Deep Learning-based CT Metal Artifact Reduction in the Lumbar Spine

Yerim Choi[1,*], Jimin Lee[2,*], Hee-Dong Chae[1,3], Hyungjoo Cho[2], Sung-Joon Ye[2], Sung Hwan Hong[1,3,4], Ja-Young Choi[1,3], Hye Jin Yoo[1,3]

[1]Department of Radiology, Seoul National University Hospital, 101 Daehak-ro, Jongno-gu, Seoul, 03080, Republic of Korea

[2]Program in Biomedical Radiation Sciences, Department of Transdisciplinary Studies, Graduate School of Convergence Science and Technology, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul, 08826, Republic of Korea

[3]Department of Radiology, Seoul National University College of Medicine, 103 Daehak-ro, Jongno-gu, Seoul, 03080, Republic of Korea

[4]Institute of Radiation Medicine, Seoul National University Medical Research Center, 103 Daehak-ro, Jongno-gu, Seoul, 03080, Republic of Korea

PURPOSE

To investigate the metal artifact reduction (MAR) performance of deep learning (DL)-based MAR technique in the evaluation of the lumbar spine CT.

METHOD AND MATERIALS

The training dataset consisted of 15,800 image pairs obtained from 200 lumbar spine CT scans without a metal prosthesis. Each image pair consists of a metal artifact-free image with a virtual metal shape embedded in the original image and a metal artifact image simulated through sinogram handling. Our DL network is a convolutional neural network with encoder-decoder structure and skip connections. The summation of MSE, SSIM, and TV losses was implemented for parameter updating. For the test dataset, we used 50 lumbar spine CT examinations from 50 patients who had a previous history of spinal instrumentation surgery. For quantitative evaluation, the mean attenuation at the most hypodense streak artifacts and the area of the hyperdense artifact within the spinal canal was calculated in the non-MAR, O-MAR, and DL-MAR images. For qualitative analysis, images were rated with a 5-point scale regarding the visualization of the spinal canal and conspicuity of the vertebral cortex.

RESULTS

In quantitative analysis, the DL-MAR protocol removed most of the hyperdense streak artifacts, whereas the O-MAR protocol introduced new hyperdense artifacts with a pseudocemented appearance within the spinal canal. The mean attenuation at the most hypodense streak artifacts was -337 HU, -71 HU, and 9 HU ($P < .001$) and the mean area of hyperdense artifacts within the spinal canal was 30 mm^2, 47 mm^2, and 18 mm^2 ($P < .001$) for non-MAR, O-MAR, and DL-MAR protocols, respectively. In qualitative analysis, DL-MAR showed significantly better visualization of the spinal canal compared to non-MAR and O-MAR protocols ($P < .001$). O-MAR caused bone deletion in many cases, resulting in worse visualization of cortical bone compared to non-MAR and DL-MAR ($P < .001$).

CONCLUSION

The DL-MAR technique showed excellent MAR performance compared to the projection completion algorithm.

In addition, DL-MAR did not introduce new artifacts such as pseudocemented appearance or bone deletion observed in O-MAR.

*Yerim Choi and Jimin Lee contributed equally to this work.

Figure 1. A lumbar spine CT of a 68-year-old male patient. In the axial image at the L1 vertebral level, the spinal canal is difficult to evaluate in the O-MAR protocol due to the pseudocemented appearance artifact (black arrow), but the spinal canal is distinctly visible in the DL-MAR image (WW 400, WL 30).

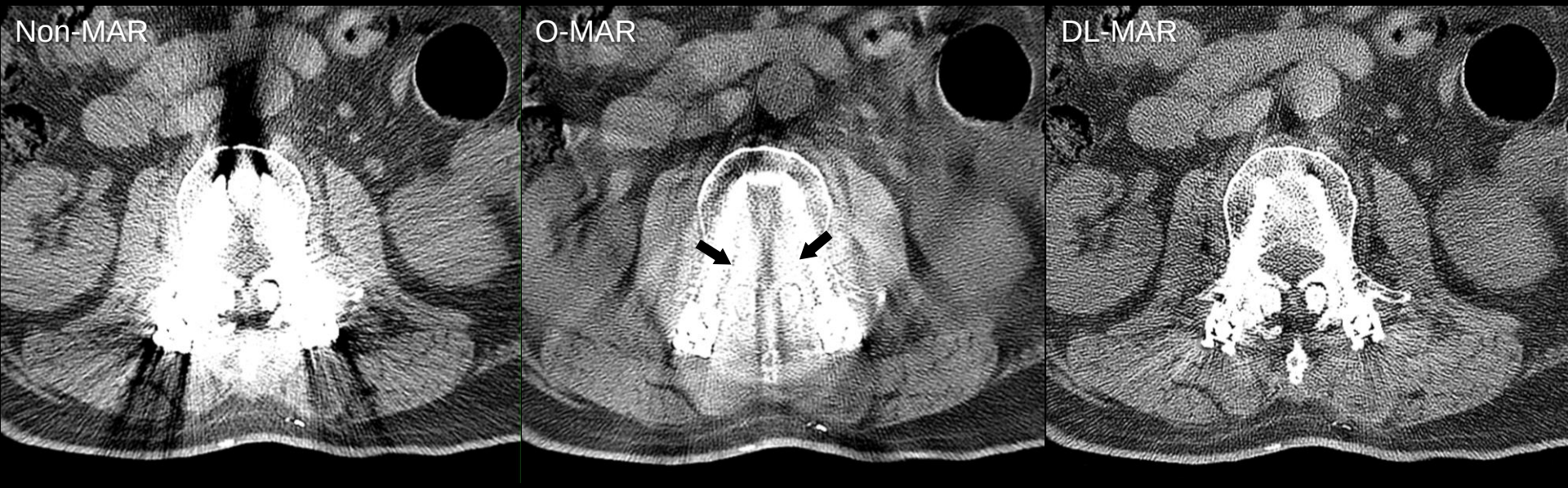

Figure 2. A lumbar spine CT of a 74-year-old female patient. In the O-MAR image, the posterior cortex of the L4 vertebral body is not clearly visible due to bone deletion (white arrow), but in the DL-MAR protocol, most of the streak artifacts is reduced while preserving the vertebral cortex (WW 2000, WL 800).