Generation of Low Dose High Quality Images in Chest Tomosynthesis using Convolutional Neural Networks

Donghoon Lee, Yonsei University

Introduction
Chest tomosynthesis is one of the recent low-dose medical imaging devices, and it provides 3-dimensional medical image with far less radiation dose than computed tomography. To further increase the usefulness of chest tomosynthesis, recently, researches have been actively tried to reduce radiation dose to the level of conventional radiography. A typical study to reduce radiation dose of chest tomosynthesis is to obtain 3 dimensional reconstructed images by iterative reconstruction under sparse sampling conditions. However, iterative reconstruction requires complicated system modeling, thus it takes a long time to generate 3 dimensional images. Therefore, in this study, we developed a new image reconstruction strategy based on medical image data and deep learning and evaluated 3-dimensional reconstruction images of sparse sampling conditions acquired by the developed technology.

Hypothesis
Our study assumes that there is a nonlinear relationship between low quality images obtained by sparse sampling and, high quality images obtained by dense sampling. If it is possible to model the nonlinear relationship between two images with deep learning, it is hypothesized that the images can be transformed into high-quality images from the degraded images.

Methods
Our developed deep learning model consisted of 3 encoder and decoder layers. Each layer contained 3 convolution layers with 3x3 kernel size, batch normalization, and rectified linear unit activated function. The training data used in this study were 500 phantom images obtained by prototype chest tomosynthesis developed by our research institute and data augmentation technique such as image rotating, and cropping were used to prevent model overfitting. We used structure similarity measure index (SSIM) to quantitatively confirm how similar between the reconstructed images acquired by the proposed method and output images. In addition, diagnostic images were quantitatively evaluated through cascade models including modulation transfer function (MTF), noise power spectrum (NPS), and noise equivalent quanta (NEQ).

Results
The developed deep learning model implements good image quality similar to reconstructed image using dense sampling and iterative reconstruction, even though it uses insufficient sampling data. Average SSIM between predicted images and output images was 0.91. In addition, we confirmed that the reconstructed image with the proposed deep learning model is high quality image with reduced image noise and artifact, while the reconstructed image with insufficient sampling data and analytic reconstruction has high image noise and streak artifacts. Cascade model analysis results including MTF, NPS, and NEQ of reconstructed images with proposed method were significantly improved compared to conventional analytic reconstruction method, and their quantitative values were similar with reconstructed images under dense sampling and iterative reconstruction.

Conclusion
We have developed a reconstruction strategy to generate 3 dimensional reconstructed images with high image quality from deficient image information by deep learning. The reconstructed images generated by the developed method provided high quality diagnostic images even though the insufficient sampling data was used.

Statement of Impact
Proposed reconstruction method not only generated high quality reconstruction images with low radiation dose, but also the medical images that have been imaged with past technology can be restored to the current level of high quality medical images.
Keywords
chest tomosynthesis, deep learning

Figure 1