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Diffusion-Based Metal Artifact Reduction for Postoperative CT Imaging Following Reverse Total Shoulder Arthroplasty Using Hybrid Sampling

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Introduction and Background

The quality of postoperative computed tomography scans after reverse total shoulder arthroplasty is often severely compromised by metal artifacts, which obscure critical anatomical structures and hinder accurate assessment. We proposed a MAR framework based on a conditional diffusion model that operates directly on reconstructed CT images.

Material and Method

We introduced two methodological innovations. First, we implemented a hybrid sampling strategy that combines Denoising Diffusion Implicit Models with Random Pointing to balance anatomical fidelity and artifact suppression. Second, we designed a quantitative evaluation protocol using implant-to-bone surface distance distributions across preoperative, postoperative, and MAR-corrected volumes. This framework offers an objective metric for validating MAR performance.
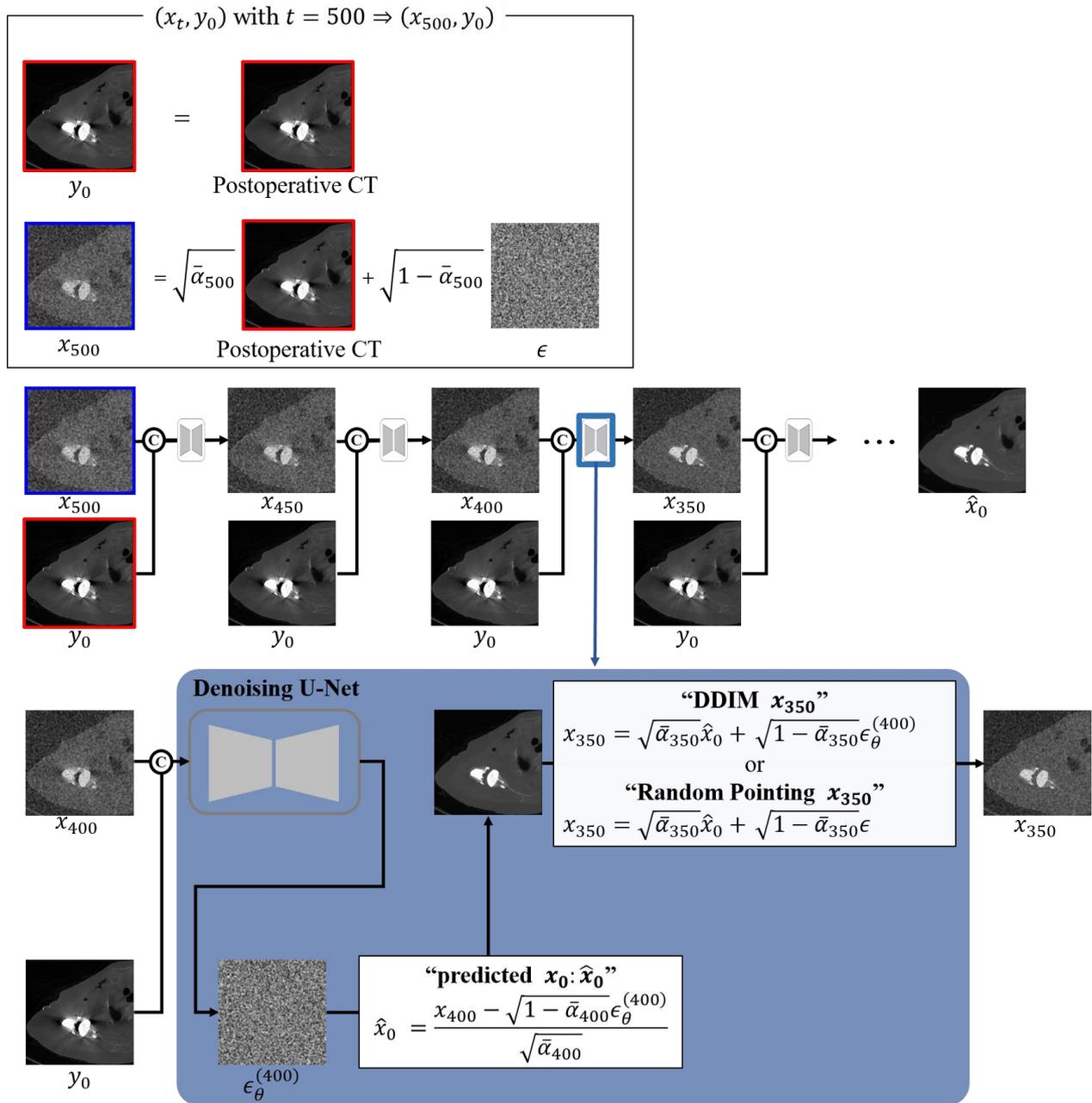
Results

Our method achieved superior performance over prior approaches, as demonstrated by improved image quality metrics (mean squared error, structural similarity index measure, peak signal-to-noise ratio) and enhanced anatomical accuracy. Furthermore, the hybrid sampling procedure consistently outperformed single-method baselines, preserving fine bone details while effectively reducing artifacts. Quantitative and qualitative evaluations confirmed that MAR-corrected volumes closely resembled preoperative anatomy and restored normal Hounsfield Unit values in artifact-prone regions.

Conclusions

This study demonstrates the efficacy of a diffusion-based MAR framework that eliminates the need for raw projection data while achieving robust performance through a hybrid sampling approach.
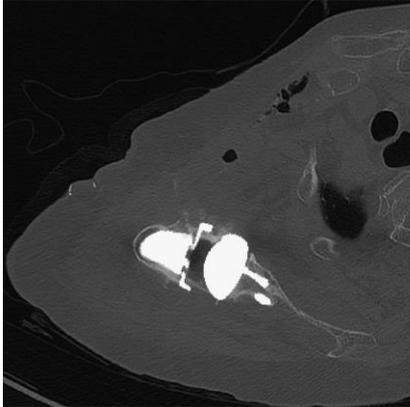
Figure & Table 1.

(x_t, y_0) with $t = 500 \Rightarrow (x_{500}, y_0)$

y_0 = Postoperative CT

$x_{500} = \sqrt{\bar{\alpha}_{500}} \cdot$ Postoperative CT $+ \sqrt{1 - \bar{\alpha}_{500}} \cdot \epsilon$

x_{500}, x_{450}, x_{400}, x_{350}, ..., $\hat{x}_0$

y_0

Denoising U-Net

x_{400}

y_0

"DDIM x_{350}"
$$x_{350} = \sqrt{\bar{\alpha}_{350}}\hat{x}_0 + \sqrt{1 - \bar{\alpha}_{350}}\epsilon_\theta^{(400)}$$
or
"Random Pointing x_{350}"
$$x_{350} = \sqrt{\bar{\alpha}_{350}}\hat{x}_0 + \sqrt{1 - \bar{\alpha}_{350}}\epsilon$$

x_{350}

"predicted x_0: $\hat{x}_0$"
$$\hat{x}_0 = \frac{x_{400} - \sqrt{1 - \bar{\alpha}_{400}}\epsilon_\theta^{(400)}}{\sqrt{\bar{\alpha}_{400}}}$$

$\epsilon_\theta^{(400)}$

Figure & Table 2.
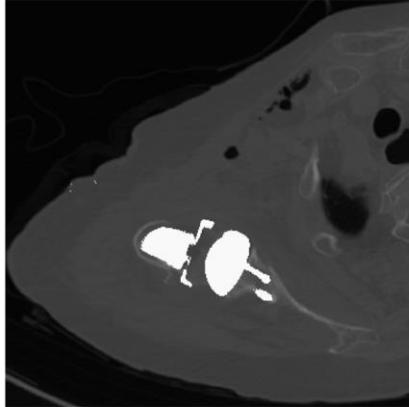
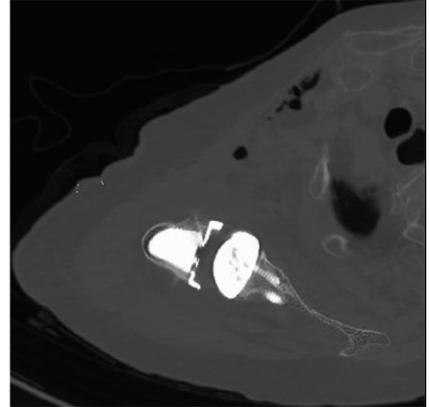| Postoperative MAR CT using DDIM | Postoperative MAR CT using Random Pointing | Postoperative MAR CT using Hybrid Sampling |