Quantitative evaluation of metal artifact reduction for coiled aneurysms in cone-beam CT

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Background and purpose
Per-interventional cone-beam CT (CBCT) can be used to inspect the cerebral tissue for hemorrhages and ventricular abnormalities [1]. During minimally invasive embolization of brain aneurysms the aneurysm sac is filled with metal coils [2]. The post-coiling CBCT image quality is impaired by artifacts originating from the radiopaque metal mass. The artifact streaks run through the brain parenchyma, which hampers its inspection for hemorrhagic and other events. Metal artifact reduction (MAR) improves the image quality of cone-beam CT affected by streak artifacts [3].

While several metal artifact reduction schemes have been described in the literature [3,4], there is little objective quantitative evaluation on clinical data. We used pre- and post-coiling CBCT data, and applied a metric (peak signal-to-noise ratio) to quantify the improvement in image quality.

Materials and methods
For 22 retrospective aneurysm coiling cases, cone-beam CT acquisitions prior and post embolization were available. The former dataset was used as gold standard reference to evaluate the latter without and with metal artifact reduction (Figure 1). To this purpose the pre- and post-cooling datasets were co-registered [5], and the brain cavity and coiling mass were segmented [6]. The peak signal-to-noise ratio (PSNR) metric [7] was then calculated for the Hounsfield values in the brain parenchyma segment (Figure 2).

Results
The mean squared error improved for 20 out of 22 patients after metal artifact reduction was applied (Figure 3 & 4). The average mean squared error was reduced by 264 HU2. The PSNR was improved by 9.8 dB. The average computational time for the metal artifact reduction algorithm amounted 20 seconds.

Discussion
The metal artifact reduction algorithm clearly decreases the impact of the coiling mass on the image quality, as can be seen from Figures 3 & 4. The outline of the aneurysm sac filled with metal coils is clearly visible in the MAR reconstruction, as opposed to the reconstruction without MAR. Also the deep streaks directly around the aneurysm have been considerably reduced. However, there are still remaining artifacts around the aneurysm, and while overall the artifacts have been reduced, sometimes new artifacts arise, e.g. in Figure 3 bottom row near the skull.

Conclusions
Metal artifact reduction has been found to objectively improve the image quality quantified by the peak signal-to-noise ratio for most patients. It is therefore considered a useful tool for interventional use when the image contains metal parts.

References

Prior publications have used a subjective evaluation of the image quality by clinical experts [8,9,10], or used the standard deviation of the Hounsfield values within a region of interest as a quantitative measure for the performance of the MAR algorithm [4,8,11], whereby a smaller standard deviation accounts for a more homogenous region. This latter approach, however, does not take into account that the brain parenchyma possesses natural variations of HU density, and does not guarantee that the reconstructed Hounsfield levels are in fact correct. While a lower standard deviation hints that the MAR algorithm performs properly, it is not an absolute evaluation method. In this work we have aimed to introduce an approach that does not suffer from this limitation, while being objective and quantitative. In this sense it is comparable to [8], where also a a statistical linear Pearson correlation of the coiled CBCT data (with and without MAR) and pre-coiling data was performed.