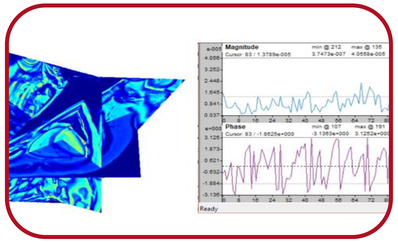
A Future of CMR AI with Inline Computing and Big-Training

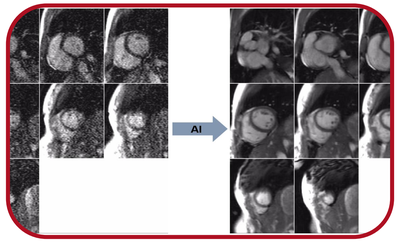
This presentation provides an overview of our CMR AI research with the focus on InlineAI and biomarker-before-reporting deployment. A global network is developed, and large data flywheel is running to curate big CMR datasets from broad imaging protocols, around the globe. The large datasets are fed into AI R&D for iterative re-training of existing models and development of new models. The self-supervised learning is introduced to CMR and provide ability to consume the large datasets, showing impressive capacity to reduce labelling effort. As a combined effect of inline computing, global network and new training scheme, a viscous cycle is established for faster, continuously improved and more CMR AI.

Hui Xue

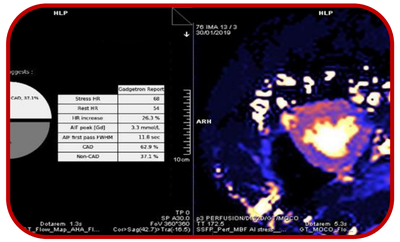
May 2022



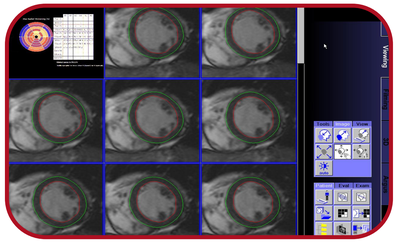
Acquisition



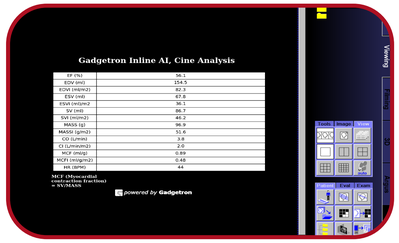
Reconstruction



Diagnosis



Analysis



Reporting

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Declaration

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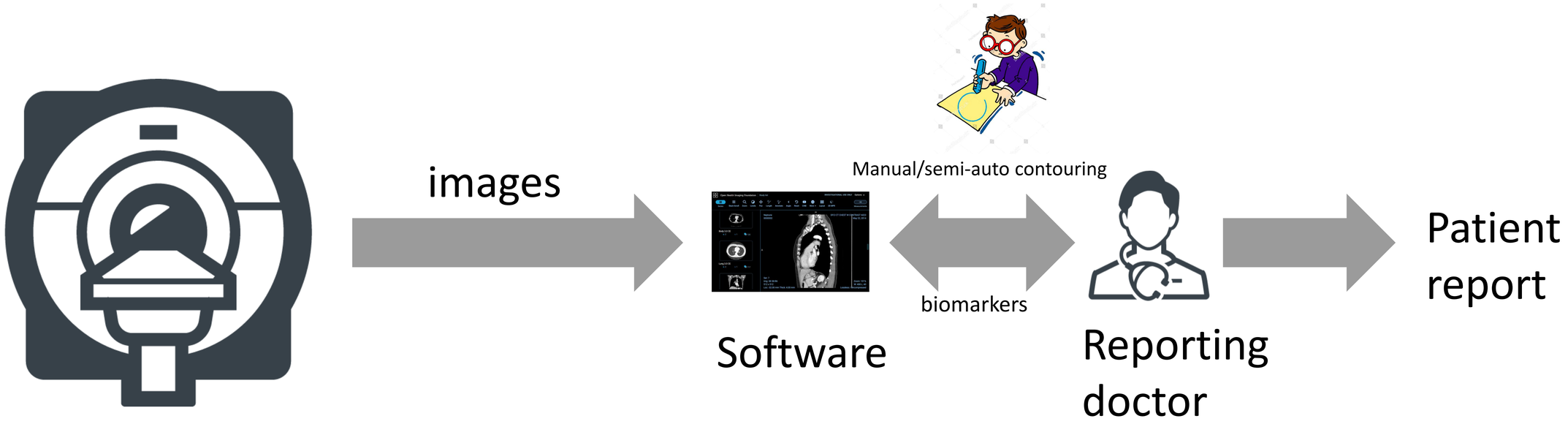
Dr Hui Xue, NHLBI, NIH

Nothing to disclose

Outline

- Inline AI for CMR – a paradigm shift
- Automation and Quantification on scanner - biomarker before reporting
- Global network and data flywheel
- Self-supervised learning CMR – put the big-data in use

Current clinical workflow requires intensive Interaction



- Interactive processing
- Established workflow
- But require expert time
- Harder to maintain and upgrade, learning curve for operators, inter-operator variation

Inline AI computing: cut the middleman with experts in the loop

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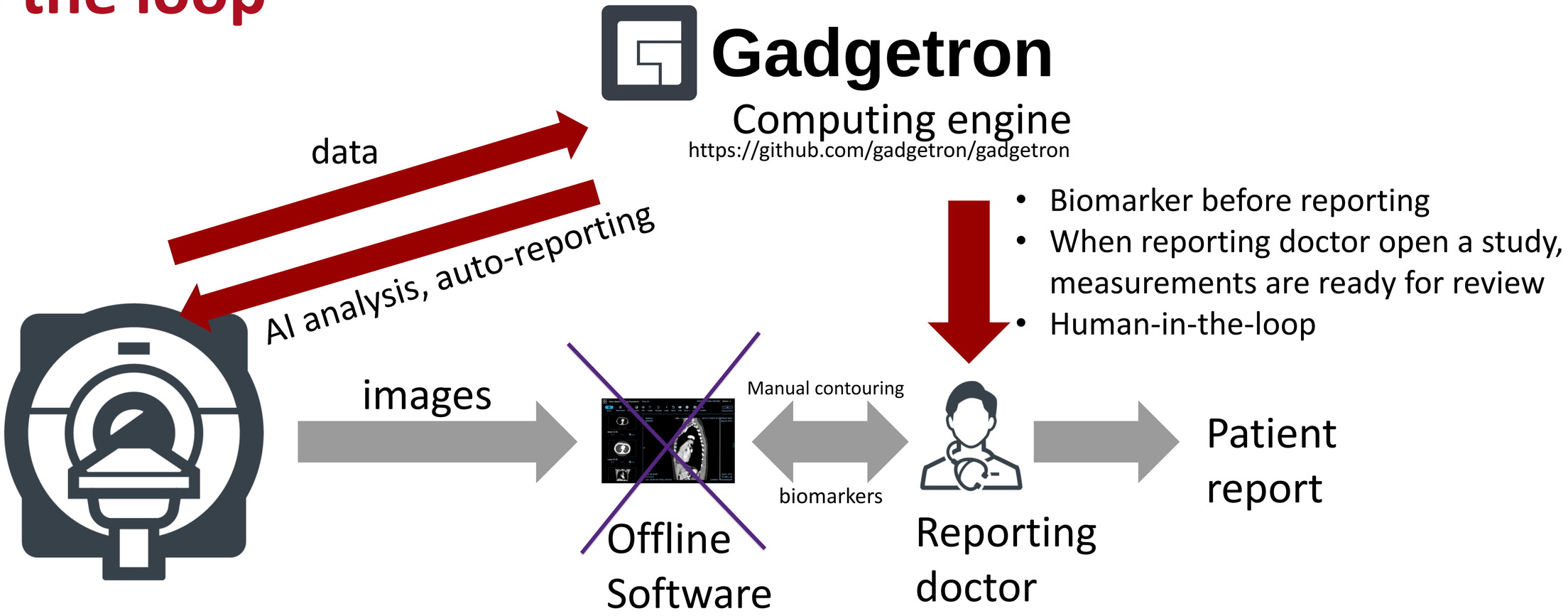
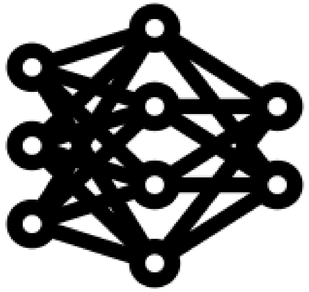


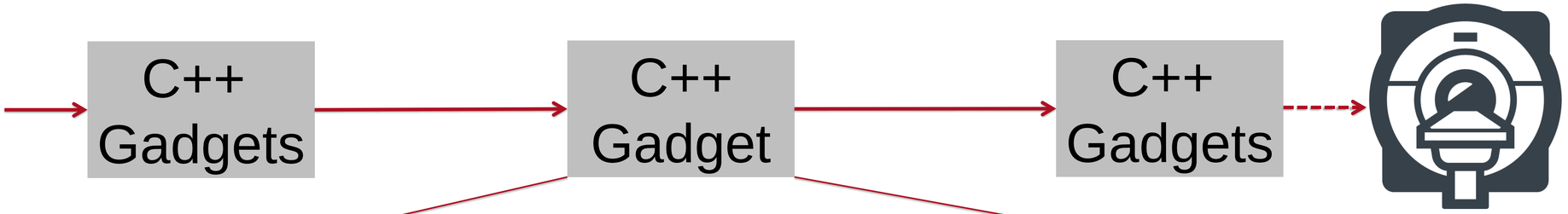
Inline AI: Model inference on MRI scanner

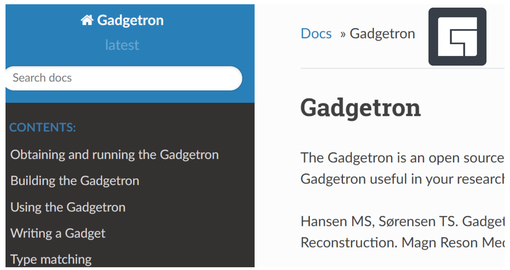


Trained NN

Model inference

- Limited computing power
- Outdated software configuration
- Clinically relevant computing time





https://github.com/gadgetron/gadgetron.git

User supplied code

model = PythonFunction<…> load_ai_model (…);

…

res = PythonFunction<…> apply_ai_model (…);

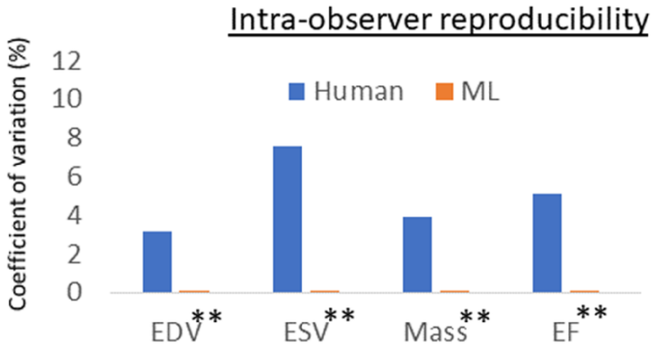
```
def load_ai_model(model_dir, model_file):

    m = None

    try:
        curr_dir = os.getcwd()

def apply_ai_model(data, model):
    #Note that data should be a torch arra
    #Note that output is also a torch arra

    mask = None
```

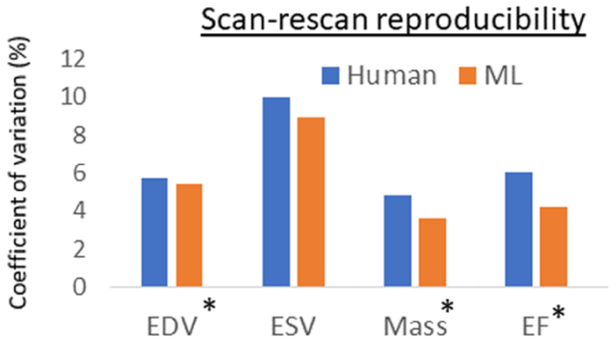
Short-axis function with Inline AI

Eliminate the need of manual measurement, with 4 deep learning models

Rhodri H Davies, James C Moon et al. Precision measurement of cardiac structure and function in cardiovascular magnetic resonance using machine learning. JCMR **24**, 16, 2022.

AI is superior in SAX function



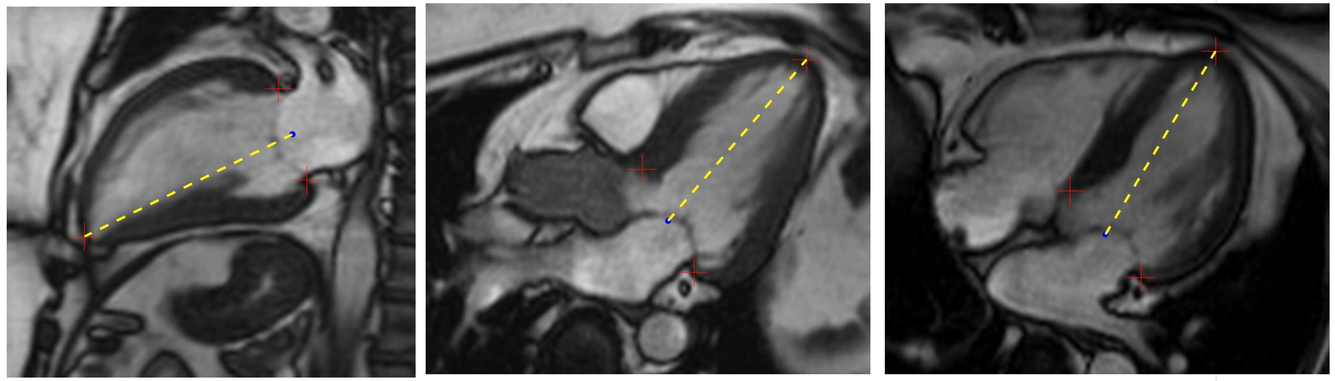


	Intra-observer Reproducibility (%)			Scan-rescan Reproducibility (%)		
	Human	Machine		Human	Machine	
EDV	3.2 (2.6 – 3.8)	0	P<0.001**	5.7 (4.8 – 6.4)	5.4 (4.3 – 6.8)	P=0.04*
ESV	7.6 (6.3—9.1)	0	P<0.001**	10 (8.1 – 11.9)	8.9 (7.6—10.3)	P=0.10
EF	5.1 (3.7-6.4)	0	P<0.001**	6 (5.1-7.0)	4.2 (3.5 – 5.0)	P<0.01*
LVM	3.9 (3.4—4.4)	0	P<0.001**	4.8 (4.1 – 5.6)	3.6 (2.9 – 4.3)	P<0.01*

- N=109 scan-rescan tests
- AI is better for full automation
- AI is better for improved reproducibility

Rhodri H Davies, James C Moon et al. Precision measurement of cardiac structure and function in cardiovascular magnetic resonance using machine learning. JCMR **24**, 16, 2022.

Long-axis function: MAPSE and global longitudinal shortening with AI landmark detection

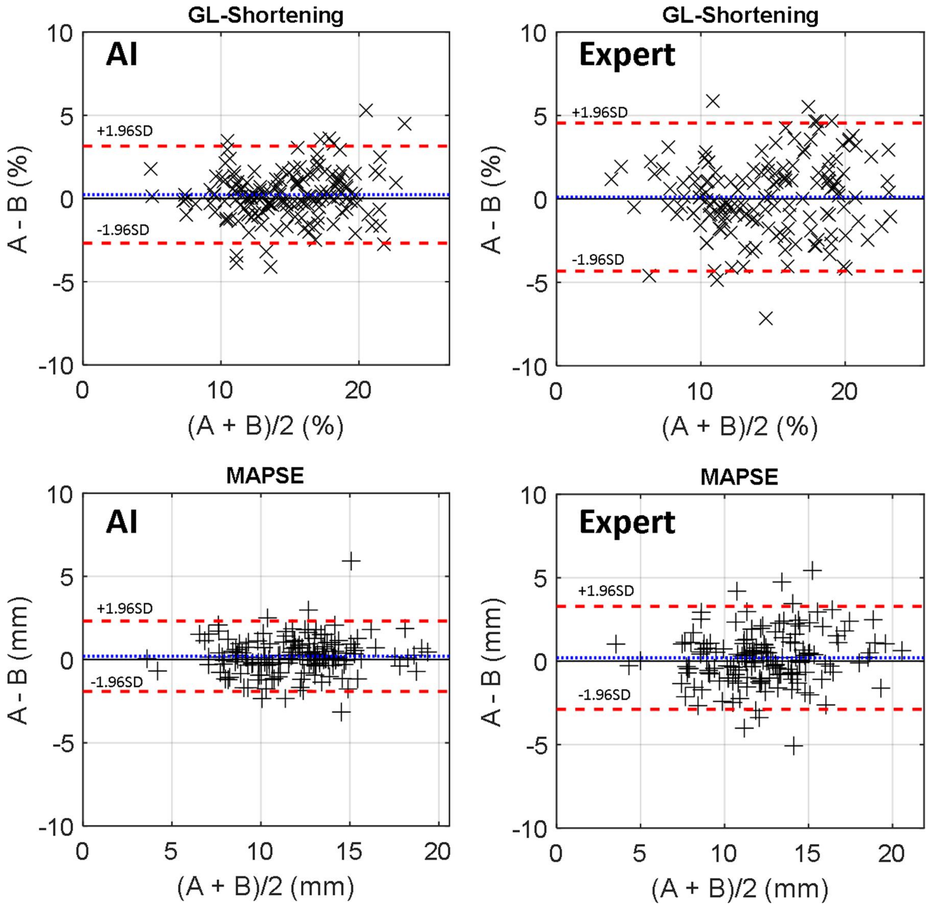


- Automated analysis of cine LAX images
- Measure MAPSE
- Measure global longitudinal shortening
- On MR scanner

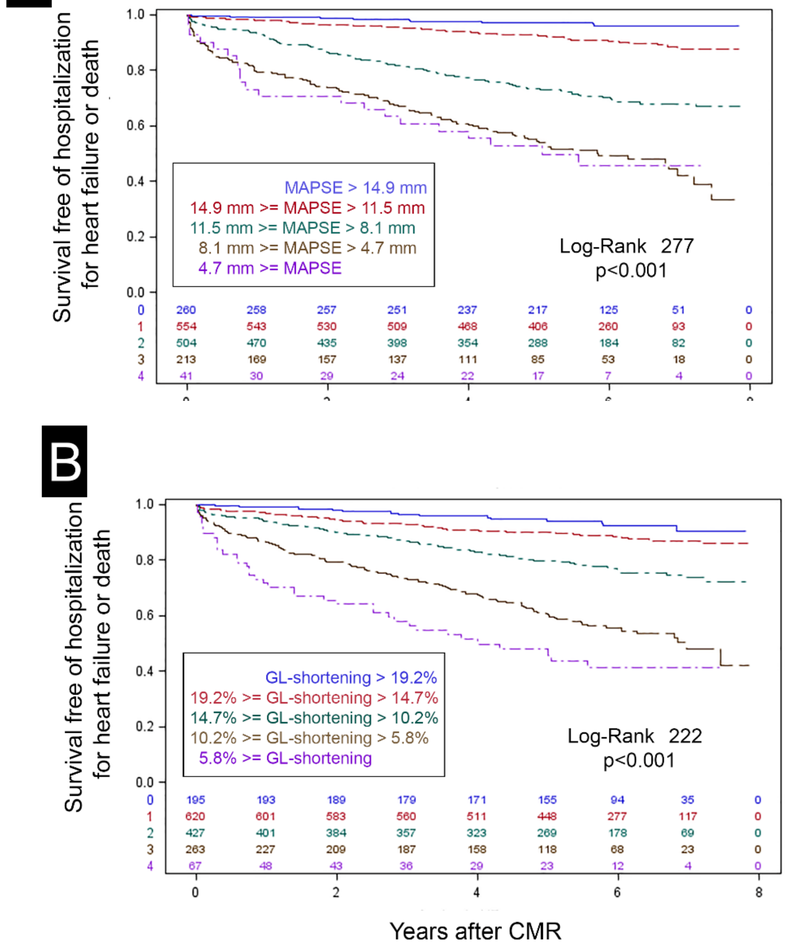
Hui Xue, Jessica Artico, Marianna Fontana, James C. Moon, Rhodri H. Davies, Peter Kellman. Landmark Detection in Cardiac MRI Using a Convolutional Neural Network. Radiology: Artificial Intelligence 2021; 3(5):e200197.

AI is superior again and prognostic

Scan-rescan test (N=160)

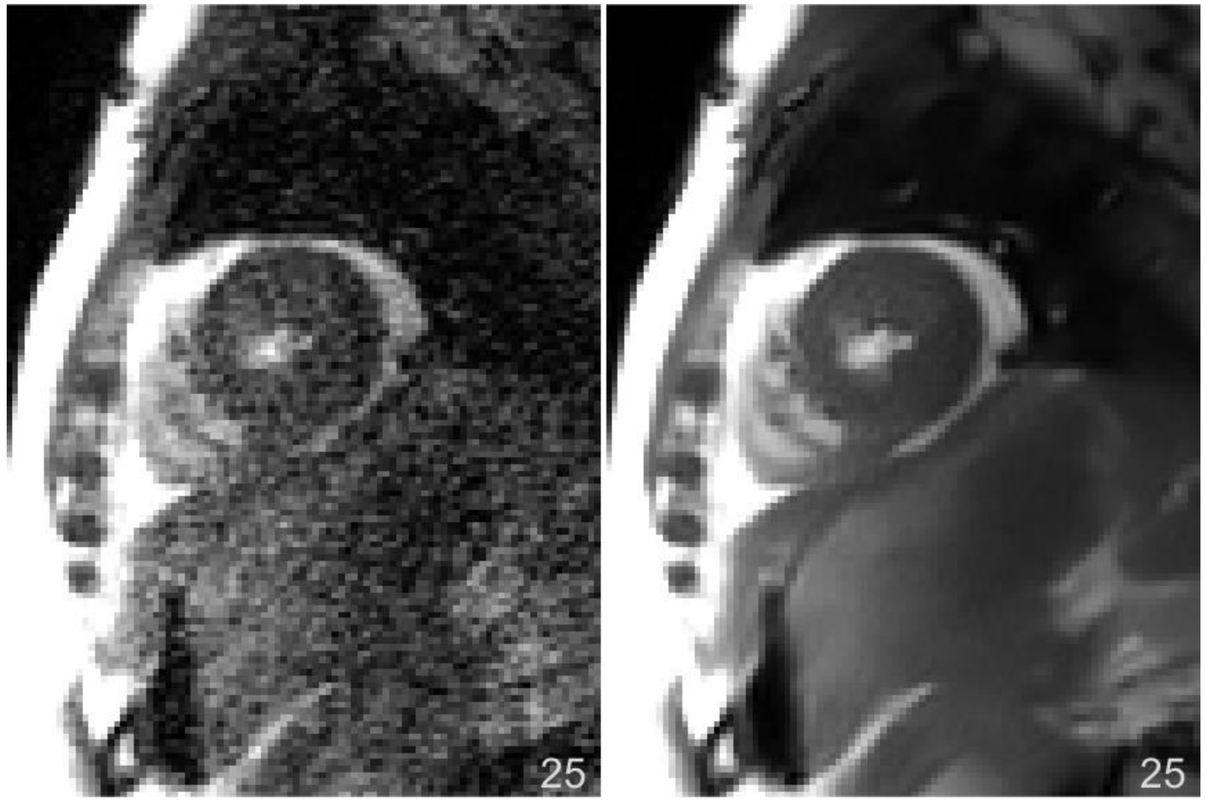


Outcome study (N=1578)



Hui Xue, James C. Moon, Rhodri H. Davies, Erik B Schelbert, Peter Kellman et al. Automated In-Line Artificial Intelligence Measured Global Longitudinal Shortening and Mitral Annular Plane Systolic Excursion: Reproducibility and Prognostic Significance. JAHA, 11,4, 2022.

AI for CMR imaging



BSSFP real-time cine, R=5, matrix size 192x144, Temporal resolution 35ms, FOV 400x300

- New model architecture: **Convolutional Neural Network Transformer (CNNT)**
- Suitable for CMR usecases
- Applicable to image enhancement, segmentation, detection and other tasks

Learn more in Azaan Rehman's talk next !

InlineAI Scales

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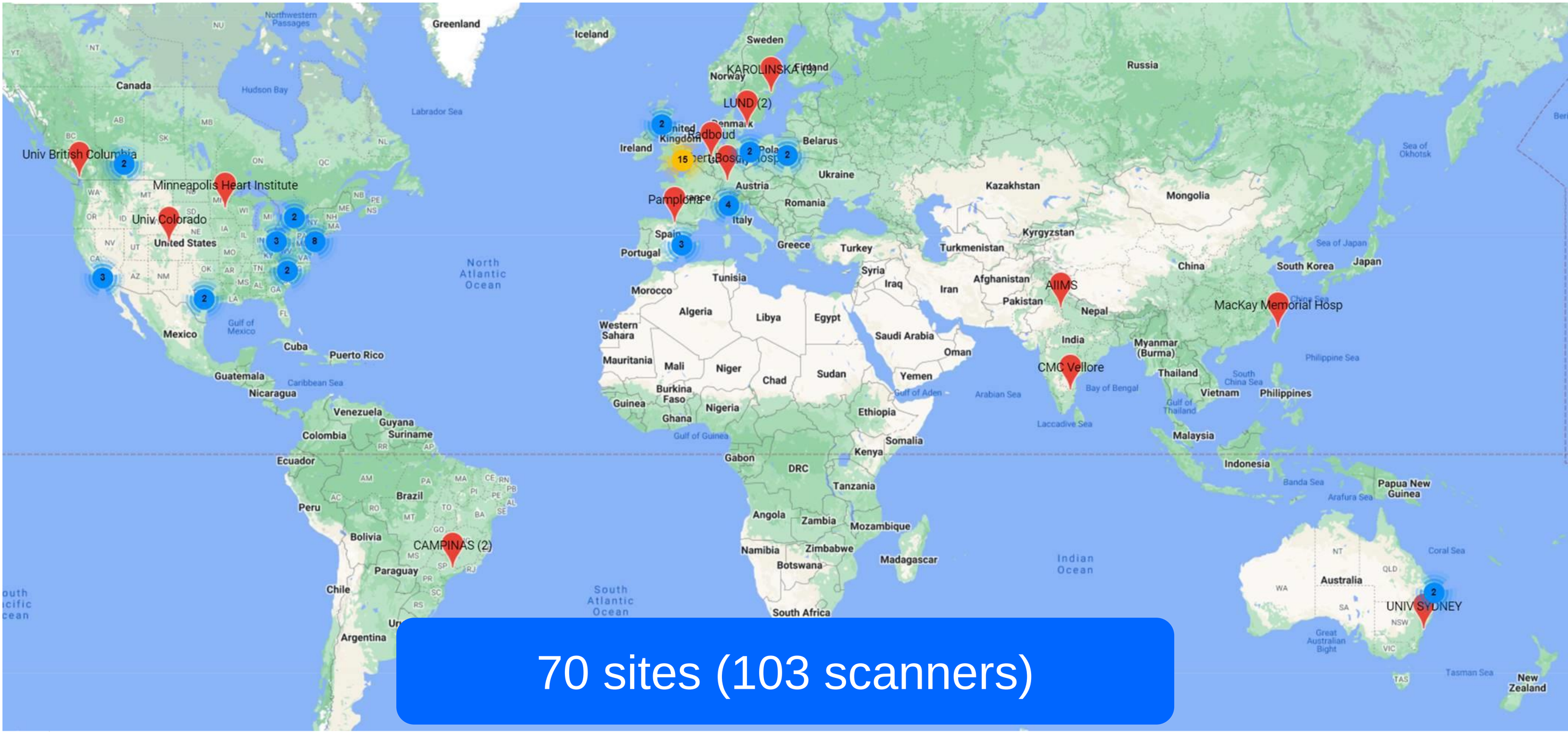

Data flywheel for CMR AI

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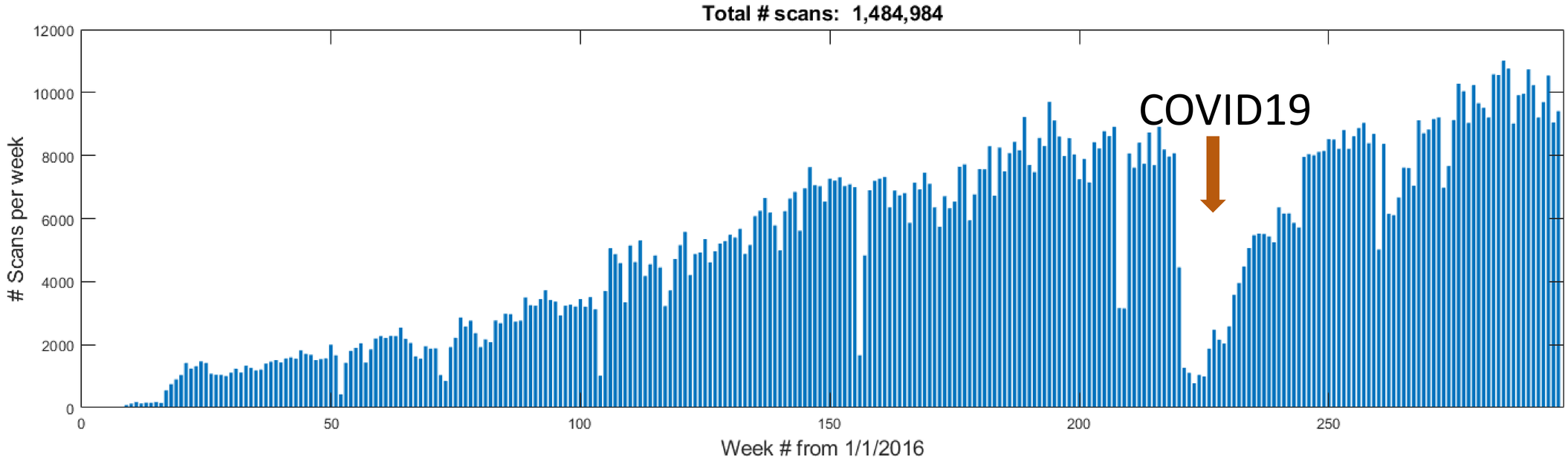
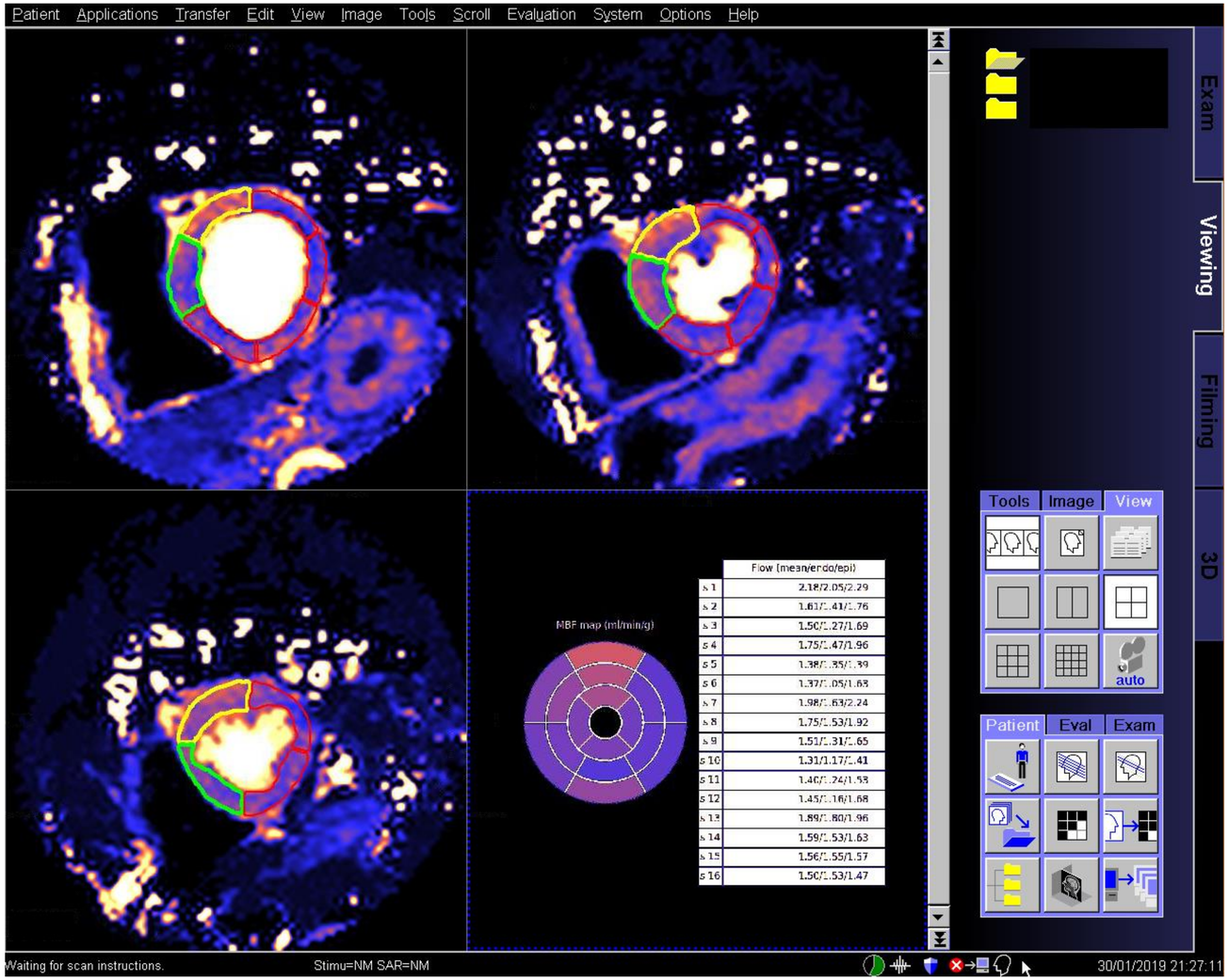
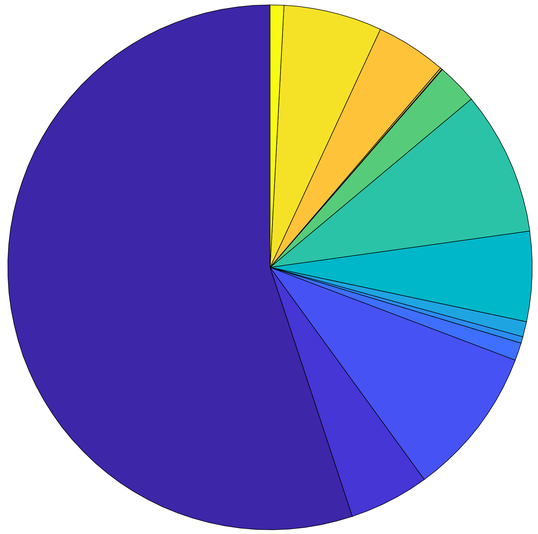
- On 30 scanners with high usage
- Based on statistics reported
- approx 1.5M scans



Revisit model training with big-data



Number of Perfusion scans is 57316, from 20160225 to 20210519



Labelled data available:

1825 perfusion series from 1034 patients

1.8% used in training

Hui Xue, Rhodri H. Davies, Louise A. E. Brown, Kristopher D. Knott, Tushar Kotecha, Marianna Fontana, Sven Plein, James C. Moon, Peter Kellman. Automated inline analysis of myocardial perfusion MRI with deep learning. Radiology: Artificial Intelligence. 2020; 2(6):e200009

Semi-supervised learning

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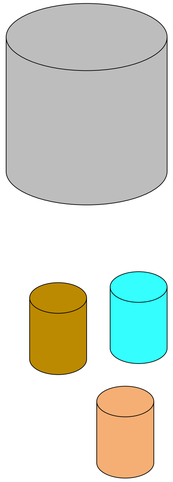
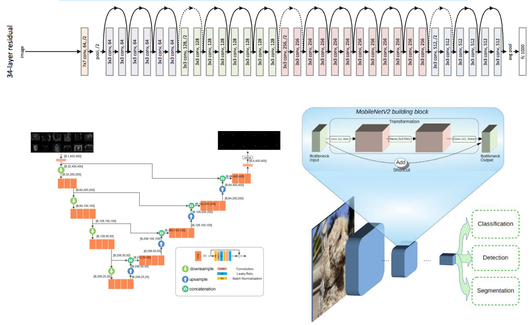
Self-supervised learning + Largest dataset + Clinical expertise

Large unlabeled data from patients

Small labeled data from experts

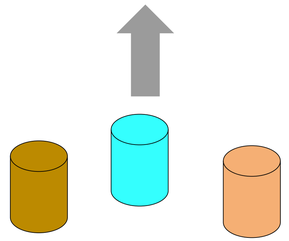


Self-supervised learning



backbone models for different applications

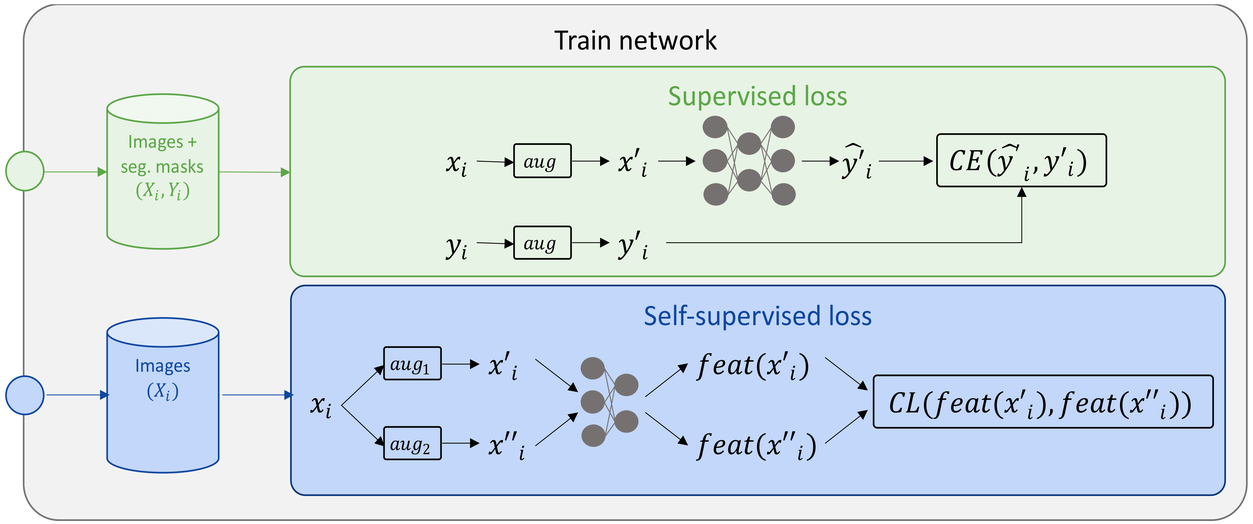
Fine-tuning



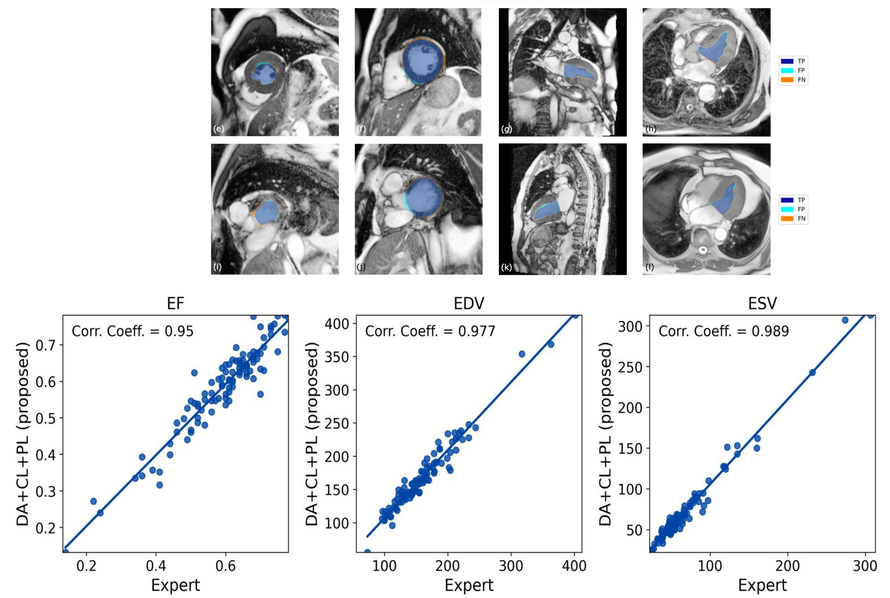
Finetune different application with small labeled datasets

Task specific model

SAX function with 99.6% labeling reduction



- Accept both labelled and unlabeled data
- Combine supervised training and contrastive learning
- Flexible backbone models for different tasks



SSL Training: 100 labeled images and 16,712 unlabeled images (**99.6% labeling reduction**)

Testing: N=108 patients, no overlap with training

SSL model correctly measures EF, EDV, ESV, SV, compared to human expert

Sarah Hooper, Hui Xue, Rhodri H Davies, James C Moon, Chris Re et al. Semi-supervised learning for cardiac cine MRI segmentation: reducing data labeling by orders of magnitude. Radiology AI, under review.

Learn more in Sarah Hooper's poster !

Inline AI *for clinical workflow : A new paradigm*

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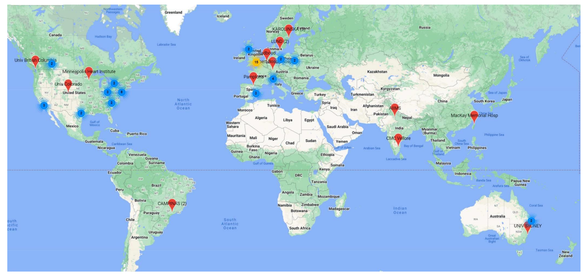
powered by Gadgetron

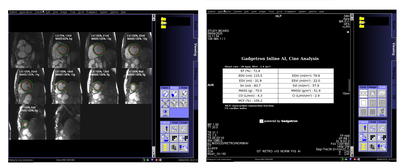
Post-processing
contouring

Reporting doctor

Gadgetron Global Network and data

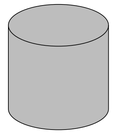


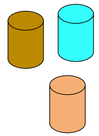
InlineAI and model deployment



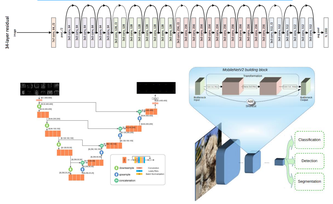
Images + AI derived biomarkers

- **Full automation**
- **Biomarker-before-reporting**
- **Expert in the loop**
- **Replace post-processing offline with inline AI**
- **AI models are more reproducible than human**



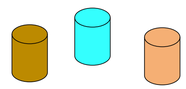


Self-supervised learning



backbone models for different applications

Fine-tuning



Training with big-data and reduced labelling