Understanding the Brain Through Imaging: AI/ML Opportunities

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Disclosures

GE Healthcare: Research support
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Nvidia: GPU donation
Biogen: Advisory panel
Subtle Medical: Co-founder, equity
A Brief History of Radiology

1895 X-rays

1927 Angiography

1972 CT

1973 MRI

2000 PACS

? 2017 ML/AI
Good News
Imaging #1 healthcare advance over last 30 yrs*

Bad News
Imaging is costly and inefficient

*Fuchs et al., Health Affairs 2001
Radiology from the Patient’s Perspective

New & Different

Image Acquisition

Enhancement & Visualization

Analytics

Interpretation

Pre-/peri-imaging

Scanner

Post-processing

Reconstruction

Diagnosis

Treatment
AI Focus Areas

- Image automation ("pre-voxel")
- Image reconstruction
- Post-processing / quantitation
- Interpretation
- New & different
Improving and Standardizing Image Acquisition

Courtesy of Robert Hu, MD, HeartVista
AI Focus Areas

• Image automation ("pre-voxel")
• Image reconstruction
• Post-processing / quantitation
• Interpretation
• New & different
How it's performed
MRI scan

A magnetic resonance imaging (MRI) scan is a painless procedure that lasts 15 to 90 minutes, depending on the size of the area being scanned and the number of images being taken.
Magnetic Resonance Imaging (MRI)

- Challenges
  - Very expensive
  - Need a lot of electricity/cooling
  - Need a lot of space
  - Need people to run them (technologists)

Upshot: not many people can get MRI's

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'Three back in 2020 for your MRI', Mumb

Konkan farmer was recently asked by Nair Hospital, already overburdened radiology department.

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English hospitals in urgent need of more scanners and staff to deal with backlog

Exclusive: more than half of NHS patients referred for imaging diagnostics are waiting six weeks or more

- MP reveals difficulty getting breast cancer scans
- Coronavirus - latest updates
- See all our coronavirus coverage
Pretty good MRI examination principles

- Examinations should consist of 10 minutes of imaging plus 5 minutes of patient handling time, for a total cycle time of 15 minutes.
- Pulse sequences should acquire 3-D data that can be reformatted in any plane.
- Pulse sequences should acquire and use multiple echoes or use SSFP to maximize SNR and CNR.
- Optimized multicoil arrays should be used to maximize SNR.
- Prescan and scanner parameter adjustment (RF transmit amplitude, RF receive gain, tuning) should be kept to <30 seconds per patient.
- Scans should be done using a high-quality imager at fields ≥ 1.5 T.
Image Transformation

Deep Residual Encoder-Decoder Convolutional Neural Network (U-Net)

What you’ve got (lower quality, faster)  What you want (higher quality)
Arterial Spin Labeling

- Non-contrast method for measuring blood flow

Low SNR!

CBF map
Improved Perfusion MRI

8 min
High SNR ASL

2 min
Low SNR ASL

2 min
Synthetic ASL

RSME 29%
Error map vs High SNR

4-fold time reduction
3-fold RSME improvement

Gong, Pauly, Zaharchuk/Stanford/Proc ISMRM 2017
De-noising of Anatomic Images

Standard Acquisition

Scan time: 3:49
Number of averages: 4
Slice thickness: 4 mm

Fast Acquisition (2x)

Scan time: 1:57
Number of averages: 2
Slice thickness: 4 mm

DL-enhanced

Scan time: 1:57
Number of averages: 2
Slice thickness: 4 mm
Super-Resolution

Deep Learning Model

- 3x resolution improvement
- Better diagnostic quality
- More confident clinical decision
- Or faster...

Tacq 4:46  Tacq 2:34  Tacq 2:34

50% reduction

12 yo M, epilepsy
Application to Automated Brain Region Analysis

Morphometry Results – Standard Scan (Scan Time 5:01)

Morphometry Results – DL-accelerated Scan (Scan Time 2:37)

Bash et al., AJNR 2021
Beyond Faster

- Replace inputs of network with other contrasts or modalities
- “100%” speed up
- Provide new info after patient leaves the scanner
- **Assumption**: Input images contain required information to create new contrast!
Modality Transfer

• MRI to CT
  • Attenuation correction for PET
  • Evaluating bony lesions
• MR sequence transfer
  • Predicting STIR from T1 and T2
• A form of style transfer

Liu et al., Radiology 2017; Jans et al., Radiology 2020
Missing Data Imputation

Take what you have and make your best guess at what you don’t have.
Can be used as a predictor of contrast-enhanced images / zero-dose

Liu et al., One Model to Synthesize Them All, ArXiv 2204.13738