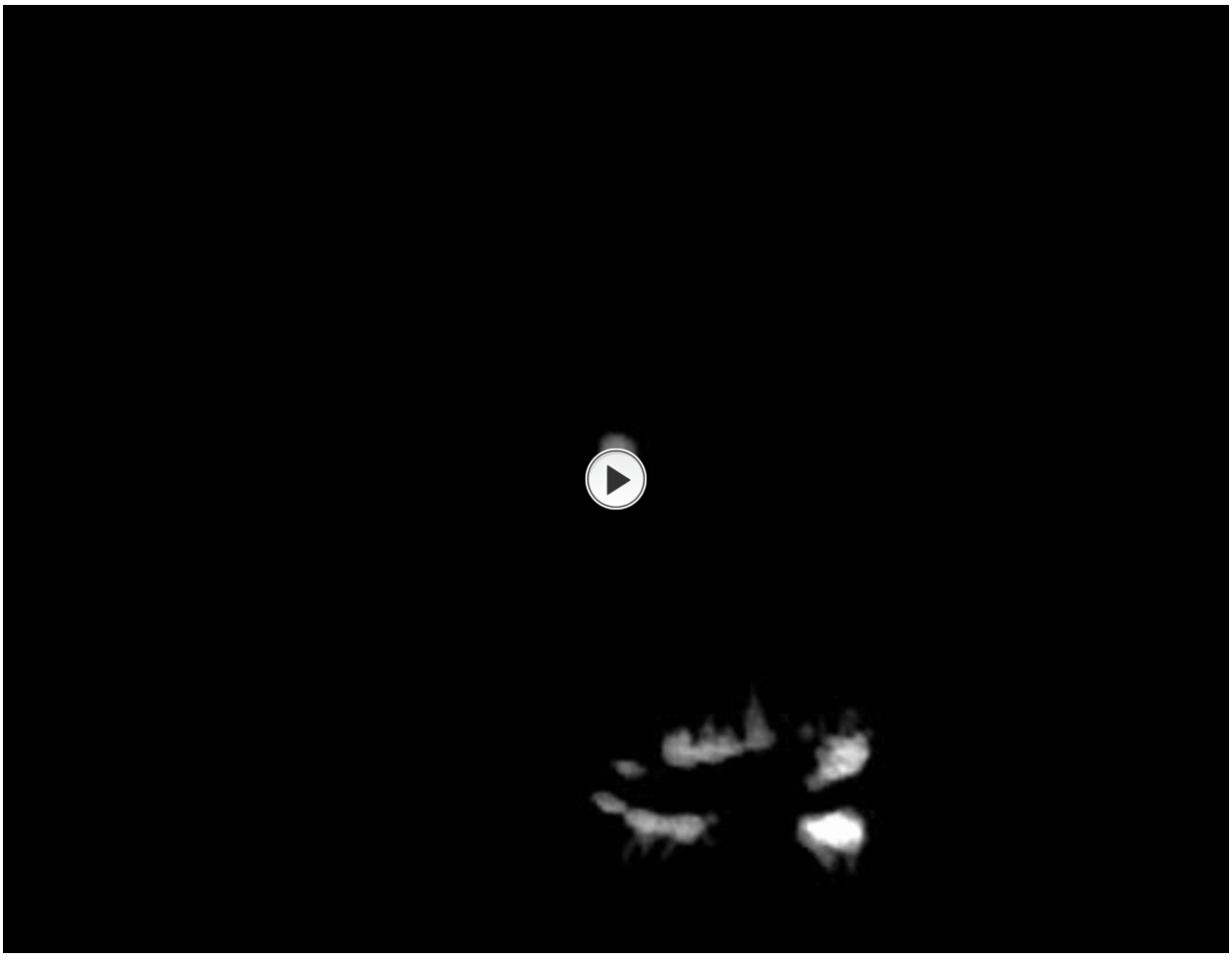

Fig. 4: High X-ray absorption areas segmented in the rotational acquisition.

Results

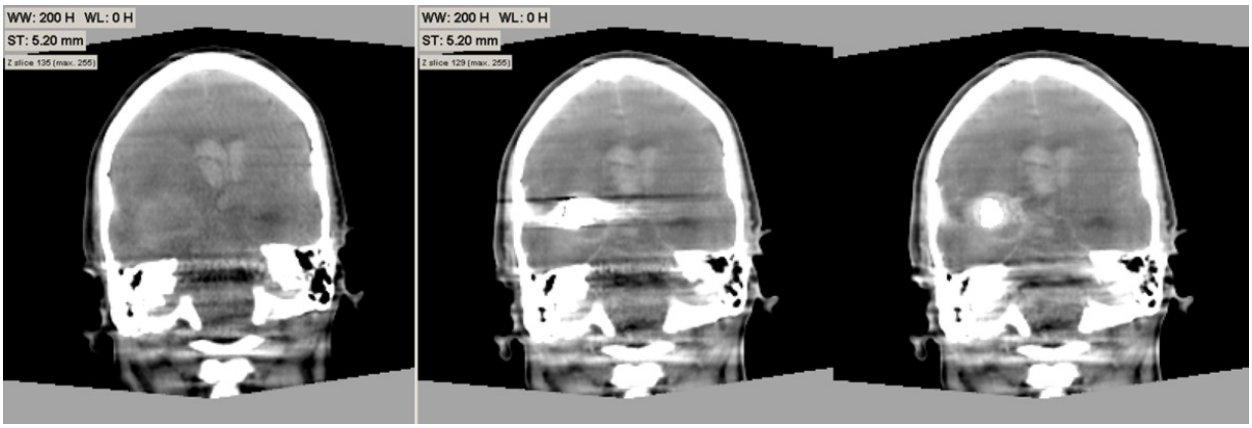

Fig. 5: Left: pre-interventional FDCT reconstruction. Middle: post-coiling reconstruction without MAR. Right: post-coiling reconstruction with MAR applied.
References: interventional X-Ray Innovation, Philips Healthcare - Best/NL

Fig. 5 on page shows a pre-interventional FDCT and a post coiling FDCT without and with MAR applied, in order to illustrate the MAR technique. The streaking artifacts have been reduced significantly in the reconstruction with MAR applied. Soft-tissue structures that are obstructed by the streaking artifacts origining from the coils in the aneurysm sac are clearly visible in the reconstruction with MAR.

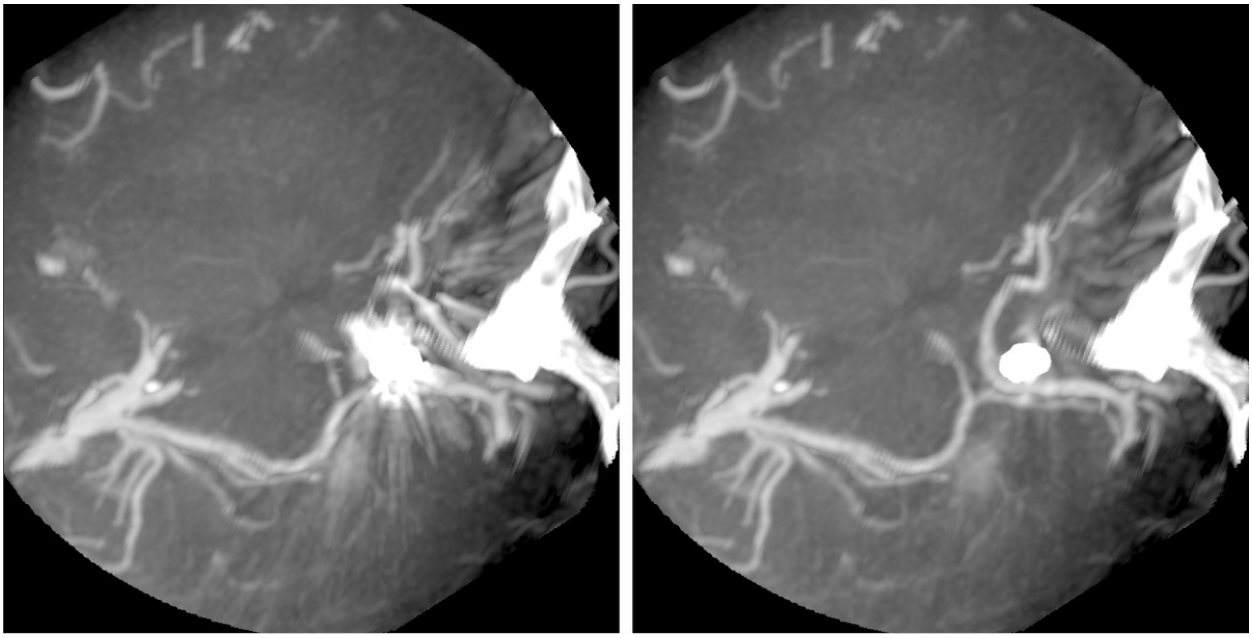

Fig. 6: Axial slab in a contrast enhanced FDCT reconstruction. Left: without MAR. Right: with MAR applied.
References: interventional X-Ray Innovation, Philips Healthcare - Best/NL

In Fig. 6 on page a reconstruction of a coiled aneurysm is shown, while the vessels have been filled with diluted contrast medium. The second pass reconstruction (right) shows clearly the vasculature obstructed by the artifacts in the first pass reconstruction (left).

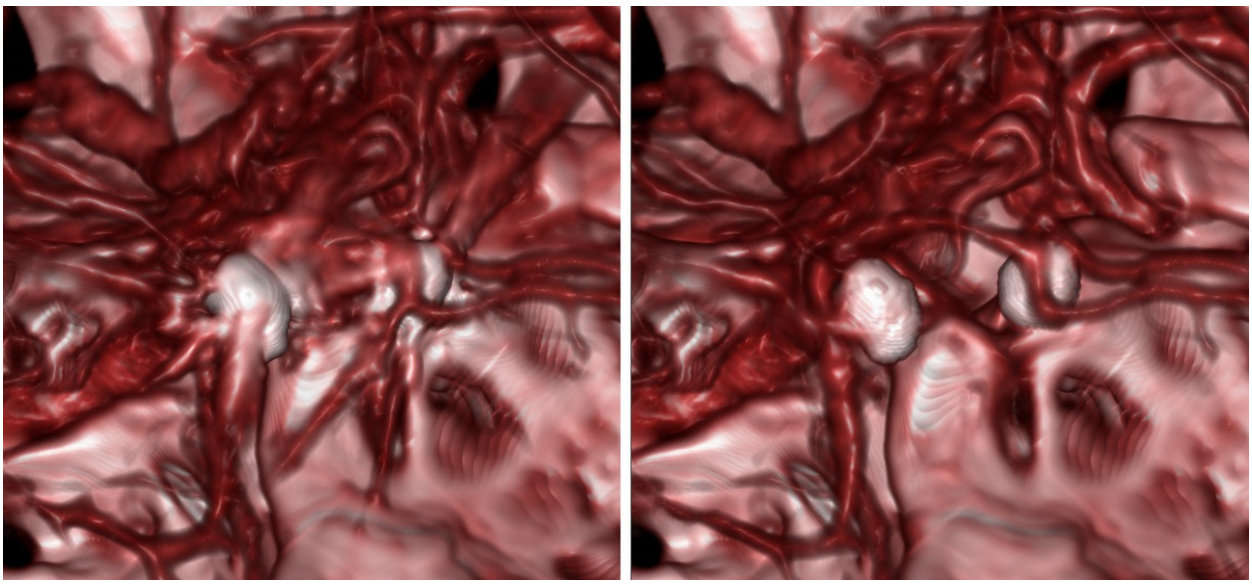

Fig. 7: Zoomed 3D rendering of a contrast enhanced FDCT reconstruction. Left: without MAR. Right: with MAR applied.
References: interventional X-Ray Innovation, Philips Healthcare - Best/NL
Fig. 7 on page shows a 3D visualization of the reconstruction in Fig. 6 on page . The streaking artifacts that origin from the coils can form false vessel lumen in the 3D representation (left), whereas this effect is not present in the MAR corrected image (right).

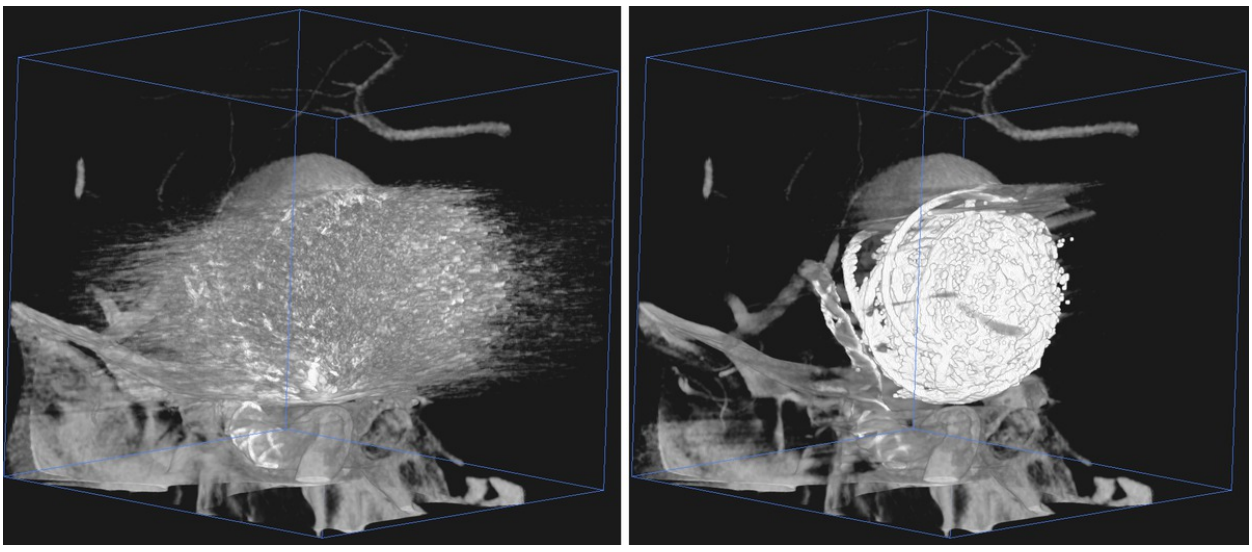

Fig. 8: Contrast enhanced FDCT reconstruction of a stent-assisted coiled large aneurysm. Left: without MAR. Right: with MAR applied.
References: interventional X-Ray Innovation, Philips Healthcare - Best/NL

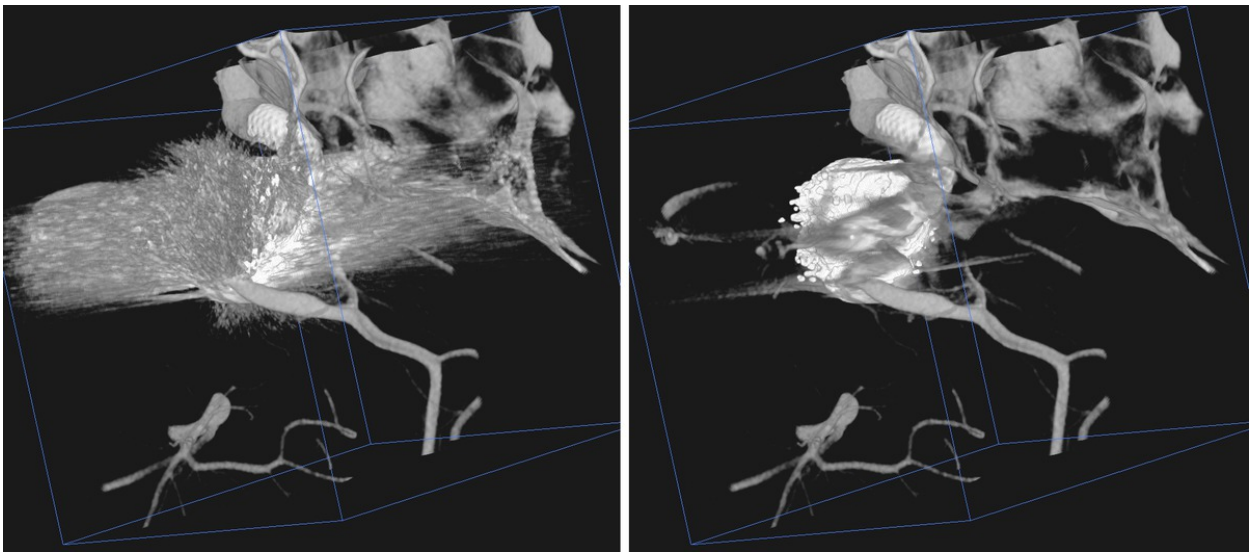

Fig. 9: Contrast enhanced FDCT reconstruction of a stent-assisted coiled aneurysm. Left: without MAR. Right: with MAR applied.
References: interventional X-Ray Innovation, Philips Healthcare - Best/NL

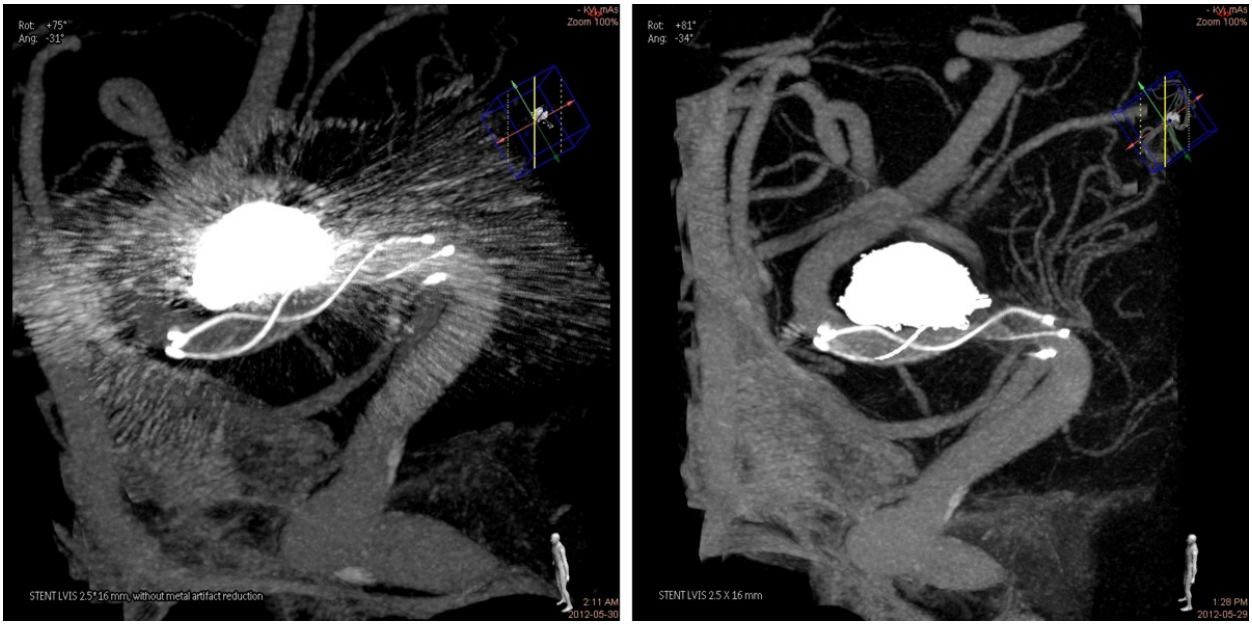

Fig. 10: Contrast enhanced FDCT reconstruction of a stent-assisted coiled aneurysm. Left: without MAR. Right: with MAR applied.
References: Courtesy: Prof. J. Moret, Neuri Hôpital Beaujon, Paris.
Fig. 8 on page , Fig. 9 on page , and Fig. 10 on page display volumetric visualizations of stent assisted coiled aneurysms. The left images show the

reconstructions without MAR applied, and the right images are the result of the MAR algorithm. Though not all stent struts affected by the metal artifacts can be reconstructed in the second pass, the visibility of the stents has improved considerably.

Conclusion

The MAR procedure significantly reduces the presence of metal streaking artifacts caused by coils placed in aneurysms. This allows the investigation of tissue and anatomical structures adjacent to the coiled volume. In case of stent/coils combinations this is especially valuable, since the streaks tend to obscure the intracranial stent. Observers in a recent study [8] gave significantly higher scores to MAR corrected FDCT images regarding the visibility of the arteries and stents adjacent to coiled aneurysms.

Especially when diluted iodine contrast medium is administrated to perform a VasoCT reconstruction, enabling to examine the vascular morphology, streaking artifacts severely disturb the evaluation of the aneurysm neck. On top of that false vessel bifurcations and branches may be introduced by the streaking artifacts. The MAR procedure largely resolves these disturbing phenomena. It removes the false bifurcations and branches, and enables the clear visualization of the aneurysm neck.

The improved second pass reconstructions significantly benefit the clinical interpretation of the tomographic images. Especially, the assessment of the stent deployment with respect to the vessel lumen is enhanced significantly for stents that are placed close to coiled aneurysms.

MAR cannot fully remove all metal artifacts. Typically, some streak-artifacts remain. The intensity of the remaining streaks depends on the complexity of nearby anatomy (like bone structures), size of metal object etc. Soft-tissue imaging of very low-contrasts will still suffer from artifacts, but the artifact level has been significantly reduced. Overall the diagnostic value of the MAR reconstructed images has been greatly enhanced, due to the considerable reduction of the artifacts.

Images for this section:

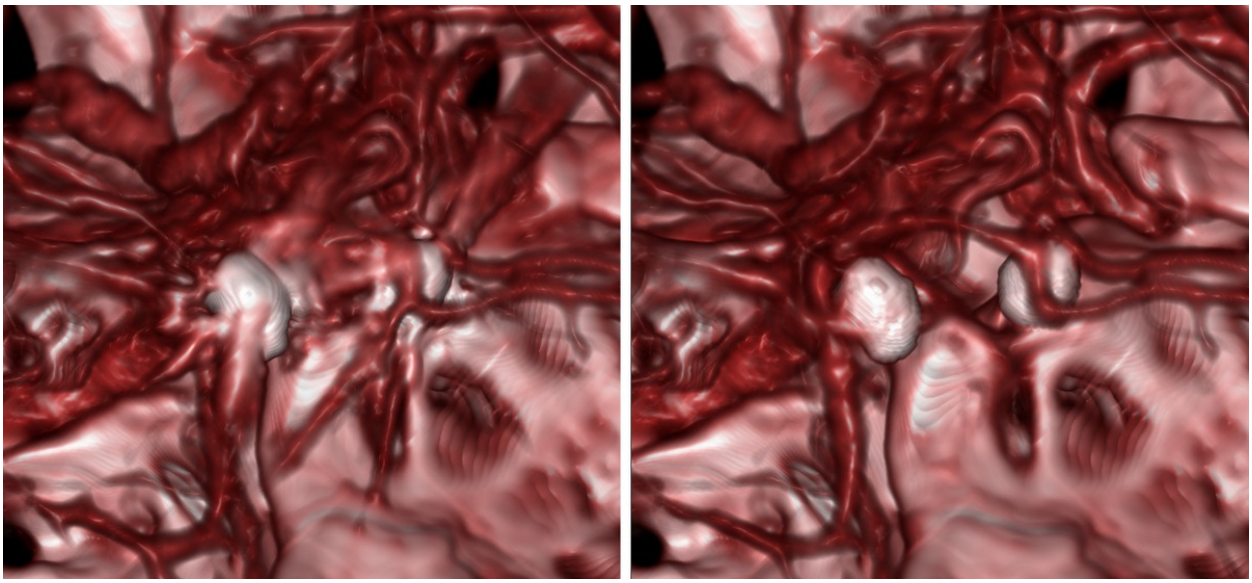

Fig. 7: Zoomed 3D rendering of a contrast enhanced FDCT reconstruction. Left: without MAR. Right: with MAR applied.

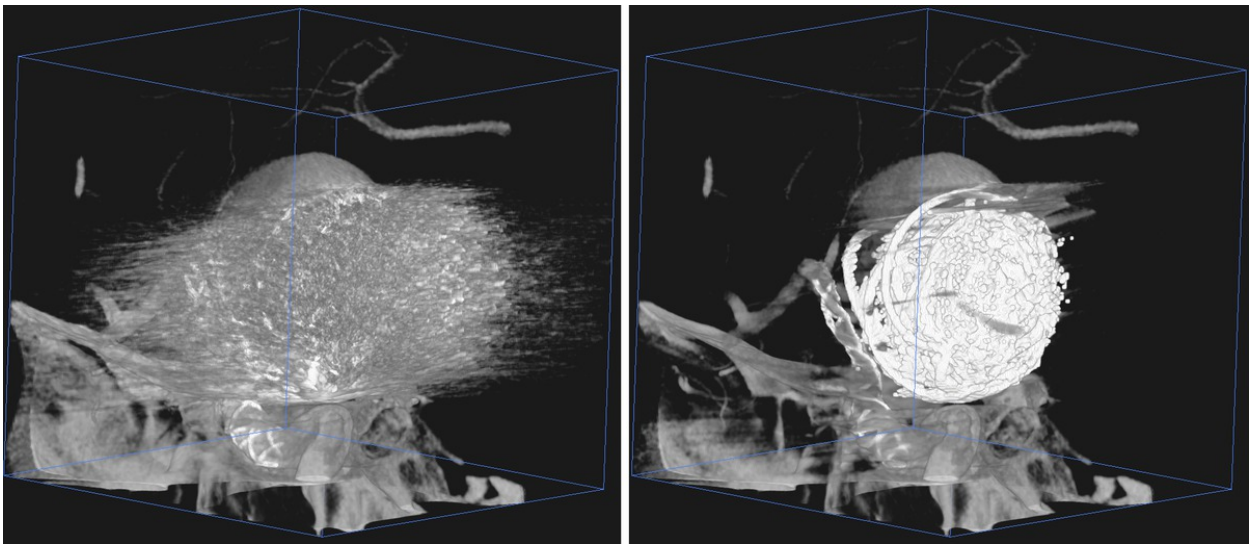

Fig. 8: Contrast enhanced FDCT reconstruction of a stent-assisted coiled large aneurysm. Left: without MAR. Right: with MAR applied.

Fig. 10: Contrast enhanced FDCT reconstruction of a stent-assisted coiled aneurysm. Left: without MAR. Right: with MAR applied.

References

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