Fully Automated Echocardiogram Interpretation in Clinical Practice

Feasibility and Diagnostic Accuracy

Zhang J et al.

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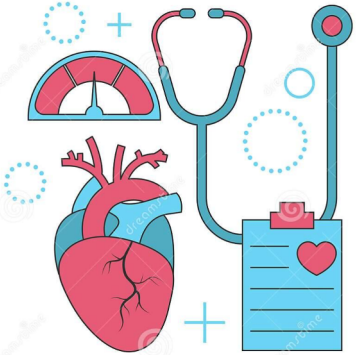
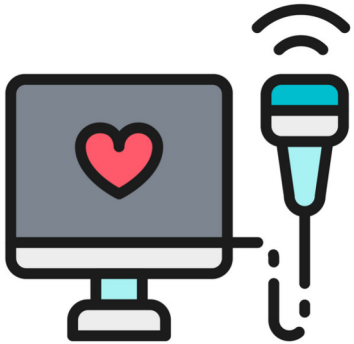
Outline

- Motivation
- Goal
- Background
- Workflow
  - View classification
  - Segmentation
  - Cardiac structure and function
  - Disease detection
- Strength and limitation

Motivation



Early detection



Echocardiography

Electronic medical records

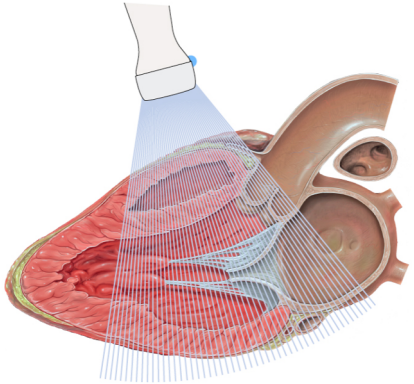
Goal

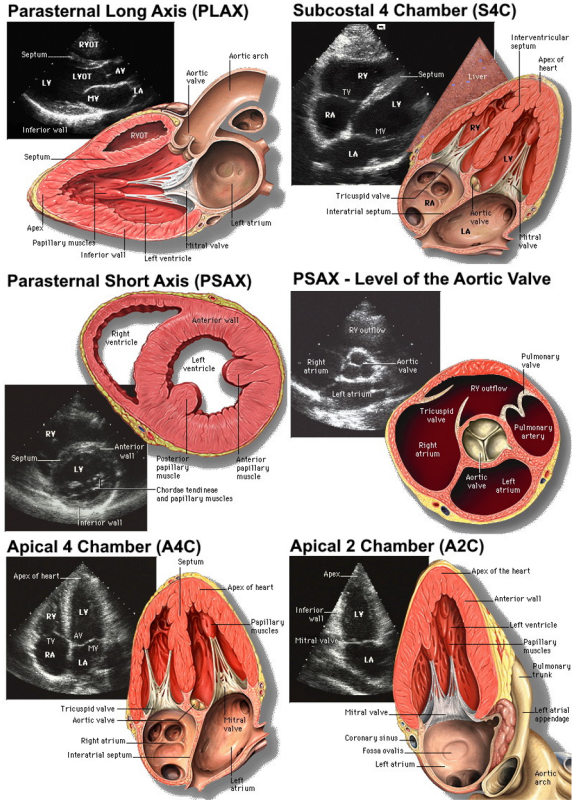
A fully automated computer vision pipeline for the interpretation of cardiac structure, function, and disease detection using a combination of computer vision approaches.

Background

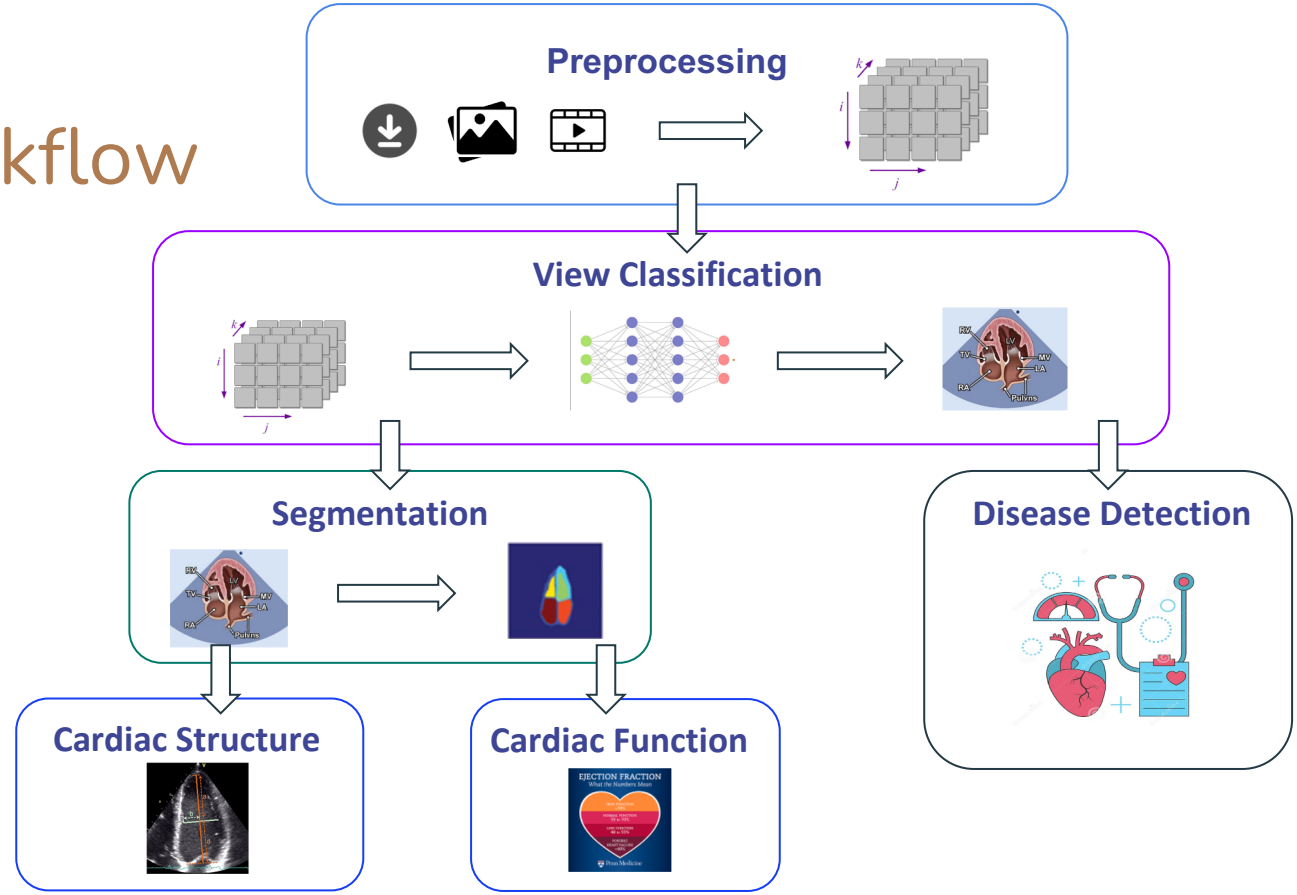
Echocardiography

- About 70 videos
- Different viewpoints



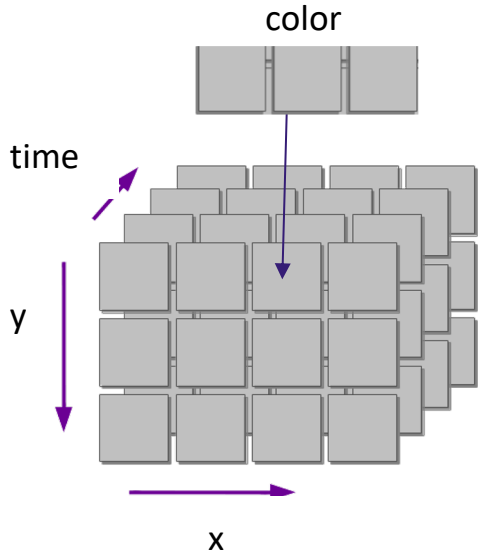


Workflow

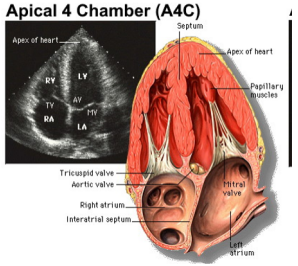

Preprocessing
View Classification
Segmentation
Disease Detection
Cardiac Structure
Cardiac Function
EJECTION FRACTION
What the Numbers Mean

Preprocessing

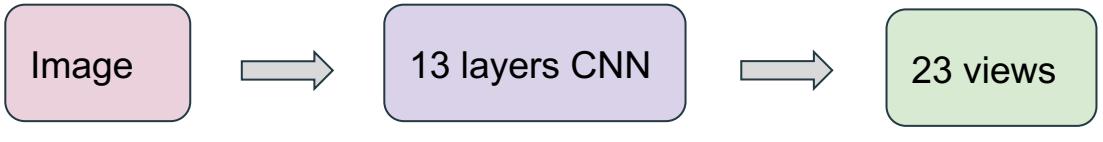
- Data from University of California San Francisco (UCSF) Studies
- Converted to multidimensional numeric arrays of pixels
- Used for 4 main tasks
  - View classification (277 echocardiograms)
  - Image segmentation (791 images over 5 views)
  - Measurements of cardiac structure and function
  - Disease detection



View classification

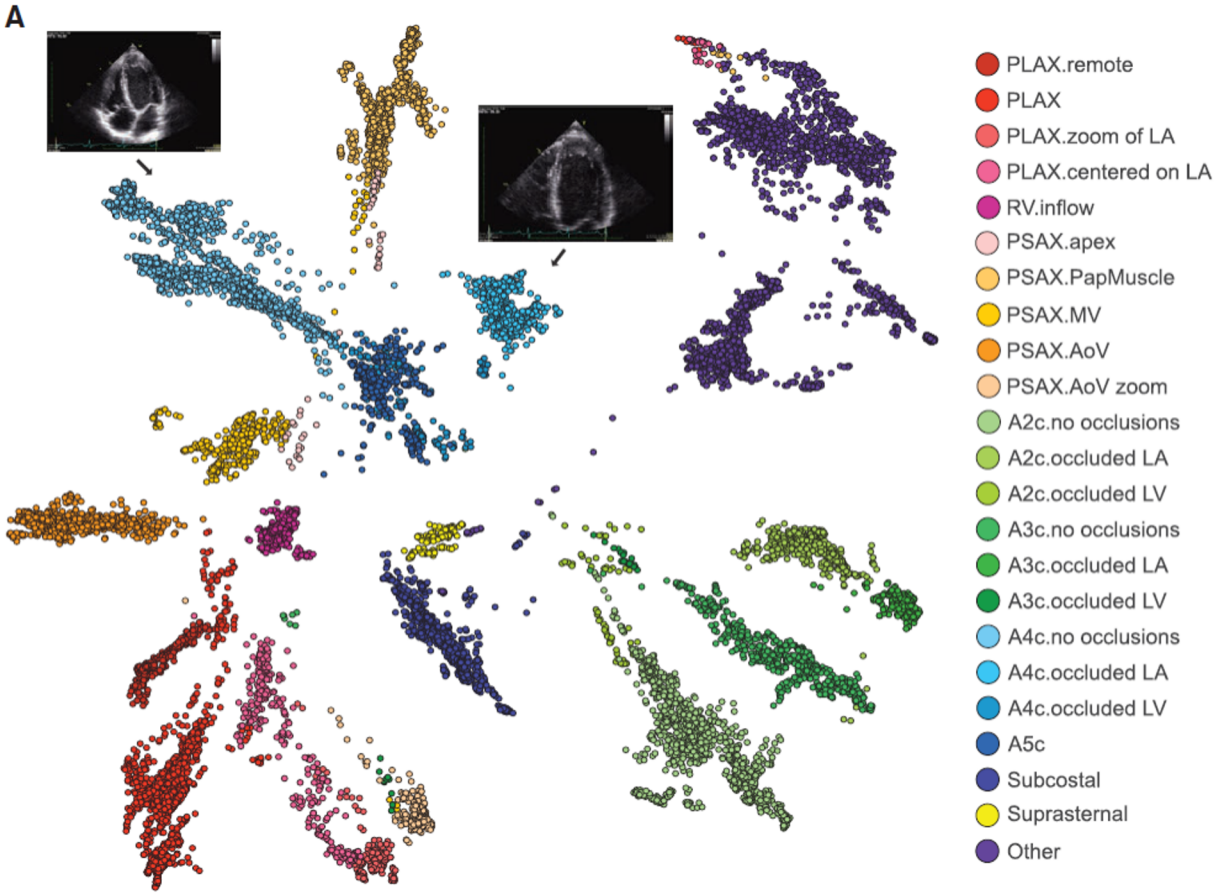


- Manual labels
- View Probability Quality Score: averaged maximum view probability for all videos in a study



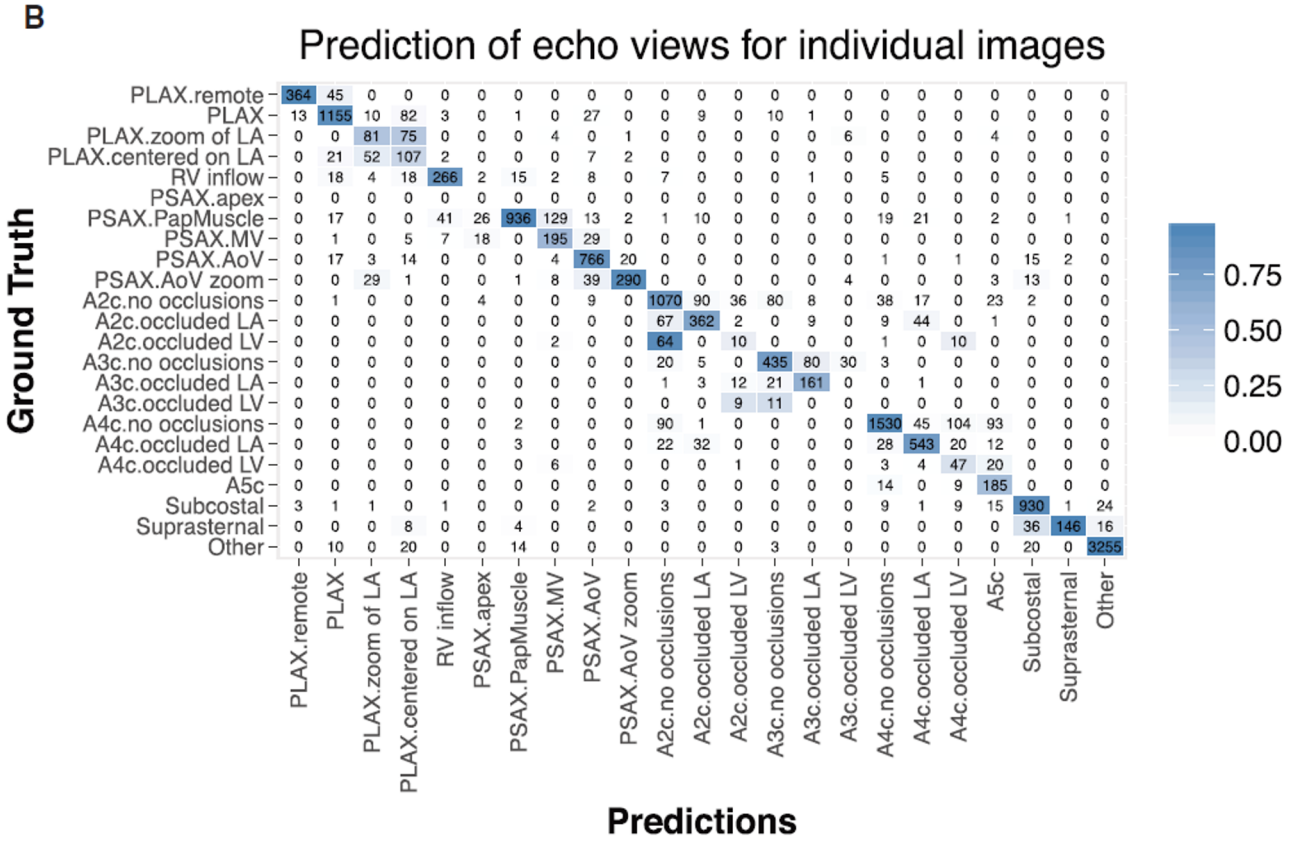
View classification results

t-Distributed Stochastic Neighbor Embedding



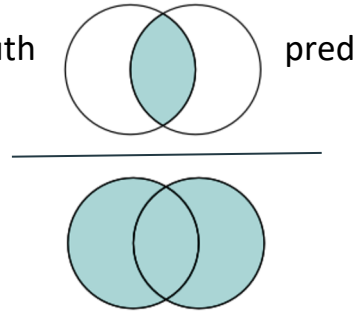
View classification results

84% accuracy

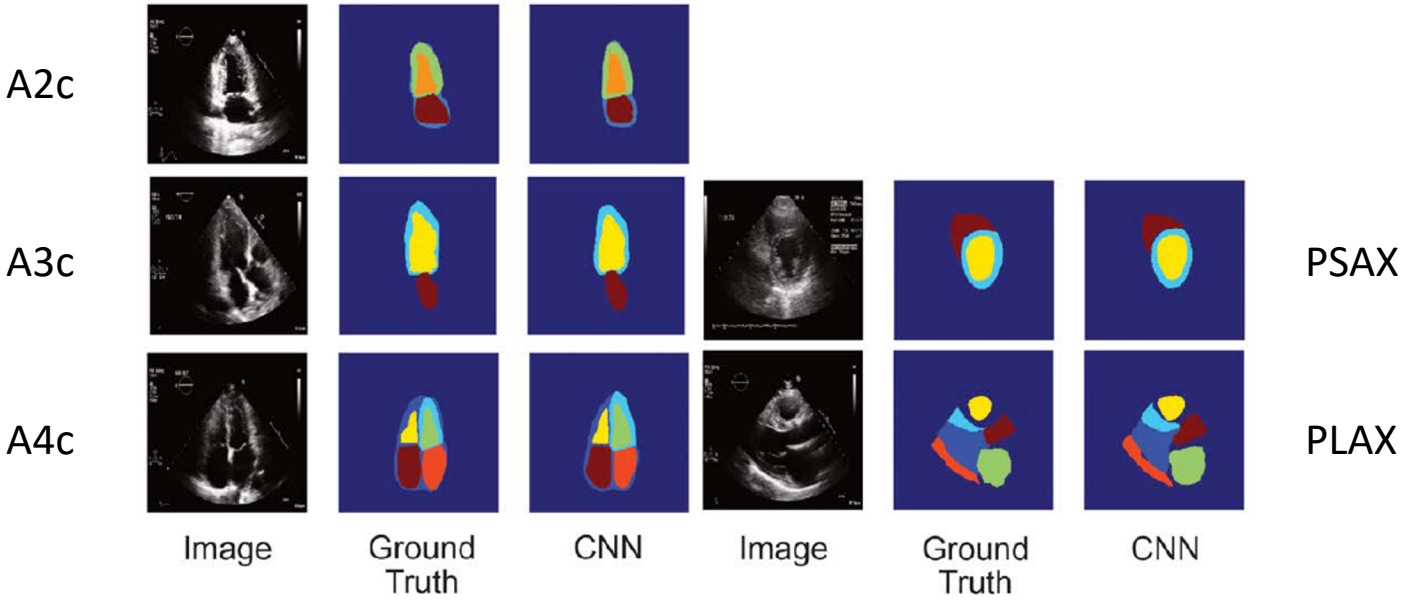


Segmentation

- CNN models with U-net algorithm
- 5 views: PLAX, PSAX, A2c, A3c, and A4c
- Manual traced cardiac structures on 791 images as ground truth
- Accuracy assessment with cross-validation using **intersection over union (IoU)** metric
- IoU:



Segmentation - results



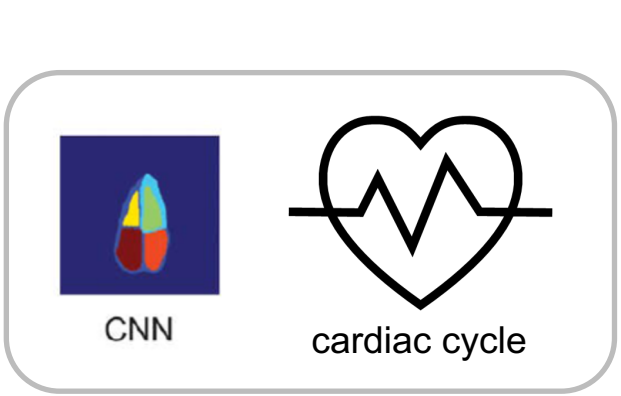
Segmentation - results

View	Number of Images Used for Training	Segmented Area	IoU Accuracy
A2c	214	Left atrium blood pool	88.2
		Left ventricle blood pool	89.1
		Left ventricle myocardium	72.2
A3c	141	Left atrium blood pool	88.3
		Left ventricle blood pool	88.3
		Left ventricle myocardium	72.7
A4c	182	Left atrium blood pool	89.8
		Left ventricle blood pool	88.9
		Left ventricle myocardium	73.7
		Right atrium blood pool	88.1
		Right ventricle blood pool	83.3
PLAX	130	Left atrium blood pool	86.1
		Left ventricle blood pool	87.9
		Right ventricle blood pool	85.2
		Aortic root	86.4
		Anterior septum	76.8
		Posterior wall	74.9
PSAX	124	Left ventricle blood pool	79.6
		Left ventricle myocardium	74.0
		Right ventricle blood pool	64.6

outlier

Cardiac structure & function

- Compare the automated and manually derived results (8666 samples)



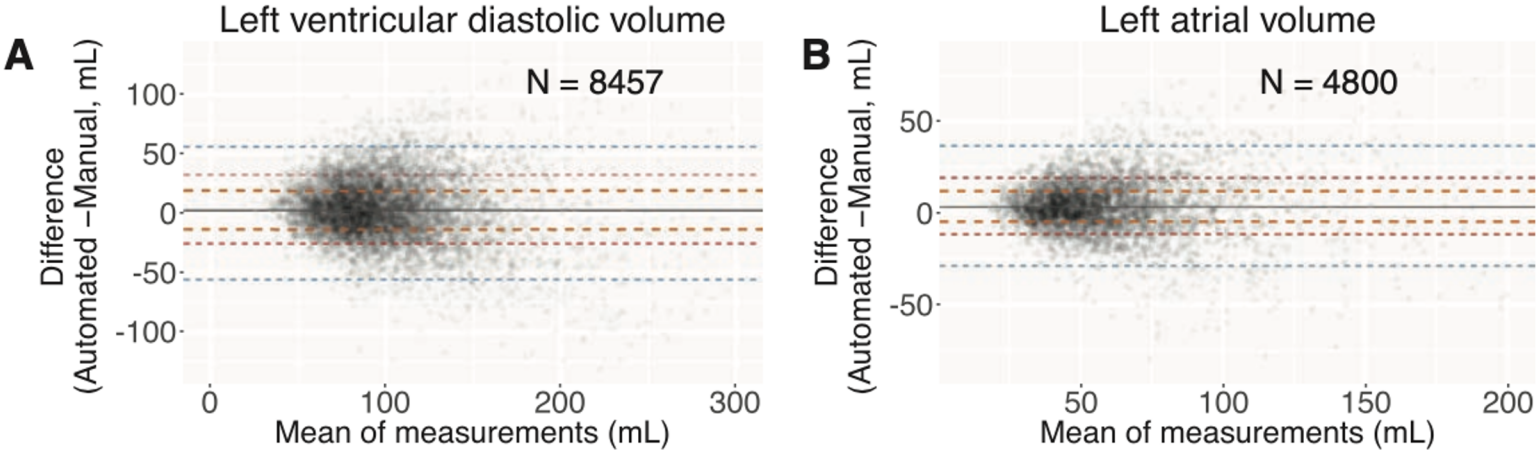
- Mass, volume
- Ejection fraction

$$\frac{stroke\ volume}{end{-}diastolic\ volume} \times 100$$

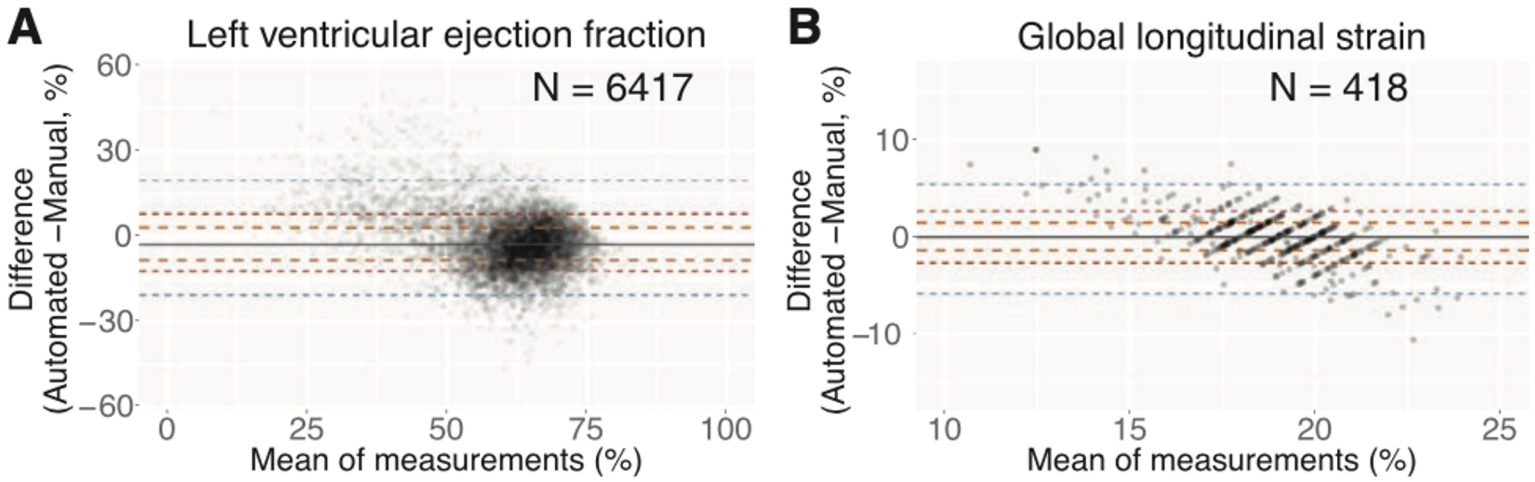
- Longitudinal strain

Lang RM et al. , Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *J Am Soc Echocardiogr*. 2015;28:1–39.e14

Cardiac structure absolute difference



Cardiac function absolute difference



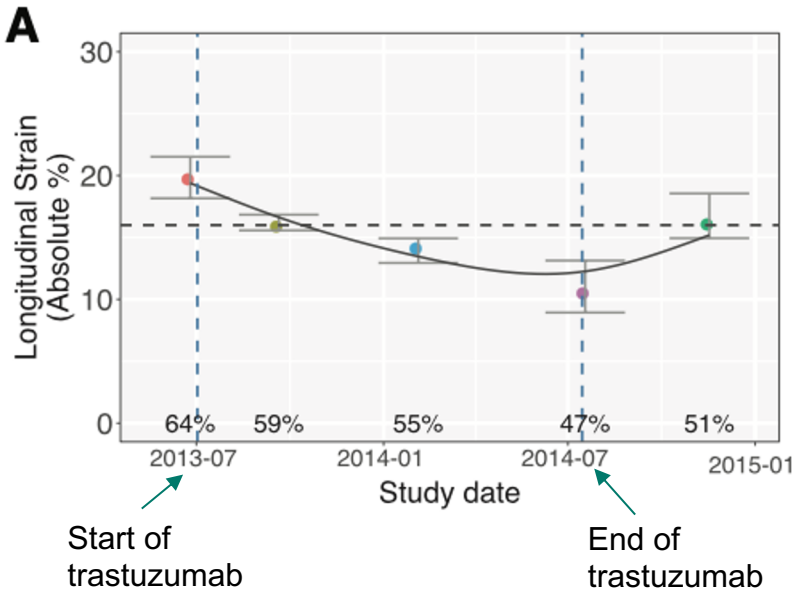
Cardiac function & structure results

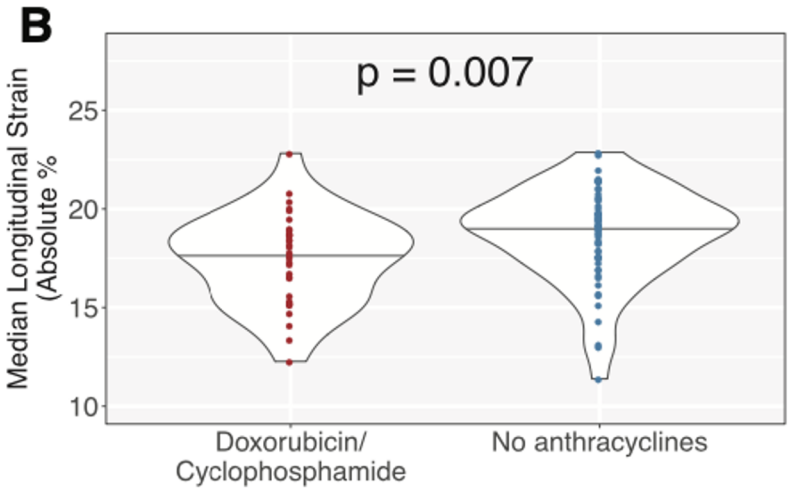
Metric	Number of Echocardiograms Used	Median Value (IQR)	Absolute Deviation: Automated vs Manual (% of Manual)		
			50	75	95
Left atrial volume, mL	4800	53 (40–71)	9 (16)	16 (29)	33 (66)
Left ventricular diastolic volume, mL	8457	92 (72–119)	16 (17)	29 (31)	56 (68)
Left ventricular systolic volume, mL	8427	33 (24–47)	9 (26)	16 (47)	39 (108)
Left ventricular mass, g	5952	148 (11–160)	23 (15)	42 (28)	91 (95)
Left ventricular ejection fraction	6407	65 (58–69)	6 (10)	11 (17)	20 (40)
Global longitudinal strain	418	19 (17–21)	1.4 (8)	2.7 (14)	5.8 (31)
Global longitudinal strain (Johns Hopkins PKD study)	110	18 (16–20)	1.6 (9)	2.8 (17)	5.4 (39)

Internal consistency

Comparison	N	Correlation – Manual vs. Manual (p-value)	Correlation – Automated vs. Automated (p-value)
Left atrial volume vs. left ventricular mass	4012	0.54 (<2e-16)	0.56 (<2e-16)
Left ventricular mass vs. left ventricular diastolic volume	5874	0.62 (<2e-16)	0.61 (<2e-16)
Left ventricular mass vs. left ventricular systolic volume	5856	0.58 (<2e-16)	0.55 (<2e-16)
Left atrial volume vs. left ventricular diastolic volume	4748	0.48 (<2e-16)	0.56 (<2e-16)
Left atrial volume vs. left ventricular systolic volume	4738	0.46 (<2e-16)	0.49 (<2e-16)
Left atrial volume vs. left ejection fraction	4720	-0.22 (<2e-16)	-0.23 (<2e-16)
Left ventricular mass vs. global longitudinal strain	243	-0.16 (0.01)	-0.27 (<2e-16)
Left ventricular mass vs. left ejection fraction	5123	-0.28 (<2e-16)	-0.28 (<2e-16)
Left ventricular diastolic volume vs. global longitudinal strain	326	-0.15 (0.006)	-0.17 (0.002)
Left ventricular systolic volume vs. global longitudinal strain	326	-0.29 (<2e-16)	-0.27 (<2e-16)
Left ventricular ejection fraction vs. global longitudinal strain	251	0.37 (<2e-16)	0.32 (<2e-16)

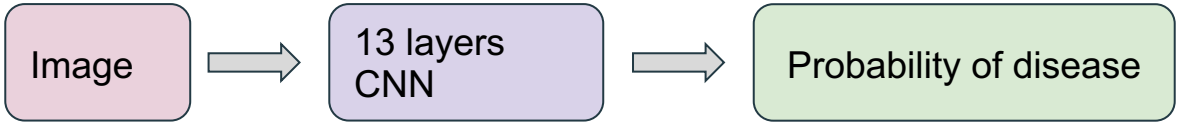
Trajectories of patients treated with cardiotoxic chemotherapies



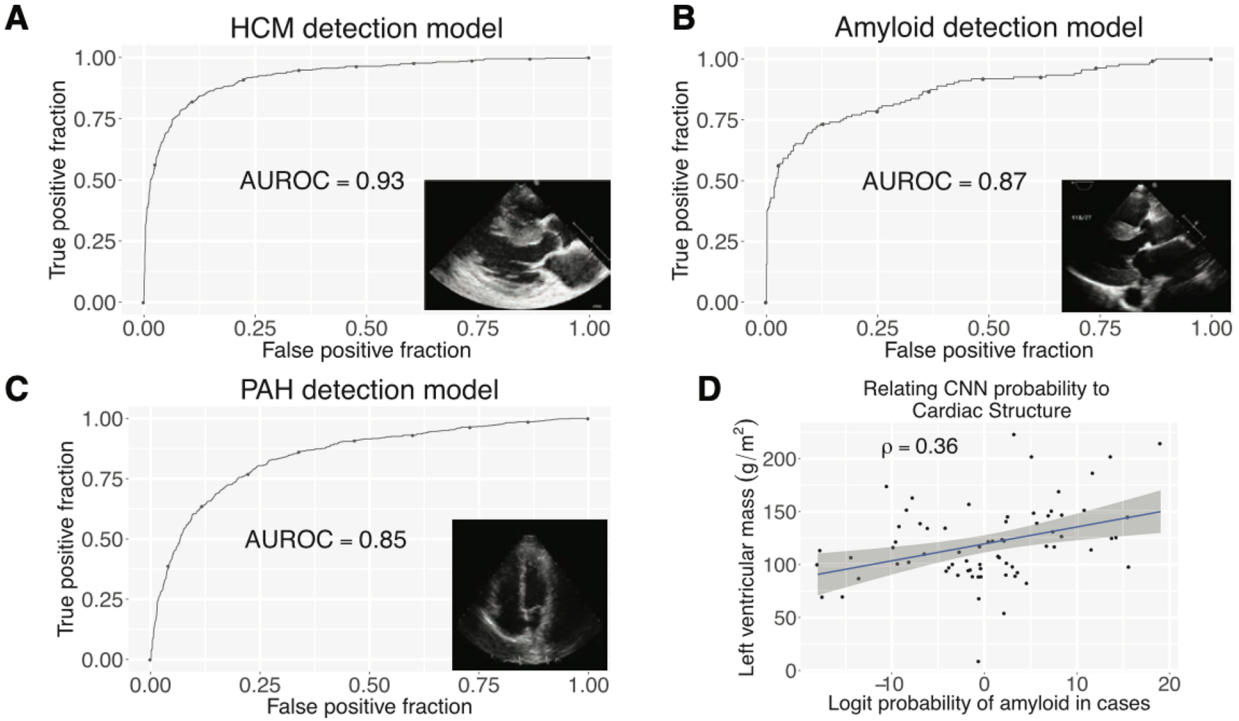


Disease detection

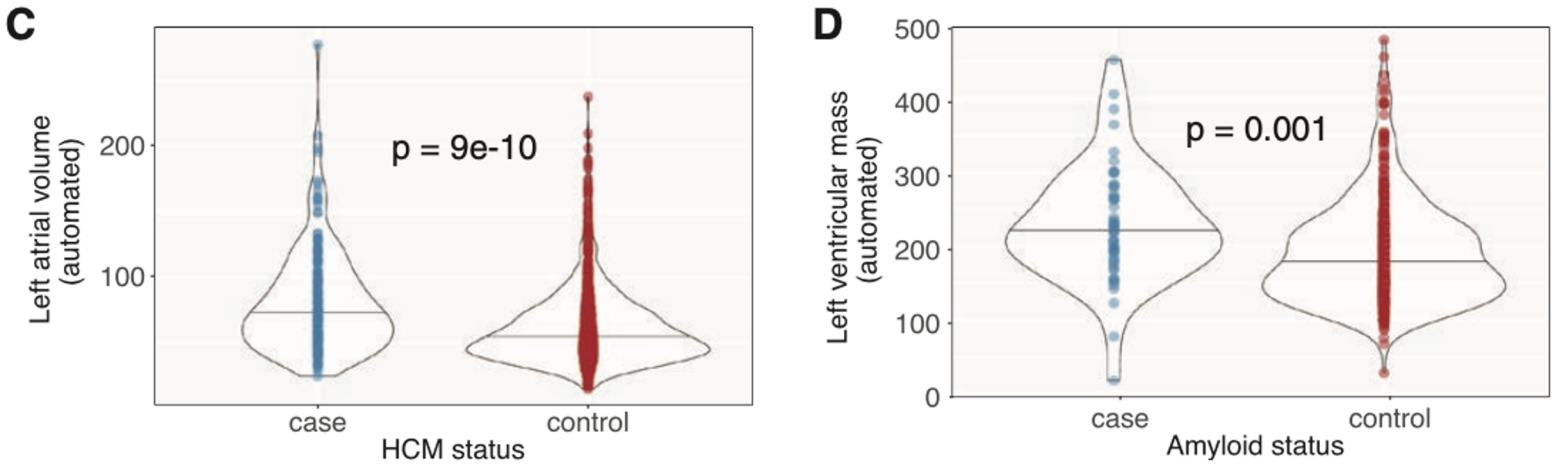
- 3 diseases:
  - Hypertrophic cardiomyopathy (HCM)
  - Cardiac amyloidosis
  - Pulmonary arterial hypertension (PAH)
- Multiple **random** images from each video for training



Disease detection result



Cardiac measurements & disease status



Strength

-  Fully automated pipeline
- Cloud-based ⟹ 
- Quality assessment + parallel improvement
- Subclasses + occlusions
- More chambers segmented
-  disease-detection models from raw images
- Surveillance of echocardiographic data

Limitations

- Outliers + large deviations
- Results affect downstream models
- Selection of frames to avoid foreshortening or irregularities
- No comparison to other models
- Lack of ECG information → bias

Thank you