

Evaluation of three commercial metal artifact reduction methods for CT simulations in radiation therapy

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Abstract

Purpose: To evaluate the success of three commercial metal artifact reduction methods (MAR) in the context of radiation therapy treatment planning.

Methods: Three MAR strategies were evaluated: Philips O-MAR, monochromatic imaging using Gemstone Spectral Imaging (GSI) dual energy CT, and monochromatic imaging with metal artifact reduction software (GSI-MARs). The Gammex RMI 467 tissue characterization phantom with several metal rods and two anthropomorphic phantoms (pelvic phantom with hip prosthesis and head phantom with dental fillings), were scanned with and without metals (baseline). Each MAR method was evaluated based on CT number accuracy, metal size accuracy, and reduction in the severity of streak artifacts. CT number difference maps between the baseline and metal scan images were calculated, and the severity of streak artifacts was quantified using the percentage of pixels with > 40 HU error ("bad pixels").

Results: Philips O-MAR generally reduced HU errors in the RMI phantom. However, increased errors and induced artifacts were observed for lung materials. GSI monochromatic 70keV images generally showed similar HU errors as con-

ventional 120kVp imaging, while 140keV images reduced HU errors. All the imaging techniques represented the diameter of a stainless steel rod to within $\pm 1.6\text{mm}$ (2 pixels). For the hip prosthesis, O-MAR reduced the average % bad pixels from 47% to 32%. For GSI 140keV imaging, the % bad pixels was reduced from 37% to 29% compared to 120kVp imaging, and GSI-MARs further reduced it to 12%. For the head phantom, none of the MAR methods was particularly successful.

Conclusion: O-MAR resulted in consistent artifact reduction but exhibited induced artifacts for metals located near lung tissue. GSI imaging at 140keV gave consistent reduction in HU errors and severity of artifacts. GSI-MARs at 140keV was the most successful MAR method for the hip prosthesis but exhibited induced artifacts at the edges of metals in some cases.

Innovation/Impact: CT streak artifacts caused by metal implants negatively affected the treatment planning process by 1) making it difficult to confidently contour the tumor and surrounding organs and 2) causing CT number errors that lead to dose calculation errors. In this study, we performed a comprehensive evaluation of these metal artifact reduction (MAR) techniques, using two types of metal implants that are commonly encountered in radiation therapy (a hip prosthesis and dental fillings) and metrics that are relevant for treatment planning and dose calculation accuracy (CT number accuracy, metal size accuracy, and severity of streak artifacts).

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Introduction/Background: The Philips O-MAR algorithm uses a projection modification approach for conventional polyenergetic CT imaging, while the Gemstone Spectral Imaging (GSI) system uses dual energy

CT data to generate monochromatic images to reduce beam hardening artifacts. The GSI-MARs algorithm further reduces artifacts by addressing the photon starvation aspect of metal streak artifacts.

Key Results:

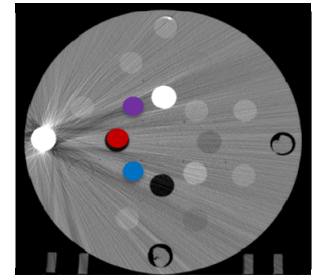
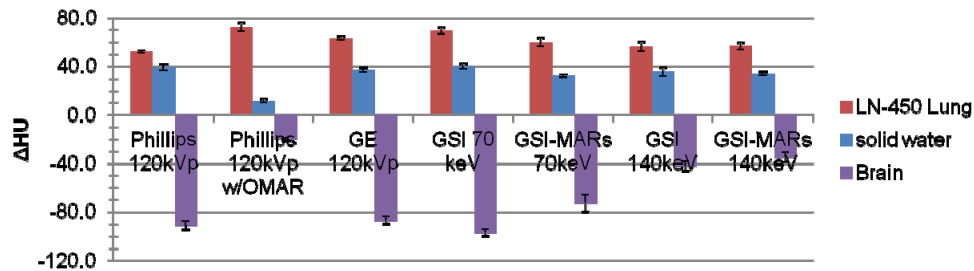


FIG. 1: Mean HU difference (ΔHU) between baseline (no metal) and metal (stainless steel) scans of the RMI phantom. ΔHU was calculated based on the mean CT number for 14 mm diameter regions of interest. Error bars indicate the standard error of the mean for three repeated scans.

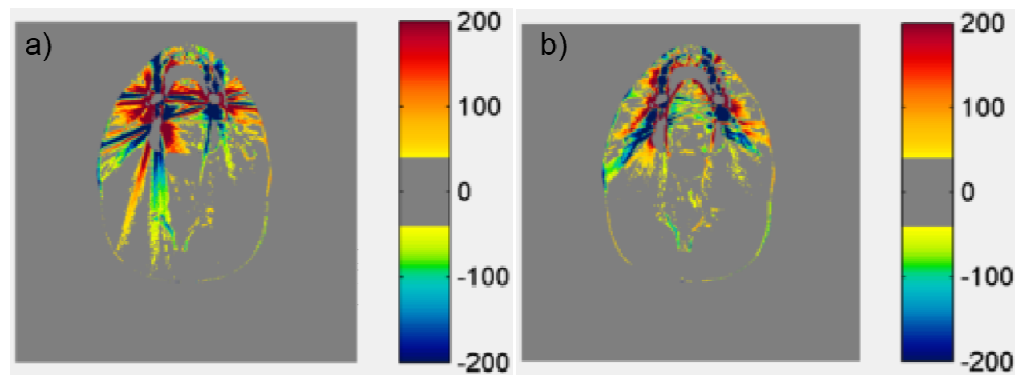


FIG. 2: CT number difference maps between baseline and metal scans for the head phantom with dental fillings for a) Philips 120kVp and b) Philips 120kVp with O-MAR. Regions of metal and air are excluded.

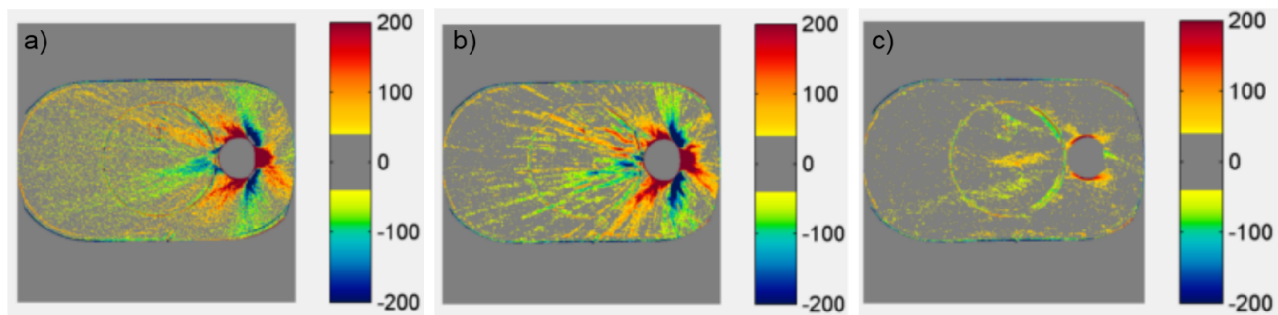


FIG. 3: CT number difference maps between baseline and metal scans for the pelvic phantom with hip prosthesis for a) GE 120kVp, b) GSI 140keV, and c) GSI-MARs 140keV. Regions of metal and air are excluded.