AAPM Symposium --

1. Overview of MIDRC and AI of COVID-19
   • Maryellen Giger (University of Chicago)

2. Image Quality and Harmonization of MIDRC Imaging Data
   • Paul Kinahan (University of Washington)

   • Michael McNitt-Gray (UCLA)

4. Role of Sequestered Datasets in MIDRC
   • Kyle Myers (FDA)

5. Grand Challenges with MIDRC
   • Samuel Armato, III (University of Chicago)
Overview of MIDRC -- and AI of COVID-19

Maryellen Giger, Ph.D.
University of Chicago
NIBIB convenes medical imaging academics, professional organizations, industry and other Federal agencies with workshops on **AI in Medical Imaging** (August 2018) & **Acceleration of Clinical Applications of Machine Intelligence in MI** (November 2019), which identified **critical gaps**:

1) Absence of large & diverse medical image datasets
2) Need to integrate siloed databases & knowledgebases
3) Need to develop non-redundant efficient AI tools
4) Need to create an **ecosystem of stakeholders** to develop clinically validated AI applications that improve patient management and clinical outcomes

Parallel workshops by ARBIR/NIST, RSNA and AAPM in 2018-2019 confirm the developing consensus.
Then there was the COVID-19 Pandemic

• COVID-19 impacts lungs, as well as heart, vessels, & brain.
• Need to collect medical images and develop artificial intelligence (AI) methods to aid in the analysis / interpretation of medical images

Various presentations of COVID-19 on chest radiographs from three different patients

Various stages of COVID-19 shown on chest CTs from three different patients

- Early Stage
- Progressive Stage
- Severe Stage
Rapid Response to COVID-19 Pandemic

University of Chicago NIBIB Contract PI: Maryellen Giger

American Association of Physicists in Medicine (AAPM) PIs:
- Maryellen Giger (University of Chicago & AAPM Data Science Committee Chair)
- Paul Kinahan (University of Washington & AAPM Research Committee Chair)

Radiological Society of North America (RSNA) PIs:
- Curtis Langlotz (Stanford University & RSNA Board Liaison for IT & Annual Meeting)
- Adam Flanders (Thomas Jefferson University & Member RSNA CDE Committee)

American College of Radiology (ACR) PIs:
- Etta Pisano (ACR Chief Research Officer & Harvard University)
- Michael Tilkin (ACR Chief Information Officer)

Gen3 PI: Robert Grossman

Established August 21, 2020
Goals

• Progress from data to deployment & hypothesis to discovery
• Accelerate the creation and transfer of knowledge for clinical management of COVID-19

A. Open Discovery Data Repository Commons
• Creation, testing, quality assurance, diversity, and data connectivity
• Large scale
• Think “ImageNet” for medical imaging/radiology

B. Machine Intelligence Computational Capabilities
• clinically relevant algorithms and software tools
• MIDRC -- radiologists & medical imaging scientists from across the nation
  • 23 institutions from academia, community practices, FDA
  • Expert collaboration with community engagement
• See website for listing of all investigators
  • [https://www.midrc.org](https://www.midrc.org)
• High-quality and diverse data commons enabling researchers to address topics no single archive could yield independently
Two Major Scientific Components

**Creation of Open Discovery Data Repository:** 5 Technology Development Projects along with three data science subcommittees and advisory committees

**Machine Intelligence Computational Capabilities:** 12 Collaborative Research Projects along with multiple trans-MIDRC scientific workgroups
MIDRC: Technology Development Projects

The **MIDRC infrastructure and processes** will be created through five **Technology Development Projects**, which will be conducted collaboratively:

1. Creating an open discovery platform for COVID-19 imaging and associated data (**led by RSNA**).
2. Creating a real-world testing and implementation platform with direct real-time connections to health care delivery organizations (**led by ACR**).
3. Developing and implementing quality assurance and evaluation procedures for usage across the MIDRC (**led by AAPM**).
4. Enabling data intake, access and distribution via a world-facing data commons portal (**led by all three plus Gen3**).
5. Linking the MIDRC to other clinical and research data registries (**led by all three plus Gen3**).

### Three MIDRC Data Science Subcommittees

- **DSIT** - Data Standards and Information Technology Subcommittee
  - led by RSNA
- **DPP** - Data Policy and Procedures Subcommittee
  - led by ACR
- **DQH** - Data Quality and Harmonization Subcommittee
  - led by AAPM
Two Data Intake Portals

RSNA COVID-19 Database
RICORD

ACR COVID-19 Imaging Research REGISTRY

One Output User Portal

University of Chicago

• To be accessed by hundreds of researchers and developers of AI.
• For training and testing of AI to reduce bias and enhance diversity.
• To expedite translation of AI to clinical care.
Gen3 Data Commons at the University of Chicago is a cloud-based software platform for managing, analyzing, harmonizing, and sharing large datasets.

- Gen3 is an open source platform for developing data commons.
- Data commons accelerate and democratize the process of scientific discovery, especially over large or complex datasets.

Gen3 hosts over a dozen Data Commons including, for example:

<table>
<thead>
<tr>
<th>NIH</th>
<th>BioData CATALYST</th>
<th>NIH</th>
<th>NATIONAL CANCER INSTITUTE</th>
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<tr>
<td></td>
<td>240,460 Subjects</td>
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<td>992 Attributes</td>
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<td>Total Size 2.93 PB</td>
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Two Data Intake Portals

- RSNA COVID-19 Database
- RICORD
- ACR COVID-19 Imaging Research Registry

One Output User Portal

AAPM -- quality assurance and evaluation procedures

University of Chicago

- To be accessed by hundreds of researchers and developers of AI.
- For training and testing of AI to reduce bias and enhance diversity.
- To expedite translation of AI to clinical care.
TDP 3: Developing and implementing quality assurance and evaluation procedures for usage across the MIDRC (led by AAPM)

• TDP 3a: Development of digital and physical imaging phantoms for COVID data
  • John Boone, Paul Kinahan, Tony Siebert, Andrey Fedorov, Nicholas Bevins, Dan Sullivan

• TDP 3b: Assessment of image quality on ingestion into MIDRC
  • Paul Kinahan, John Boone, Tony Siebert, Andrey Fedorov, Nicholas Bevins, Dan Sullivan

• TDP 3c: Development of benchmarking methods for the various technology assessment and clinical tasks in COVID-19 research and translation
  • Michael McNitt-Gray, Berkman Sahiner, Karen Drukker, Maryellen Giger

• TDP 3d: Development of task-based distribution methods
  • Kyle Myers, Maryellen Giger, Heather Whitney, Natalie Baughan
MIDRC Data Dashboard

Total ingested into MIDRC

# of Imaging Studies
41,071

Undergoing MIDRC Data Quality and Harmonization

# of Imaging Studies
38,927

Quality checked
Diversity assessed
Clinical Task AI

Released by MIDRC

# of Imaging Studies
2,144

Goal of 60,000 curated imaging studies to be released by MIDRC by Sept 2021
midrc.org is for:
- researchers
- data contributors
- the public

https://www.midrc.org/register-to-receive-newsletter

data.midrc.org is for searching and downloading data
MIDRC: Collaborative Research Projects (CRPs)

- Each of the three lead organizations, RSNA, ACR, and AAPM, have major data science committees that are already actively pursuing aspects of big data science in medical imaging and the role of machine intelligence.
  - RSNA has its Radiology Informatics Committee (RIC)
  - ACR has its Data Science Institute (DSI)
  - AAPM has its Data Science Committee (DSC)
- Thus, the MIDRC PIs, serving as the initial Executive Advisory Committee, developed the twelve research projects to be immediately funded through the MIDRC within the initial contract in order to expedite the AI research leading to rapid translation to the public and clinical impact.
- The investigators were selected from current members of the RSNA-RIC, ACR-DSI, or AAPM-DSC, thus, effectively spanning the nation and spanning the medical imaging community.
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**Trans-MIDRC scientific workgroups**

- **Grand Challenges Work Group**
  - Created to coordinate effort on all aspects of challenges
  - Potential to merge top performing algorithms to benefit the common good
- **Bias and Diversity Work Group**
  - Goal of assessing and mitigating bias in data and ML
  - Diversity in MIDRC investigators and users
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CRPs led by AAPM members

• CRP 9: Radiomics & Machine Intelligence of COVID-19 for detection and diagnosis on chest radiographs and thoracic CTs
  • Sam Armato, Lubomir Hadjiski, Karen Drukker

• CRP 10: Visualization & Explainability of Machine Intelligence of COVID-19 for prognosis and monitoring therapy
  • Maryellen Giger, Hui Li, Issam El-Naqa, Jonathan Fuhrman, Isabelle Hu, Naveena Gorre

• CRP 11: Investigation of image-based biomarkers for radiogenomics of COVID-19
  • Weijie Chen, Sandy Napel, Maryellen Giger, Diane Lauderdale

• CRP 12: Determining COVID-19 image data quality, provenance, and harmonization
  • Paul Kinahan, Andrey Fedorov, Dan Sullivan
Example of MIDRC CRP Activity:

CRP10: Visualization & Explainability of Machine Intelligence of COVID-19 for prognosis and monitoring therapy

• Developing white papers to aid the AI investigators better understand AI for medical imaging

• Developing machine learning methods to predict severity of COVID-19
  • Accurate prognosis of COVID-19 is crucial as it enables implementation of appropriate treatment for individual patients and medical resource allocation optimization
  • Use “surrogate markers” of severity in the training
  • Fuhrman et al.
    • Assess severity (prognosis) of COVID-19 in CT scans.
    • Predict that a COVID-19 patient would be recommended for steroid treatment or not.
    • Temporal evaluation for monitoring treatment.
  • Hu et al.
    • Assess severity (prognosis) of COVID-19 in Chest Radiographs
    • Predict patients’ needs for intensive care, defined as intubation (invasive mechanical ventilation) and/or intensive care unit (ICU) admission
AI to predict severity of COVID-19

Pretrained VGG19 network feature extraction approach operating on a two-dimensional (2D) CT section.
- Max pooling layer features with the given dimensions were averaged and concatenated to produce a representative feature vector for each slice.
- Full cascaded transfer learning workflow for pretreatment assessment and during-treatment monitoring analysis.
- The feature extraction scheme displayed on the left is utilized at the “Deep Transfer Learning: VGG19 Feature Extraction” stage of right.
Pretreatment: Cascaded Transfer Learning of CT for COVID-19 Management Recommendation

- Classification ability of the cascade transfer learning method for estimating the likelihood that a COVID-19 patient would be recommended for steroid treatment or not. AUC = 0.85

During-Treatment: Transfer Learning for COVID-19 Longitudinal Analysis of CT Scans

- The SVM-output prediction score assessed **temporally** across the duration of hospitalization.
- The shaded regions denote one standard deviation above and below the fit line.

Fuhrman et al. 2021
Chest radiography (CXR) is recommended for triaging at patient presentation and disease monitoring due to its fast speed, relatively low cost, wide availability, and portability.

- Develop an AI method to perform prognosis for COVID-19 patients using CXR, predicting patients' needs for intensive care, which we defined as intubation (invasive mechanical ventilation) and/or intensive care unit (ICU) admission.

- CXR exams from adult patients who underwent COVID-19 RT-PCR tests
  - 1670 CXR from 1178 COVID-19+ patients

- Input: Standard or portable CXR of COVID-19+ patients

- Curriculum learning approach employed to train the model on a sequence of gradually more specific and complex tasks, mimicking the human learning process.
COVID-19 Prognosis Results

Proposed COVID-19 prognostic method achieved an AUC [95% CI] of 0.77 [0.70, 0.84] when predicting the need for intensive care 24 hours in advance, and at least 0.73 [0.66, 0.80] for earlier predictions (48 – 96 hours in advance) based on single CXR exams.
Diversity of the data is an essential component in the developing and testing of unbiased data.

**US Census**
- White: 72%
- Black or African American: 13%
- Asian: 5%
- Native Hawaiian/Pacific Islander: 3%
- American Indian or Alaska Native: 4%
- Two or more races: 5%
- Other: 6%

**Gender**
- Male: 49%
- Female: 51%

**MIDRC**
- White: 64%
- Black or African American: 18%
- American Indian or Alaska Native: 0%
- Asian: 20%
- Native Hawaiian/Pacific Islander: 12%
- Unknown or no information: 0%
- Other: 8%

As of incoming data May 31, 2021
Outreach & Collaborations: presentations, meetings, townhalls, ...

- Annual Meeting (Dec 2020)
- Data Contribution Townhall (March 2021) & another Townhall planned (July 2021)
- Congressional Briefing (Mar 2021) - with the Academy for Radiology & Biomedical Imaging Research
- NCATS N3C (multiple times)
- NHLBI BioData Catalyst (multiple times)
- ODSS (NIH Office of Data Science Strategy)
- SPIE (on supporting challenges)
- ARBIR (Academy for Radiology & Biomedical Imaging Research) (Dec 2020)
- AIUM (American Institute of Ultrasound in Medicine) (multiple times)
- ASNRC (American Society of Neuroradiology) (multiple times)
- MDRIG (Medical Device Research Interest Group) (April 2021)
- MDIC (Medical Device Innovation Consortium) (April 2021)
- Various invited talks by MIDRC PIs
  - Special symposium at AAPM in July 2021 and Special course at RSNA in November 2021
What is next for MIDRC?

• Beyond chest radiographs and thoracic CTs for COVID-19
  • Include images of the cardiovascular system (heart) and the nervous system (brain)
  • Include images beyond diagnosis and response to therapy, to include images to monitor post-COVID patients (including the “long haulers”)
  • Collaborate with the non-imaging COVID-19 data commons to integrate across clinical data, imaging exams, histology, and genomics

• Beyond COVID-19
  • MIDRC, with its developed infrastructure, AI algorithms, and evaluation tools, will be ready for all medical images and other diseases
  • Thus, MIDRC will be a national resource for medical imaging

• Currently funded for two years for COVID-19 data and AI
• Require additional funds to continue with other diseases.
"After clinical data are used to provide care, the primary purpose for acquiring the data is fulfilled. At that point, clinical data should be treated as a form of public good. All who interact with or control the data have an obligation to ensure that the data are used for the benefit of future patients and of society."

Note, for a given medical image,

-- A patient has already benefited through medical care.
-- A hospital/medical center has already benefitted through reimbursement.
-- Now, the public can benefit with the MIDRC secondary usage of the images.
-- We all can help change the future of medical imaging and increase its impact on public health.
Summary: MIDRC is more than just a data registry

- A **high-quality and diverse data commons** led by **major imaging societies** enabling researchers to address topics no single archive could yield independently.

Including:

- Proactive, encouraging system for **changing the culture of contributing data for the common good**.
- **User-friendly open output portal** for browsing/exploring the data, creating cohorts, and downloading data.
- **Research on AI development** including algorithms as well as techniques for digital reference phantoms, computer annotating & crowd sourcing for “truth”, NLP of radiology reports, and virtual clinical trials.
- **Sequestered data commons** of diverse cases that will be used to independently evaluate AI algorithms for specific claims, clinical tasks, and populations (while retaining the integrity of the test set).
- **Public website** for **dissemination of information** on metrics of evaluation, task-based distribution methods, related software, and white papers such as ones on explainability of AI.
- Mechanism for hosting of **Grand Challenges**.
- **Welcoming scientific community** for collaboration with other societies, institutes, and organizations.
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Including:

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- Research on AI development including algorithms as well as techniques for digital reference phantoms, computer annotating & crowd sourcing for “truth”, NLP of radiology reports, and virtual clinical trials.

- Sequestered data commons of diverse cases that will be used to independently evaluate AI algorithms.

- Public website for dissemination of information on metrics of evaluation, task-based distribution methods, related software, and white papers such as ones on explainability of AI.

- Mechanism for hosting of Grand Challenges.

- Welcoming scientific community for collaboration with other societies, institutes, and organizations.

Thank you, please donate imaging studies, and let’s work together.