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IMPLICATIONS OF ARTEFACTS REDUCTION IN THE PLANNING CT ORIGINATING FROM IMPLANTED FIDUCIAL MARKERS

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Abstract—The efficacy of metal artefact reduction (MAR) software to suppress artefacts in reconstructed computed tomography (CT) images originating from small metal objects, like tumor markers and surgical clips, was evaluated. In addition, possible implications of using digital reconstructed radiographs (DRRs), based on the MAR CT images, for setup verification were analyzed. A phantom and 15 patients with different tumor sites and implanted markers were imaged with a multislice CT scanner. The raw image data was reconstructed both with the clinically used filtered-backprojection (FBP) and with the MAR software. Using the MAR software, improvements in image quality were often observed in CT slices with markers or clips. Especially when several markers were located near to each other, fewer streak artefacts were observed than with the FBP algorithm. In addition, the shape and size of markers could be identified more accurately, reducing the contoured marker volumes by a factor of 2. For the phantom study, the CT numbers measured near to the markers corresponded more closely to the expected values. However, the MAR images were slightly more smoothed compared with the images reconstructed with FBP. For 8 prostate cancer patients in this study, the interobserver variation in 3D marker definition was similar (<0.4 mm) when using DRRs based on either FBP or MAR CT scans. Automatic marker matches also showed a similar success rate. However, differences in automatic match results up to 1 mm, caused by differences in the marker definition, were observed, which turned out to be (borderline) statistically significant (p = 0.06) for 2 patients. In conclusion, the MAR software might improve image quality by suppressing metal artefacts, probably allowing for a more reliable delineation of structures. When implanted markers or clips are used for setup verification, the accuracy may slightly be improved as well, which is relevant when using very tight clinical target volume (CTV) to planning target volume (PTV) margins for planning.

Key Words: **Metal artefact reduction, Fiducial markers, Planning CT, Prostate cancer.**

INTRODUCTION

In radiotherapy, computed tomography (CT) images are essential in 2 aspects of treatment planning: (1) 3D definition of the target volume and organs at risk (OAR) in relation to the body surface, and (2) provision of electron densities, which are derived from the Hounsfield units (HU) in the CT scan, to be used for tissue heterogeneity corrections in dose calculations.[1] Often, high-density objects, such as metal prostheses, surgical clips, tumor markers, or dental fillings, generate streaklike artefacts in CT images. The main source for these artefacts is an inaccurate beam-hardening correction in filtered back-projection (FBP), the algorithm most commonly used for CT image reconstruction. FBP assumes that the X-ray beam is monoenergetic, yielding a total attenuation that is linear with the object thickness. But in reality the X-ray beam is polyenergetic. To reduce this problem, CT scanners generally have correction software that is optimized for soft tissue and bone, but this does not solve the problem for metal objects with a much higher attenuation coefficient. Because of the streak artefacts, accurate delineation of the target volume and sensitive structures may be difficult, and near the artefacts the obtained HU may not be representative of the real electron densities.

During patient treatment, metal markers or clips that are implanted in or near the target are used for online and offline position verification.[2,3] Although a tumour is generally not visible on megavoltage or kilovoltage transmission images acquired during treatment, the metal markers are often easily visible. An advantage of the use of the markers is that their position is more representative for the tumor position than the surrounding bony structures, allowing the use of smaller clinical target volume to planning target volume (CTV-PTV) margins during treatment planning. However, these small metal inserts also produce artefacts that are often visible in the CT images. When using the CT to derive digitally reconstructed radiographs (DRRs) as reference for position verification, the exact position and orientation of the markers might be obscured, especially when several of

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them are located closely to each other, which possibly results in inaccurate match results and a reduced success rate when an automatic match procedure is used.

To minimize metal artefacts in CT images, improved image reconstruction algorithms based on the raw projection data, *i.e.*, the matrix of ray attenuations related to different angles acquired by the scanner, have been studied.[1,4–8] In iterative reconstruction methods, projection data associated with metal objects are ignored and the images are reconstructed based on the remaining data using a dedicated correction algorithm being applied in an iterative procedure.[8–10] In projection interpolation–based methods, the projection through metal objects are replaced using an interpolation of neighbor projections.[1,6,11–13] Recently, a metal artefact reduction (MAR) image reconstruction algorithm, which was described by Mahnken *et al.*,[6] was implemented by Siemens in a research version of their CT software. For patients with large metal implants, it was demonstrated that this MAR software significantly improved CT image quality.[1,5,14,15]

In this study we evaluate the efficacy of this MAR software to suppress artefacts from small metal objects, like tumor markers and surgical clips, both in reconstructed CT images and DRRs used for position verification. For a group of 8 prostate cancer patients, we evaluated the impact on the accuracy of marker definition and position verification when using DRRs derived from CT scans that were reconstructed without and with the MAR software, respectively.

MATERIALS AND METHODS

MAR image reconstruction algorithm

The MAR image reconstruction algorithm, described in detail by Mahnken *et al.*[6] uses a projection interpolation method. First, the metal objects are extracted from a conventionally reconstructed image using a threshold-based segmentation of pixels with a high HU value. These pixels are then projected forward to identify channels in the projection images that pass through the metal object. Each affected projection is then corrected by replacing metal shadows in the raw projection data using estimated values. Next, a conventional FBP of the modified data is computed, yielding images with reduced streak artefacts. Finally, the metallic objects are reinserted in the corrected images using an adaptive mixing process, yielding the final image dataset.

Application of MAR software for artefact reduction caused by small metal objects

To investigate the efficacy of the MAR software to reduce artefacts from small metal objects in CT image reconstruction, both a phantom study and a study on CT scans for 15 clinical patients with different tumor sites were performed.

For the phantom study, a homogeneous slab phantom consisting of a stack of square plates of RW3 (PTW, Freiburg, Germany) water-equivalent material was used.

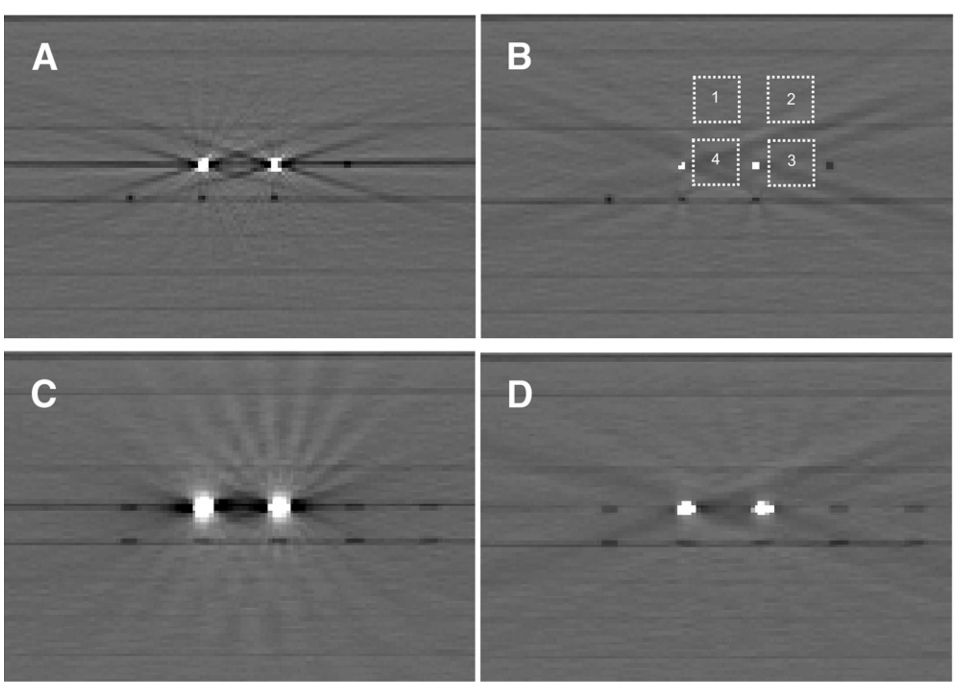

Fig. 1. Example of reconstructed images from the phantom in which the markers were positioned parallel (A, B) and perpendicular (C, D) to the CT scan direction. The images in (A) and (C) were reconstructed using the conventional FBP algorithm, whereas for reconstruction of the images in (B) and (D), the MAR software was used. To evaluate the differences in the reconstructed images, the mean CT values and the standard deviations were calculated for regions 1–4.