Low Dose CT Grand Challenge

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• Co-leaders
  – JG Fletcher, MD
  – Lifeng Yu, PhD
  – Shuai Leng, PhD
  – Rickey Carter, PhD
  – David Holmes III, PhD

• Trainees
  – Baiyu Chen, PhD
  – Kyle McMillan, PhD
  – Chi Ma, PhD

• Staff
  – Tammy Drees
  – Greg Michalak, PhD
  – Alice Huang
  – Kris Nunez
  – Shane Dirks

With special thanks to Farhana Khan of AAPM headquarters staff

On behalf of our team at Mayo Clinic

LOW Dose CT Grand Challenge

➤ Image reconstruction and denoising experts
  ➤ Test your algorithm against others in the field

➤ Using real patient projection data
  ➤ In vendor-neutral format
  ➤ w/ and w/o pathology

➤ Winners announced at AAPM 2016
  ➤ Free meeting registration
  ➤ Participation in a low-dose CT session
  ➤ Manuscript co-authorship

www.aapm.org/GrandChallenge/LowDoseCT
Radiologist Interpretation

- Host site provided radiologist interpretation of twenty test cases
- Reader pool was composed of senior residents, fellows, and faculty.
- No reader read the same case twice.
- Cases from any given participant were dispersed among readers so as to minimize the impact of reader bias on any one participant.
- A standardized reading tool was used for marking of the lesions.
- Rigorous reader training was performed to ensure consistent marking between readers.
- For each case, the radiologist was required to mark the location of any detected metastasis, or to grade the case as normal if no lesions are detected.

Reading design

- Given the time constraints and the high potential of recall (e.g., 20 cases shown repeatedly with limited washout time), we designed a Latin squares reading framework.
- Design assumes that readers will be exchangeable in performance. Differences in individual reader performance is assumed to be distributed uniformly across participants.

Score

- Reader lesion markings (or notation of case as normal) were compared to reference standard for each case and data scored on a per lesion and per case basis.
- Reader markings were considered correct if the location marked as center of the lesion fell anywhere within the true lesion's boundaries.
- Per lesion scoring (included penalty for false positive and negative markings):
  - +1 for true positive marking of a lesion (correctly marking a lesion)
  - -1 for false positive marking of a lesion (no lesion exists at that location)
  - -2 for false negative (a lesion exists that was not marked)
- Per case scoring (included penalty for false positive and negative markings):
  - +1 for true negative case (no lesions marked in a case with no lesions)
  - +1 for true positive case (at least one lesion was correctly marked in a case with lesions)
  - -1 for false negative (no lesions marked in a case that had lesions)
  - -1 for false positive (at least one lesion marked in a case with no lesions)
Scoring

- Per lesion normalized score
  \[ (NS) = \frac{\text{per lesion score}}{\text{total number of lesions}} \times 100\% \]
- Per case normalized score
  \[ (NS) = \frac{\text{per case score}}{20} \times 100\% \]
- False positive and false negative markings could result in a negative score
- Overall performance score was calculated as:
  \[ \left( \frac{\text{per lesion NS} + \text{per case NS}}{2} \right) \]
- In the event of a tie, JAFROC figure of merit (AUC), which takes into account reader confidence, was used.

Library of patient CT projection data

- The library
  - stores projection data in an open and standardized format
    - **DICOM-CT-PD**
    - **HEADER**
      - (0008,0060): Modality
      - (7029,1010): Number of Detector Rows
      - (7037,100A): Type of Projection Geometry
    - **IMAGE**
      - (0018,1010): Projection image
      - (7FE0,0010): Projection image

*Chen et al., “Development and validation of an open data format for CT projection data” Med Phys. 42, 6964 (2015).*

- The library
  - includes scans of various types
    - Routine non-contrast head exams
    - Low dose non-contrast chest exams for lung nodule screening
    - Routine contrast-enhanced abdomen exams
The library
- stores projection data in an open and standardized format
- includes scans of various types
  - Routine head exams
  - Low dose chest exams for lung nodule screening
  - Routine contrast-enhanced abdomen exams
  - Gated exams
  - Dual-energy exams
- includes a wide range of patients and pathologies

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Cases shared

- 10 training patient cases + ACR CT Phantom scan
  - Projection and all image data sets, full and low dose
    - 1 and 3 mm thick images
    - B30 and D45 reconstruction kernels
- 20 test patient cases + ACR CT Phantom scan
  - Projection or one image data set, low dose only

26 countries represented by 103 registrants

Describe your background:

- Doctor: 10.84%
- Physician: 9.57%
- Medical Physicist: 26.60%
- Electrical Engineer: 23.68%
- Mathematician: 6.34%
- Computer Scientist: 23.40%
- Other: 16.44%
Participation

103 registrants
90 unique sites
77 data sharing agreements
41 downloads of test data
22 sites returned
20 interpretable sites

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<tr>
<th>PI Name</th>
<th>Institute</th>
<th>Country</th>
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<tbody>
<tr>
<td>Cheng Cheng</td>
<td>Shanghai United Imaging Healthcare Co., Ltd.</td>
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<td>Dan Ruan</td>
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Overall case performance

Detection rates by site

Numerical Results
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What range of performance was observed at 25% dose?
Routine dose
1st – Site 29 (-)
2nd – Site 47 (-)
3rd – Site 11 (-)
4th – Site 63 (+)
5th – Site 19 (-)
6th – Site 13 (+)
7th – Site 31 (-)

Quarter dose FBP

6th – Site 13 (+)  Routine dose (-)

False positive unique to this site

6th – Site 13 (+)  Routine dose (-)

False positive unique to this site
Future work

- Evaluate demographic data, looks for trends
  - Image domain vs projection domain data
  - Algorithm processing speed
  - Who worked with a radiologist
  - Etc.
- Evaluate top performers with full MRMC study design
  - Validate the pseudo observer approach used with full MRMC study
- Evaluate phantom data to predict MRMC results
  - Are there unique properties or “looks” that did best

False positive unique to this site
1st – Site 29
2nd – Site 47
3rd – Site 11
4th – Site 63
Routine dose
5th – Site 19
6th – Site 13
7th – Site 31
Quarter dose FBP

And the Winners are ...

- 3rd – Dr. Larry Zeng, Professor of Engineering at Weber State University in Ogden, Utah
- 2nd – Eunhee Kang, PhD student at the Korea Advanced Institute of Science and Technology in South Korea, her colleague, Junhong Min, and her advisor, Dr. Jong Chul Ye.
  – Dr. Ye will be presenting
- 1st – Dr. Kyungsang Kim, post-doctoral research fellow at Massachusetts General Hospital in Boston, Massachusetts, and his advisor, Dr. Quanzheng Li.
  – Dr. Kim will be presenting