Reconstruction by AI: A Replacement for Iterative Reconstruction?

Shuai Leng, PhD, FAAPM
Professor of Medical Physics
Department of Radiology
Mayo Clinic, Rochester, MN
Outline

- CT reconstruction
- FBP
- IR: limitations of patchy looking, LCD
- Deep learning (AI): Architecture, Cost Function (Penalty function), Training
- Talk about image quality assessment, need to prove outcome improvement, e.g. low contrast detectability improvement, like IR. Avoid pitfalls seen in early IR.
The power of DL lies in its ability to handle complex models and a vast number of parameters far beyond the abilities of human engineers and scientists [6, 7].
AiCE DLR: Pushing the Envelope of Reconstruction Technology

- Breakthrough low-contrast resolution†**
- Improved low-contrast detectability, noise and spatial resolution relative to hybrid iterative reconstruction
- Image noise appearance similar to FBP compared to MBIR reconstruction**
- Dose neutral industry-leading ultra-high resolution*
- Fast reconstruction

†1.5mm @ 0.3%
*Aquilion Precision, Dose neutral between Ultra-high resolution mode with AiCE and normal resolution mode with hybrid iterative reconstruction
**Aquilion ONE Genesis
TrueFidelity (GE)

- First FDA cleared DLIR
- Trained with high quality **FBP data** sets to learn how to differentiate noise from signals
- Preferred noise texture
- Fast reconstruction speed
- IR: optimization of the solution with a limited number of parameters, typically less than a hundred, either calculated or manually tuned
- IR still requires explicit model, DL not
- ‘Inputting a low dose sinogram through the Deep Neural Network and comparing the output image to a ground truth image’ – sounds like true reconstruction
TrueFidelity (GE)

- Ground truth training data are CT images reconstructed by FBP (both phantoms and patients) that can faithfully represent the scanned object.

- The ground truth training data are based on images collected from both phantoms in the laboratory and patients in a clinical setting, and span a variety of acquisition protocols. A massive number of patient and phantom cases that cover different body habitus and anatomies, scan conditions, and clinical indications.
Deep Learning Reconstruction (AiCE, Canon)

- A fast reconstruction algorithm including both raw data and image domain components to reduce artifact and noise.

- Ten-layer linear residual network with common CNN components: convolution, batch normalization, and RELU activation function.

- Trained to extract signal from low-dose hybrid IR images to have similar image quality as the high-dose model-based IR (MBIR) target

Kirsten Boedeker, AiCE Deep Learning Reconstruction: Bringing the power of Ultra-High Resolution CT to routine imaging, Canon Whitepaper 2019
Tatsugami F et al, Deep learning–based image restoration algorithm for coronaryCT angiography, European Radiology 2019
Deep Learning Reconstruction

135 kV  17.5 mAs  0.5 mm x 80  CTDIvol: 1.7 mGy

Hybrid IR  DLR

Hybrid IR  DLR

Courtesy Drs. Erin Angel and Dhruv Mehta, Canon
Clinical Study – Abdominal CT

- Retrospective study: 46 patients, UHRCT (Canon)
- Image noise was significantly lower and CNR significantly higher on DLR (AiCE, Canon) than hybrid-IR and MBIR
- Vessel conspicuity was better on MBIR
- Did not evaluate hepatic lesion detection

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<thead>
<tr>
<th>Table 1</th>
<th>Image noise and CNR on hybrid-IR, MBIR, and DLR images</th>
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<td>Hybrid-IR</td>
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<td>Hybrid-IR vs MBIR</td>
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<td>Image noise (HU)</td>
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<tr>
<td>HAP</td>
<td>24.9 (14.8–46.9)</td>
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<td>EP</td>
<td>25.5 (18.3–40.1)</td>
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<th>Table 2</th>
<th>Qualitative analysis scores of hybrid-IR, MBIR, and DLR images</th>
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<td>Hybrid-IR vs MBIR</td>
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<tr>
<td>HAP</td>
<td>3.50 (0.62)</td>
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<tr>
<td>Overall image quality</td>
<td>2.91 (0.51)</td>
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Akagi et al, Deep learning reconstruction improves image quality of abdominal ultra-high-resolution CT, European Radiology 2019
Clinical Study – Coronary CTA

Tatsugami F et al, Deep learning–based image restoration algorithm for coronary CT angiography, European Radiology 2019
ClariPi

- ClariPi FDA cleared
- http://www.claripi.com/eng/sub/sub02_01.php
on the software side, AIDOC and ZEBRA are two Israeli companies that have FDA approved AI tools that use CT images for a few different time sensitive or quantitative applications (hemorrhages, PE, spine fractures, coronary calcium scoring).

https://www.mobihealthnews.com/content/zebra-medical-vision-receives-its-first-510k-clearance-coronary-artery-calcification
DL

- Training
- Validation
- Testing
Detectability,

Early days of IR, dose reduction based on IQ

Perry Pickhard’s paper MBIR loses lesions.

Model observer

JG’s slides on 1) compare with low dose FBP; 2) compare with full dose FBP.