AI for CMR Reporting - Technique Talk I

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6th May 2022

SCMR
Society for Cardiovascular Magnetic Resonance

EACVI
European Association of Cardiovascular Imaging
European Society of Cardiology

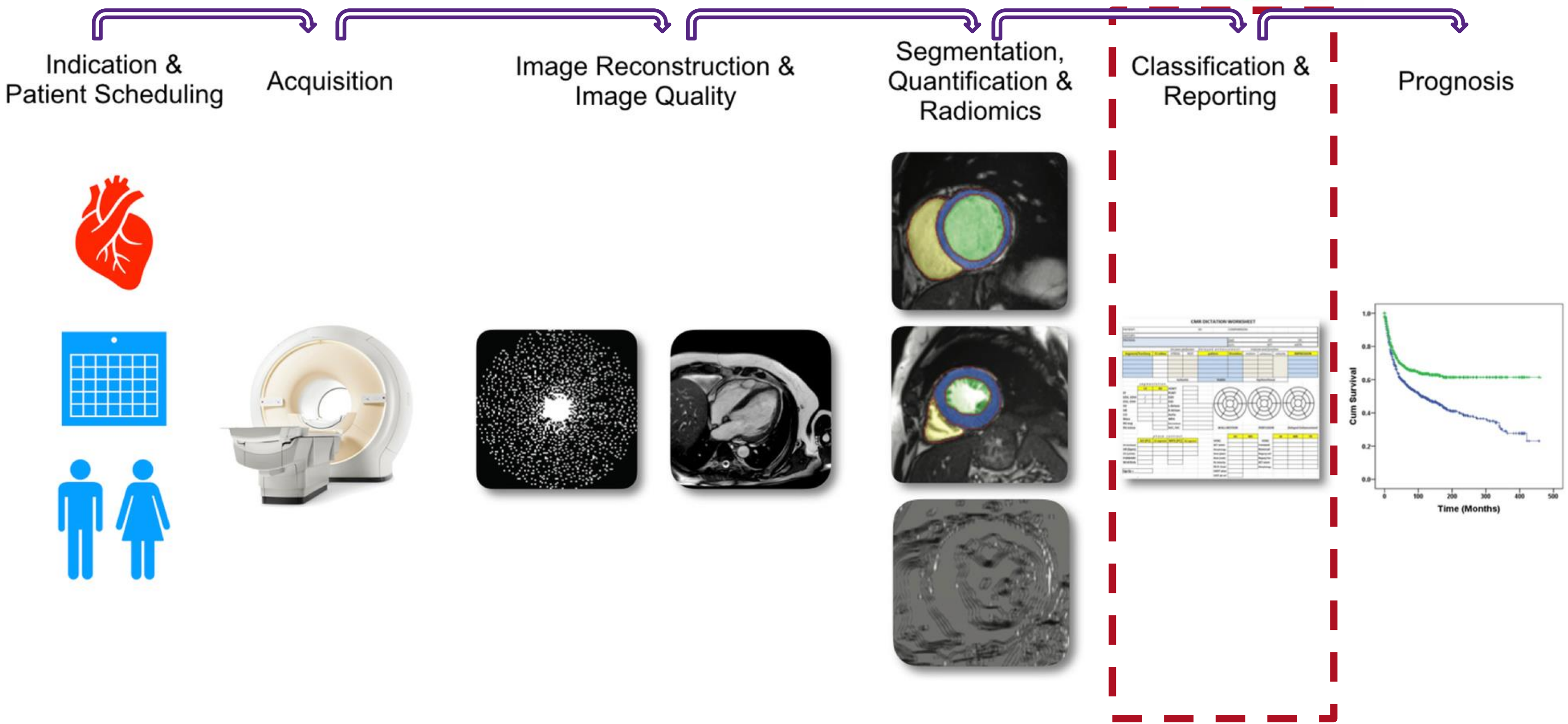
Declaration of Interest

- **None**

Outline

- Impact on the reporting process
- Report structuring and organisation through NLP
- Pitfalls

Opportunities for AI in CMR



Leiner T, Rueckert D, Suinesiaputra A, Baeßler B, Nezafat R, Išgum I, Young AA. Machine learning in cardiovascular magnetic resonance: basic concepts and applications. *Journal of Cardiovascular Magnetic Resonance*. 2019;21:61.

Impact of Automation in CMR Reporting

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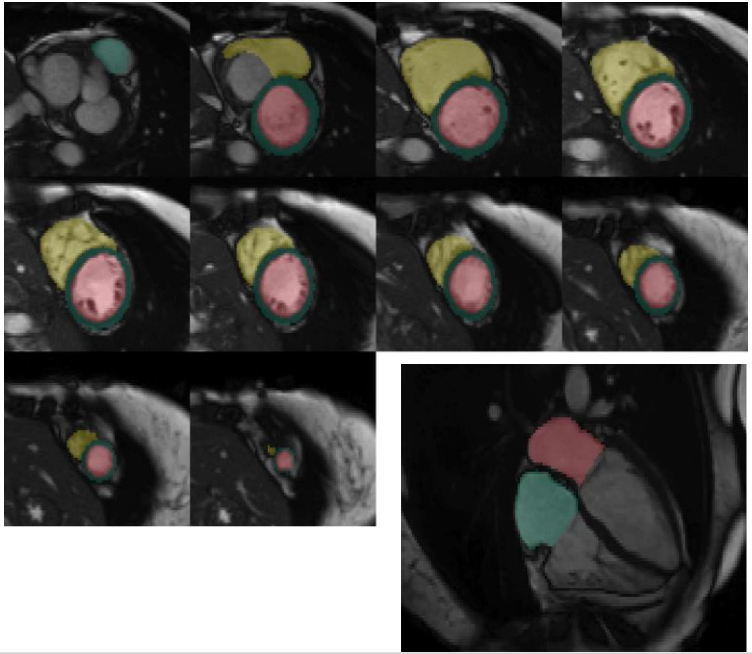
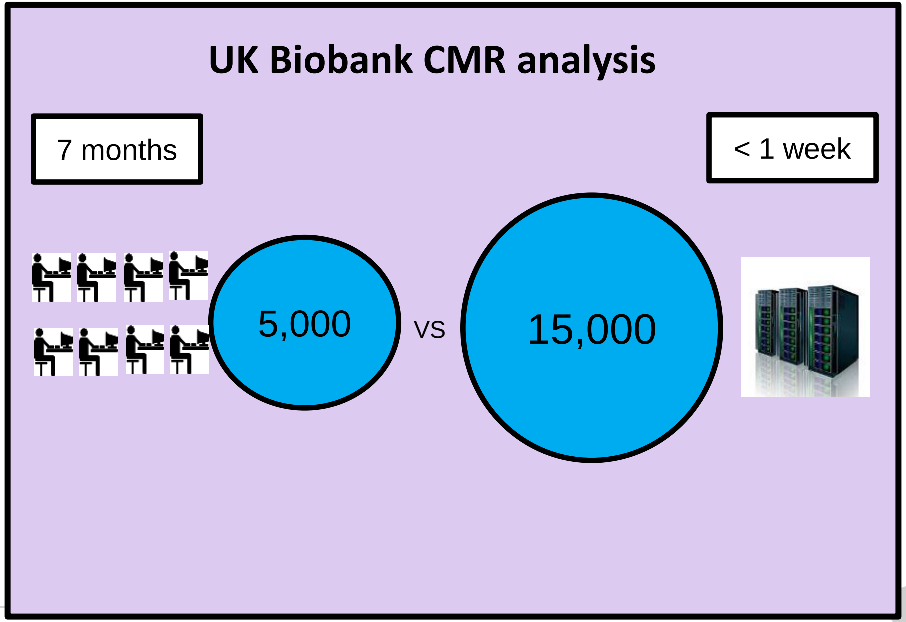
Manual segmentation is time-consuming, tedious and at times distracting.

Time taken to analyse 1 study

ML ~ 2 seconds vs Human ~ 5-10 minutes





AI Improves Reproducibility

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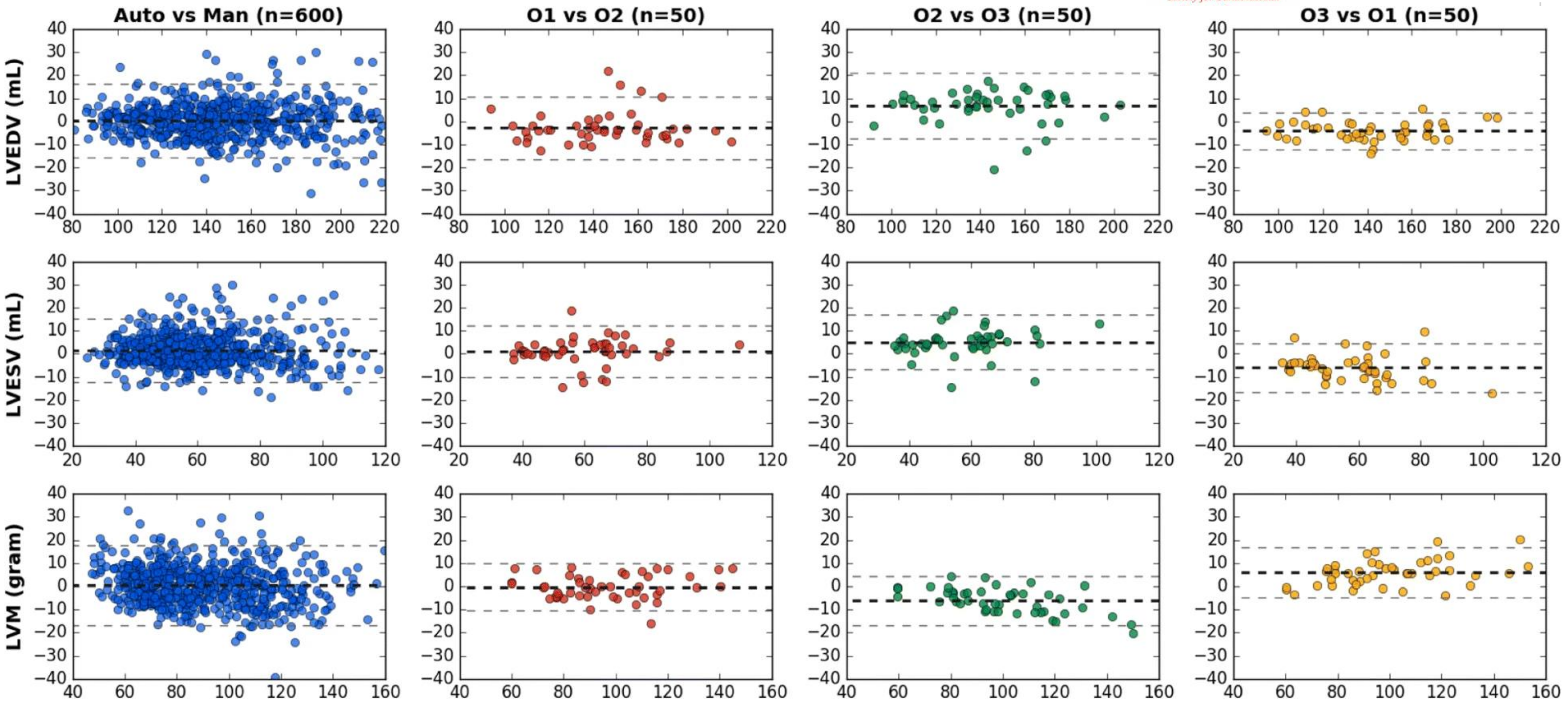
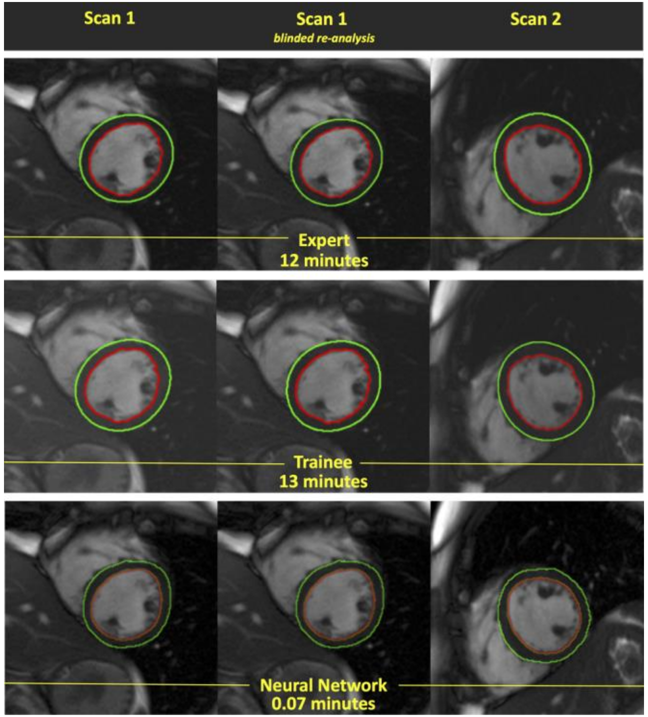
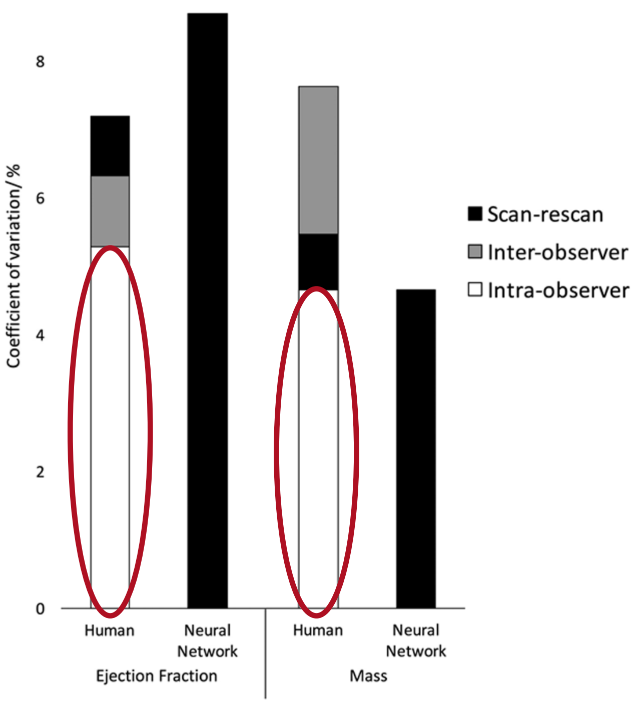


Bai W, Sinclair M, Tarroni G, Oktay O, Rajchl M, Vaillant G, et al. Automated cardiovascular magnetic resonance image analysis with fully convolutional networks. Journal of Cardiovascular Magnetic Resonance. 2018 Sep 14;20(1):65.

Speed and Precision

Multi-centre scan-rescan study of 110 patients with a mix of pathology.





2 – 4s per study for neural network

Bhuva A, et al. A Multicenter, Scan-Rescan, Human and Machine Learning CMR Study to Test Generalizability and Precision in Imaging Biomarker Analysis. *Circulation: Cardiovascular Imaging*. 2019;12:e009214.

Fully automated analysis pipelines

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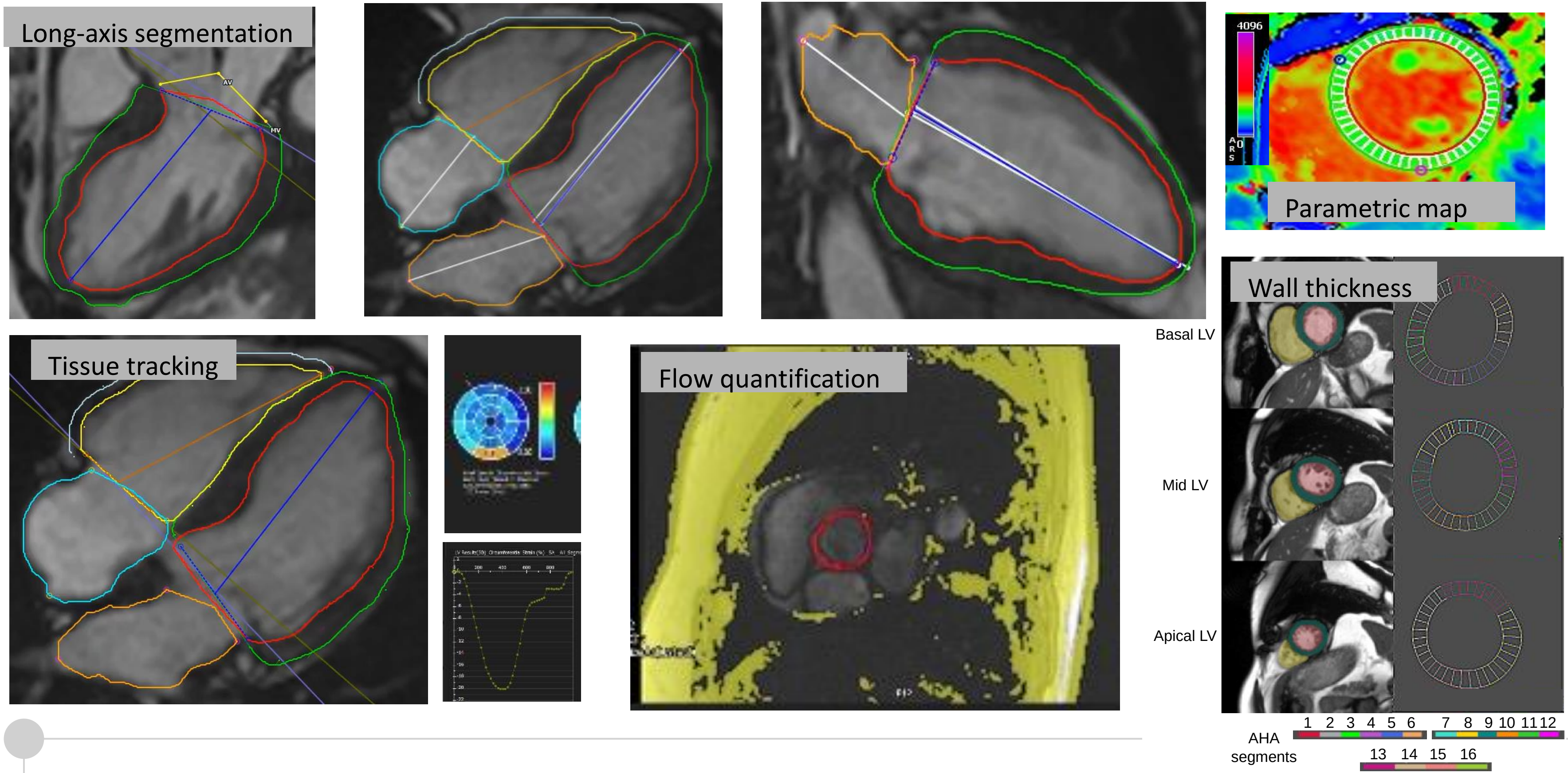

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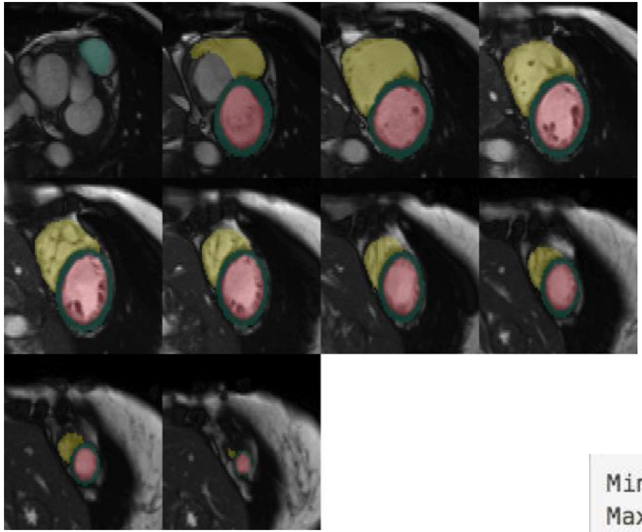
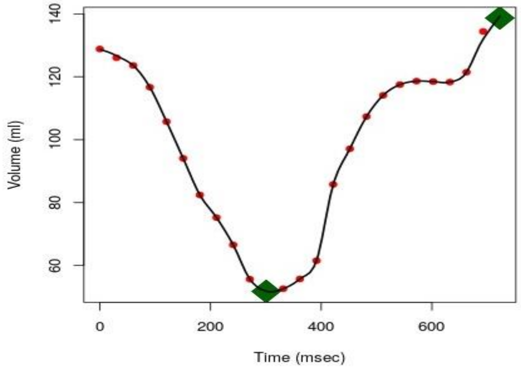
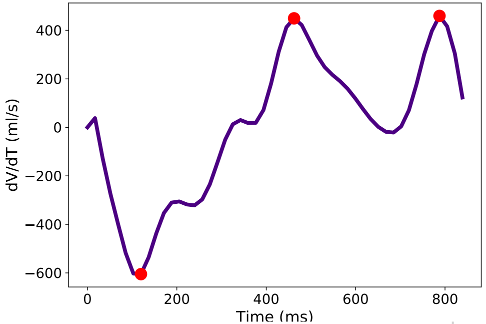
Accessibility to Novel or Underused Phenotypes







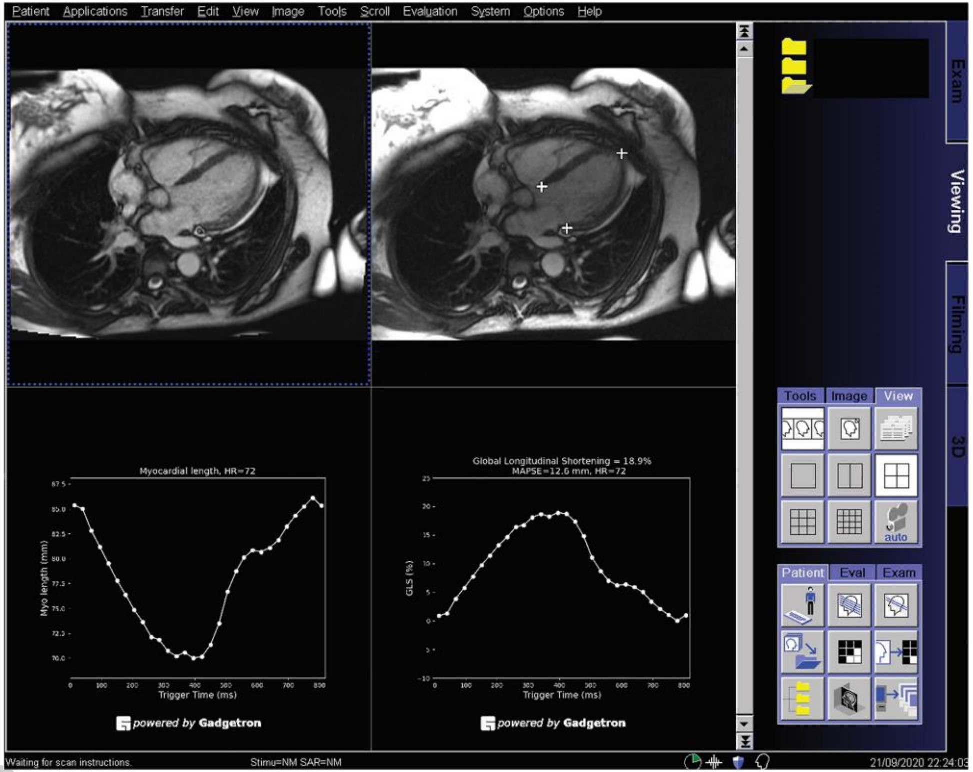
Minimum volume (single-click): 52.8 ml
Maximum volume (double-click): 139.7 ml
Stroke volume: 86.9 ml
Position:
Time to peak filling rate: 109.8 ml
Diastolic volume recovery: 150.6 ms

Ewave (single-click): 55.4 ml/s
Awave (double-click): 440.4 ml/s
SV-adjusted peak-filling rate: 0.6 per
Position:
Deceleration time: 164.6 ms

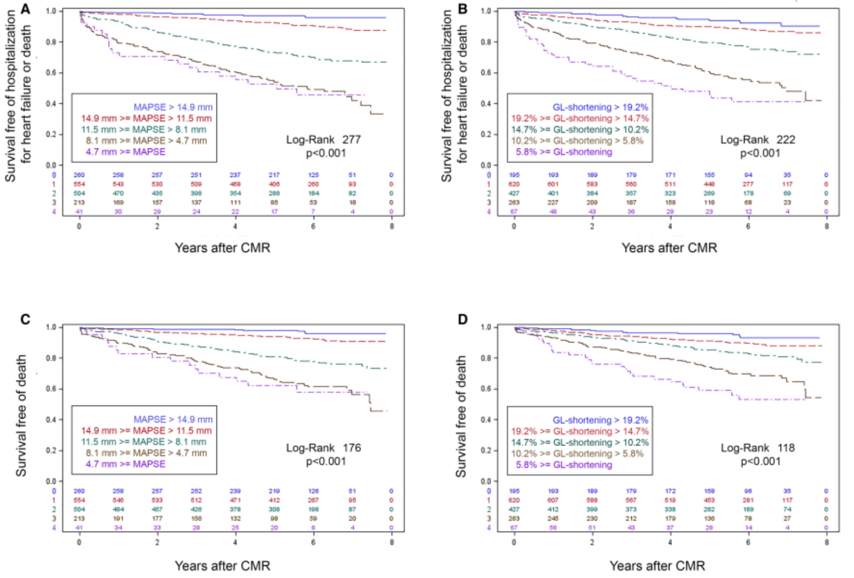
Aung N et al. Annotation and quality assessment of left ventricular filling and relaxation pattern using one-dimensional convolutional neural network. AI in CMR Imaging Summit 2022 [Poster]

Accessibility to Novel or Underused Phenotypes

In-Line CNN model via Gadgetron tool

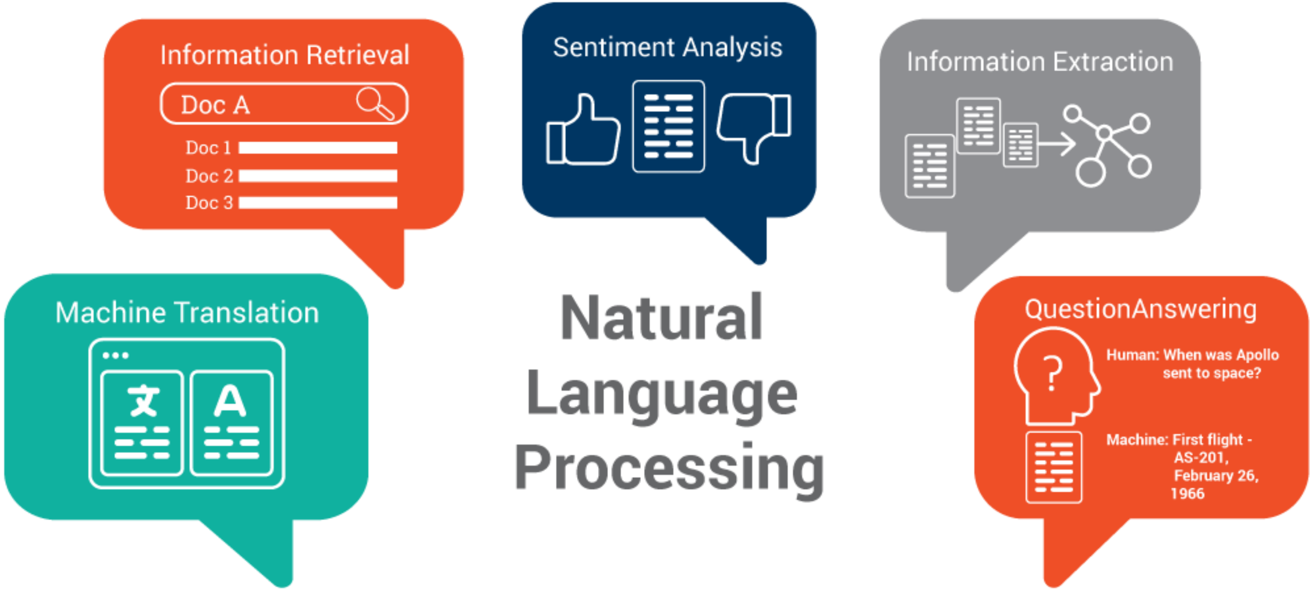


Relationship between MAPSE/GLS and outcomes



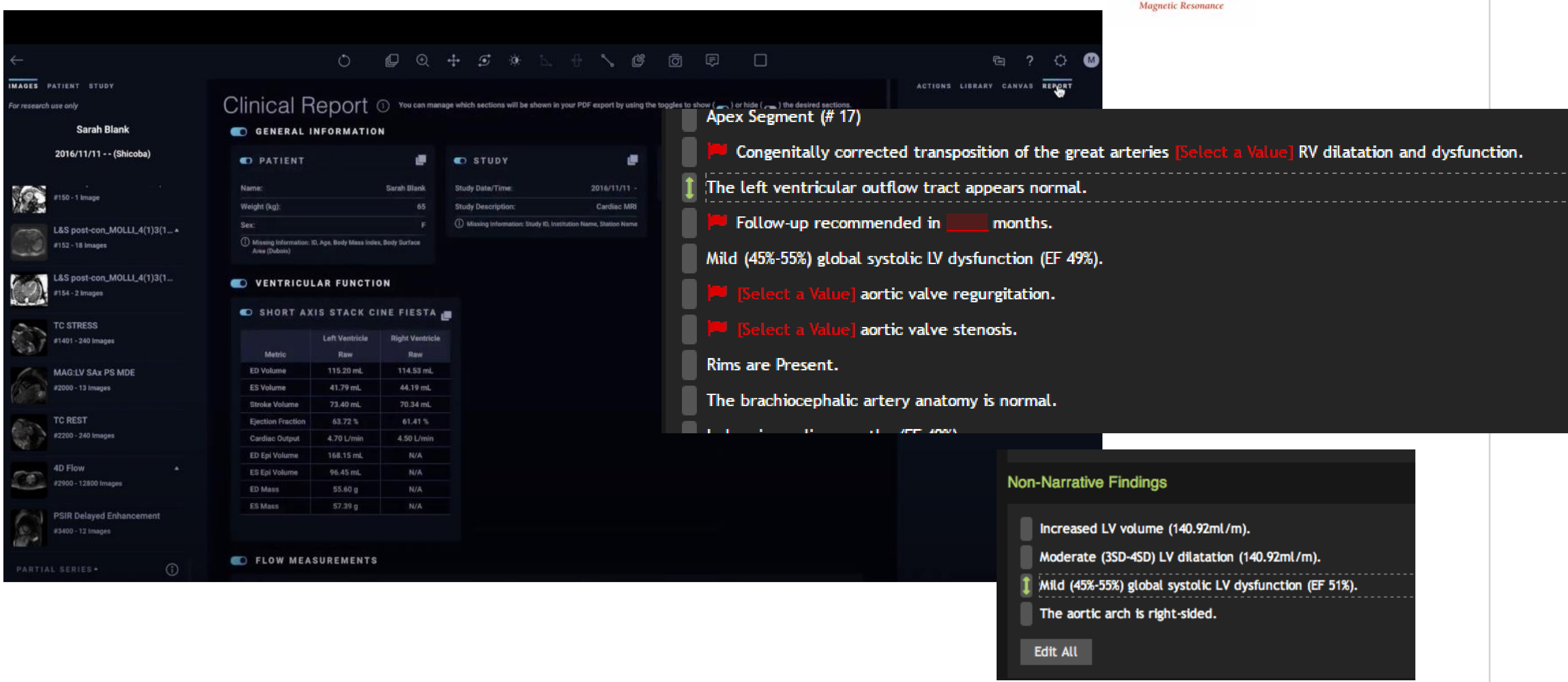
Xue H, et al. Automated In-Line Artificial Intelligence Measured Global Longitudinal Shortening and Mitral Annular Plane Systolic Excursion: Reproducibility and Prognostic Significance. *Journal of the American Heart Association*. 2022;11:e023849.

Report Organisation

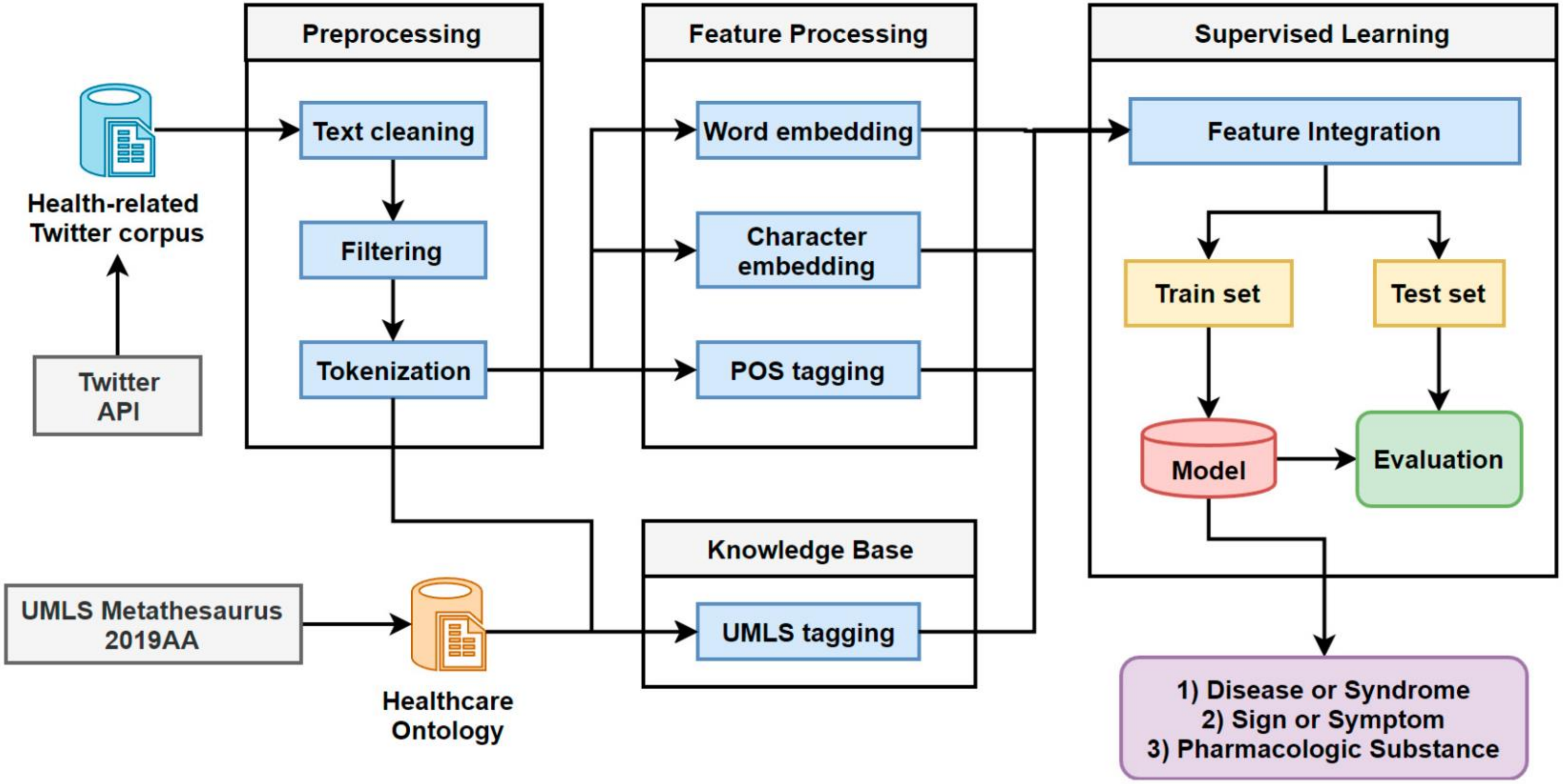


Source: www.ontotext.com/blog/top-5-semantic-technology-trends-2017/

Structured vs Unstructured Text



Free text to Ontology



Batbaatar E, Ryu KH. Ontology-Based Healthcare Named Entity Recognition from Twitter Messages Using a Recurrent Neural Network Approach. International Journal of Environmental Research and Public Health 2019;16:3628.

Named Entity Recognition: Imaging Reports

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CMR report

Severely impaired LV systolic function. Transmural MI in basal to mid anterior wall. Inducible ischaemia in lateral segments.

NLP annotation

Severely impaired LV systolic function. Transmural MI in basal to mid anterior wall. Inducible ischaemia in lateral segments.

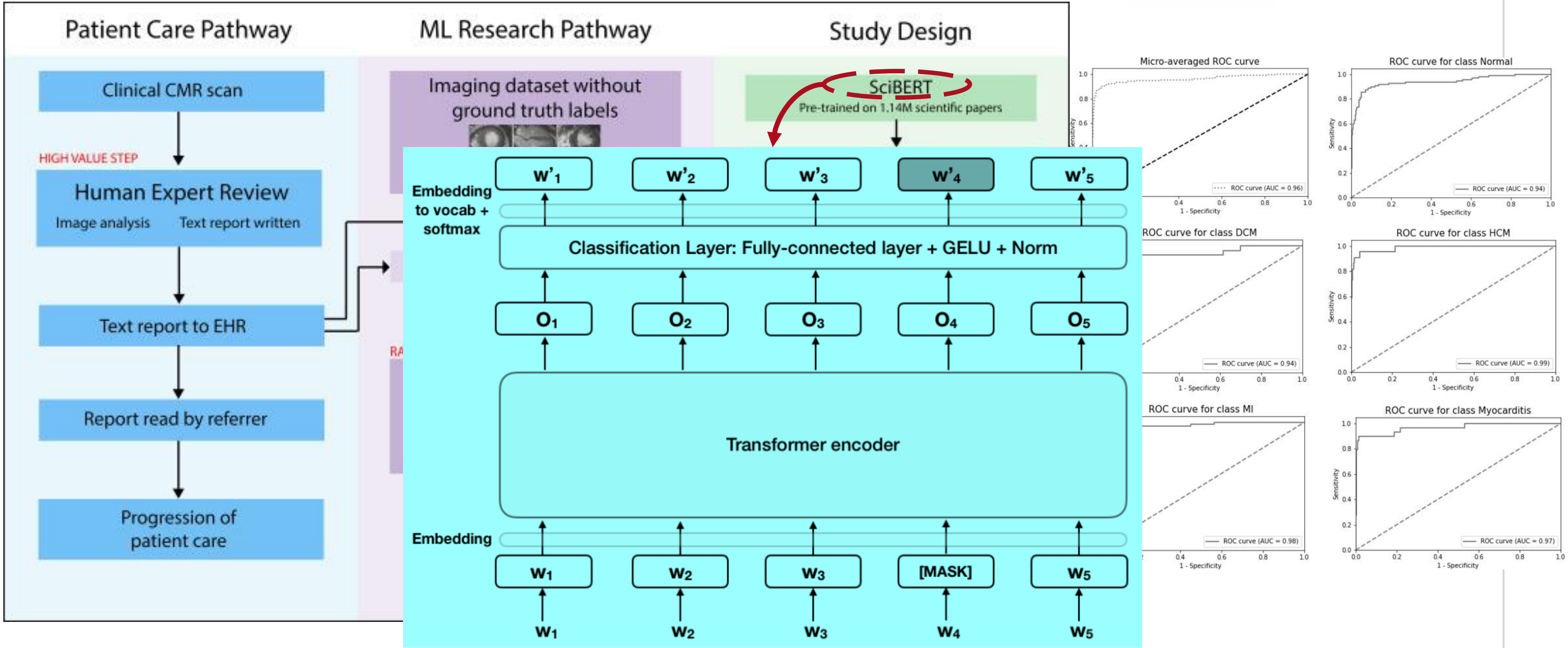
Tagged entity	SNOMED CT unique identifier	Name	Semantic type
Severely	24484000	SEVERE	T-11000 - QUALIFIER VALUE
impaired	260379002	IMPAIRED	T-11000 - QUALIFIER VALUE
LV	87878005	LEFT CARDIAC VENTRICULAR STRUCTURE	T-01000 - BODY STRUCTURE
systolic	111973004	SYSTOLE, FUNCTION	T-14310 - ATTRIBUTE
Transmural	277064003	TRANSMURAL	T-11000 - QUALIFIER VALUE
myocardial infarction	22298006	MYOCARDIAL INFARCTION	T-02100 - DISORDER
basal	57195005	BASAL	T-11000 - QUALIFIER VALUE
mid	255562008	MID	T-11000 - QUALIFIER VALUE
anterior wall	263943000	ANTERIOR WALL	T-11000 - QUALIFIER VALUE
Inducible	16404004	INDUCED	T-11000 - QUALIFIER VALUE
ischaemia	52674009	ISCHEMIA	T-02100 - DISORDER
lateral segments	264060003	LATERAL SEGMENT	T-11000 - QUALIFIER VALUE

Medical Concept Annotation Tool

CogStack

Unpublished: Aung et al.

Automated Diagnostic Labelling



Zaman S, et al. Automatic Diagnosis Labeling of Cardiovascular MRI by Using Semisupervised Natural Language Processing of Text Reports. *Radiol Artif Intell*. 2021;4:e210085.

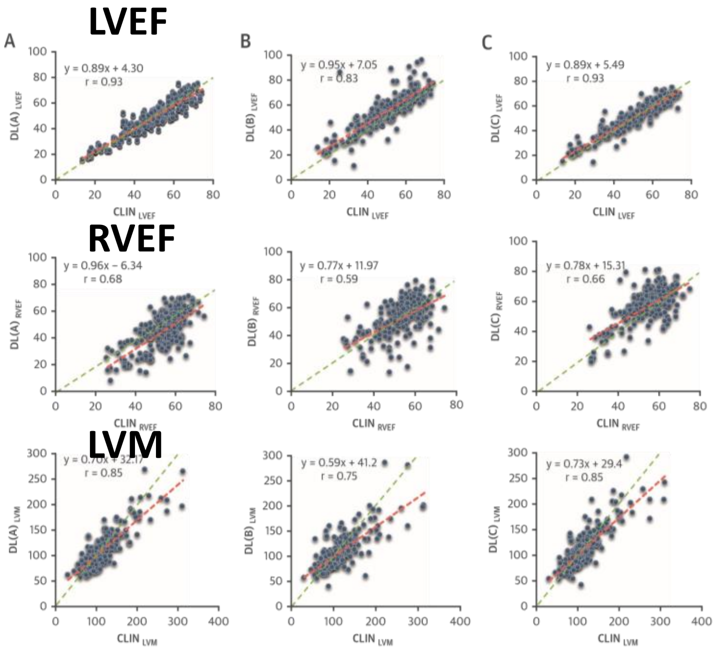
NLP potentials in CMR reporting

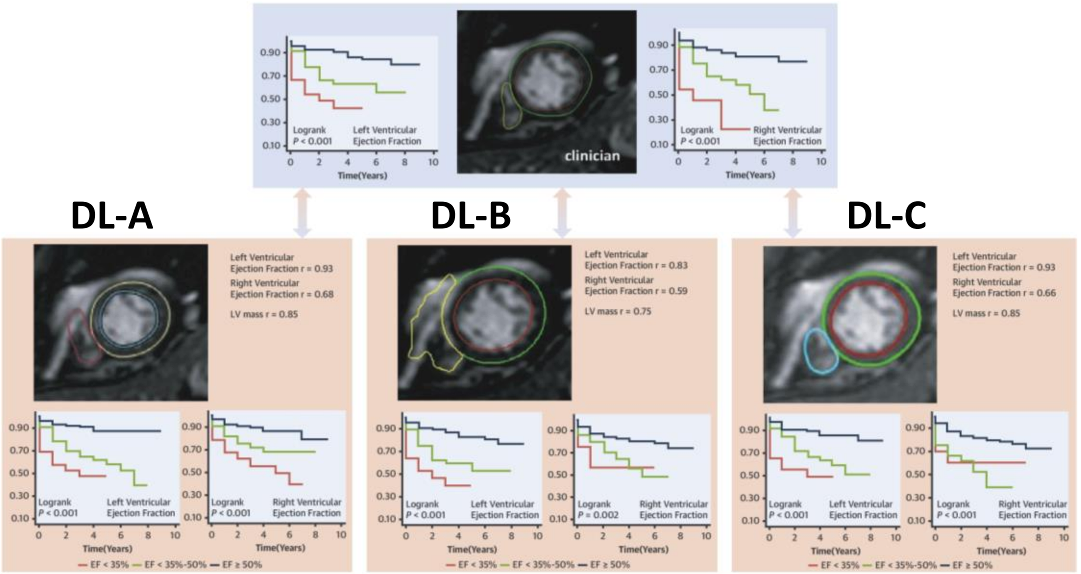
- Instant report structuring
- Automated extraction of salient data from EHR and historical reports
- Computational phenotyping
- Trial participant identification
- Automated registry reporting

Pitfalls

Biventricular segmentation performance among commercially available software

Δ>10% between manual and DL approaches in 5-18% of cases for LVEF and 23-43% for RVEF





Wang S, et al. AI Based CMR Assessment of Biventricular Function: Clinical Significance of Intervendor Variability and Measurement Errors. *JACC: Cardiovascular Imaging*. 2022;15:413–427.

AI (un)Fairness

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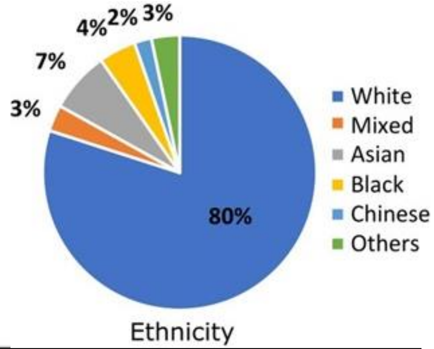
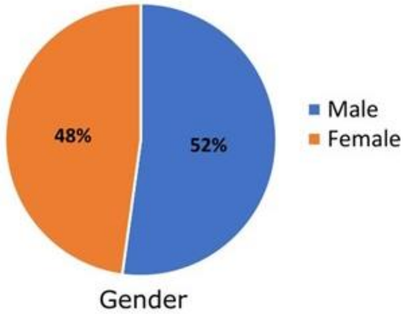
	DSC (%)						
	ED			ES			Avg
	LVBP	LVM	RVBP	LVBP	LVM	RVBP	
Total	96.34	90.20	93.48	93.88	89.58	90.29	92.29
Male	96.32	90.41	93.38	94.00	89.77	90.37	92.37
Female	96.35	90.01	93.56	93.76	89.40	90.22	92.22
White	96.32	90.08	93.58	94.02	89.55	90.88	92.40
Mixed	92.70	78.94	86.91	86.70	82.54	79.32	84.52*
Asian	94.53	87.33	90.51	90.13	88.94	81.94	88.89*
Black	92.77	85.93	89.49	89.42	85.74	71.91	85.88*
Chinese	91.81	74.51	85.74	86.39	85.12	79.34	83.82*
Others	91.74	78.94	89.50	88.53	84.96	80.27	85.65*

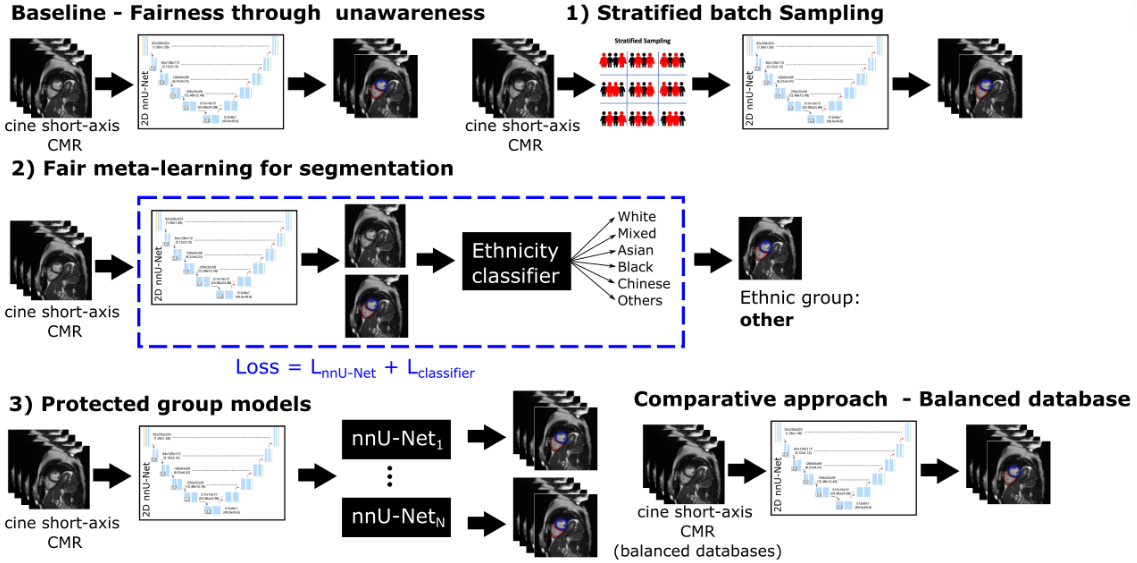
	Volumes											
	Manual						Auto vs Manual - Absolute difference					
	LVEDV (mL)	LVESV (mL)	LVEF (%)	RVEDV (mL)	RVESV (mL)	RVEF (%)	LVEDV (mL)	LVESV (mL)	LVEF (%)	RVEDV (mL)	RVESV (mL)	RVEF (%)
Total	147	60	60	155	68	56	4.90 (3.5)	3.97 (3.5)	2.49 (2.2)	6.57 (5.3)	5.50 (4.5)	3.53 (2.8)
Male	148	60	60	156	69	56	4.80 (2.7)	3.34 (2.3)	1.93 (1.5)	5.63 (4.5)	4.96 (3.8)	3.15 (2.6)
Female	129	51	61	133	56	58	4.75 (3.4)	3.96 (3.6)	2.56 (2.3)	6.74 (5.5)	5.51 (4.5)	3.56 (2.8)
White	147	60	60	155	68	57	4.24 (2.7)	3.37 (2.7)	2.06 (18)	5.84 (4.7)	5.05 (3.9)	3.27 (2.7)
Mixed	142	57	60	153	68	56	7.12 (3.9)*	6.07 (3.0)*	3.81 (2.4)*	8.39 (3.2)*	7.07 (3.3)*	4.61 (2.1)*
Asian	146	60	60	151	67	56	6.20 (3.4)*	5.05 (4.1)*	3.44 (2.5)*	7.91 (4.2)*	6.14 (3.5)*	4.06 (2.9)*
Black	143	58	60	151	68	55	6.46 (3.2)*	5.44 (5.1)*	3.62 (3.2)*	8.01 (2.9)*	6.38 (3.5)*	4.19 (2.4)*
Chinese	150	65	58	160	74	54	7.92 (3.9)*	6.17 (3.8)*	3.85 (2.1)*	8.66 (4.4)*	7.25 (4.2)*	4.88 (2.9)*
Others	150	60	60	157	69	56	6.70 (3.3)*	5.60 (3.6)*	3.79 (2.7)*	8.29 (6.2)*	6.58 (3.3)*	4.30 (2.8)*





Puyol Anton E, Ruijsink B, Piechnik SK, Neubauer S, Petersen SE, Razavi R, King AP. Fairness in AI: are deep learning-based CMR segmentation algorithms biased? *European Heart Journal*. 2021;42:ehab724.3055.

Fairness through awareness – Mitigation strategies



Puyol-Anton E, et al. Fairness in Cardiac MR Image Analysis: An Investigation of Bias Due to Data Imbalance in Deep Learning Based Segmentation. *arXiv:210612387* Available from: http://arxiv.org/abs/2106.12387

Approach	Segmentation							Fairness	
	White	Mixed	Asian	Black	Chinese	Others	Avg	SD	SER
Baseline - Fairness through unawareness	93.51	84.52	88.90	85.88	87.63	85.66	87.68	**3.25**	**2.38**
1. Stratified batch sampling	90.88	93.84	93.65	93.07	94.35	93.50	93.22	**1.22**	**1.62**
2. Fair meta-learning for segmentation	92.75	88.03	90.64	89.60	88.18	88.27	89.58	**1.86**	**1.65**
3. Protected group models	91.03	93.17	93.34	92.15	93.04	93.08	92.64	**0.89**	**1.35**
Comparative approach - Balanced database	79.32	80.98	80.37	79.78	80.82	80.72	80.33	**0.65**	**1.09**

Conclusion

- AI-assisted image post-processing reduces the reporting time and improves precision of measurements.
- Significant intervendor variation exists.
- NLP approaches to structure CMR reports hold great potentials.
- Proactive mitigation of AI biases is needed for clinical integration.

Acknowledgements

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Dr Musa Abdulkareem

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MESA - Dr Jose Vargas, Dr David Bluemke
Imperial College London - Dr Wenjia Bai, Prof Daniel Rueckert
UK Biobank image annotation core laboratories (Oxford/QMUL)

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