ESPR
European Society of Paediatric Radiology

56th Annual Meeting &
42nd Post Graduate Course

jESPeR Lecture

Artificial intelligence in cardiac imaging

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Director of Innovation - Great Ormond Street Hospital for Children

Disclosures

Medtronic speaker

Hospital funding via Sensyne, ViroCell, Roche


A STEVEN SPIELBERG FILM
MINORITY
REPORT

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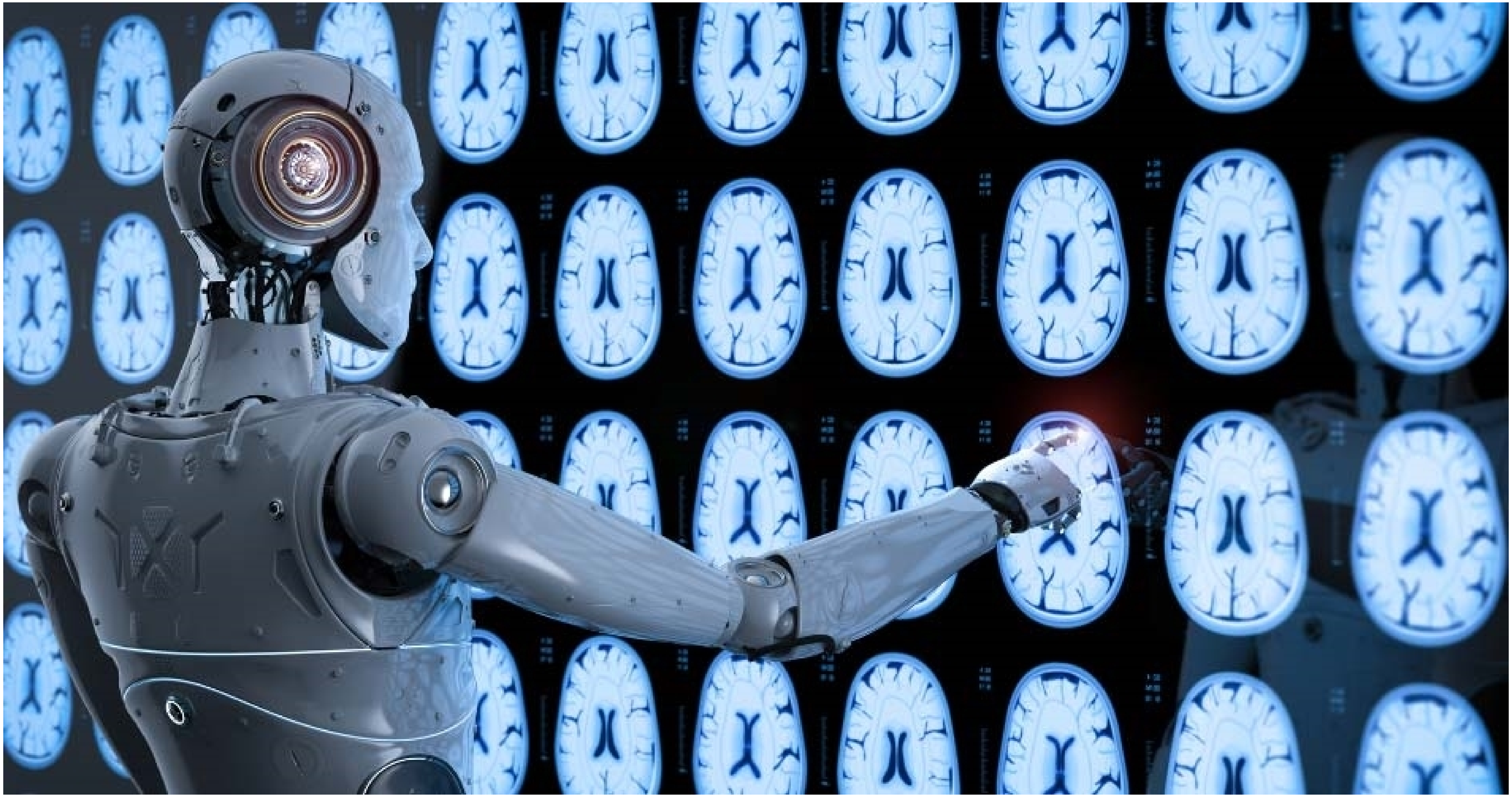

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Artificial intelligence and machine learning

AI is the ability to sense, reason, engage & learn

Machine learning is the ability to learn

Though ML forms the basis of most AI systems and may look intelligent, it isn't!

AI definitions

Artificial intelligence is a computerised system that exhibits behaviour that is commonly thought of as requiring intelligence

or

Artificial intelligence is the science of making machines do things that would require intelligence if done by man

AI definitions

The founding father of AI, Alan Turing, defines this discipline as:

"AI is the science and engineering of making intelligent machines, especially intelligent computer programs."

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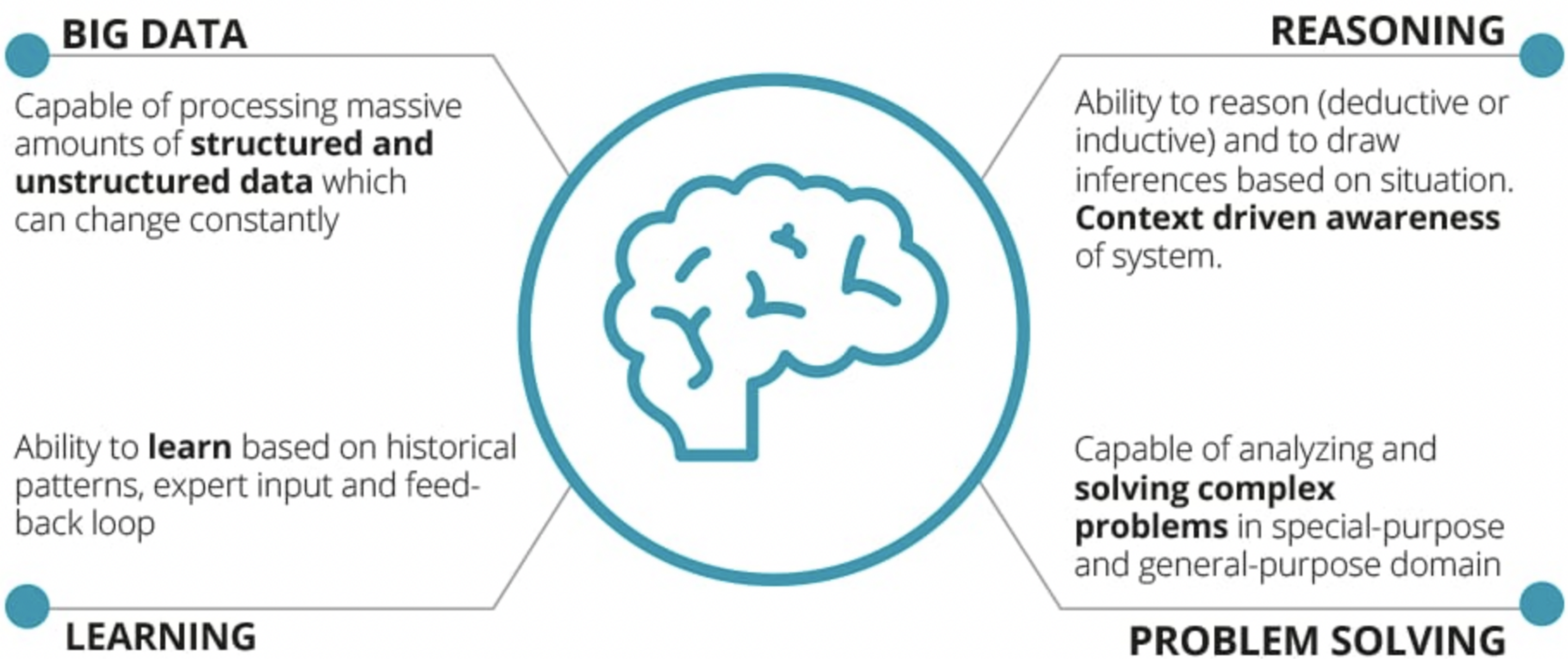
AI concepts



https://www2.deloitte.com/se/sv/pages/technology/articles/part1-artificial-intelligence-defined.html

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What is AI good at

Narrow well defined problems:

- face recognition
- chess computers
- calculus, translation

General AI is the ‘holy-grail’

AI beats the human!

AlphaGo

Convolutional Neural Network

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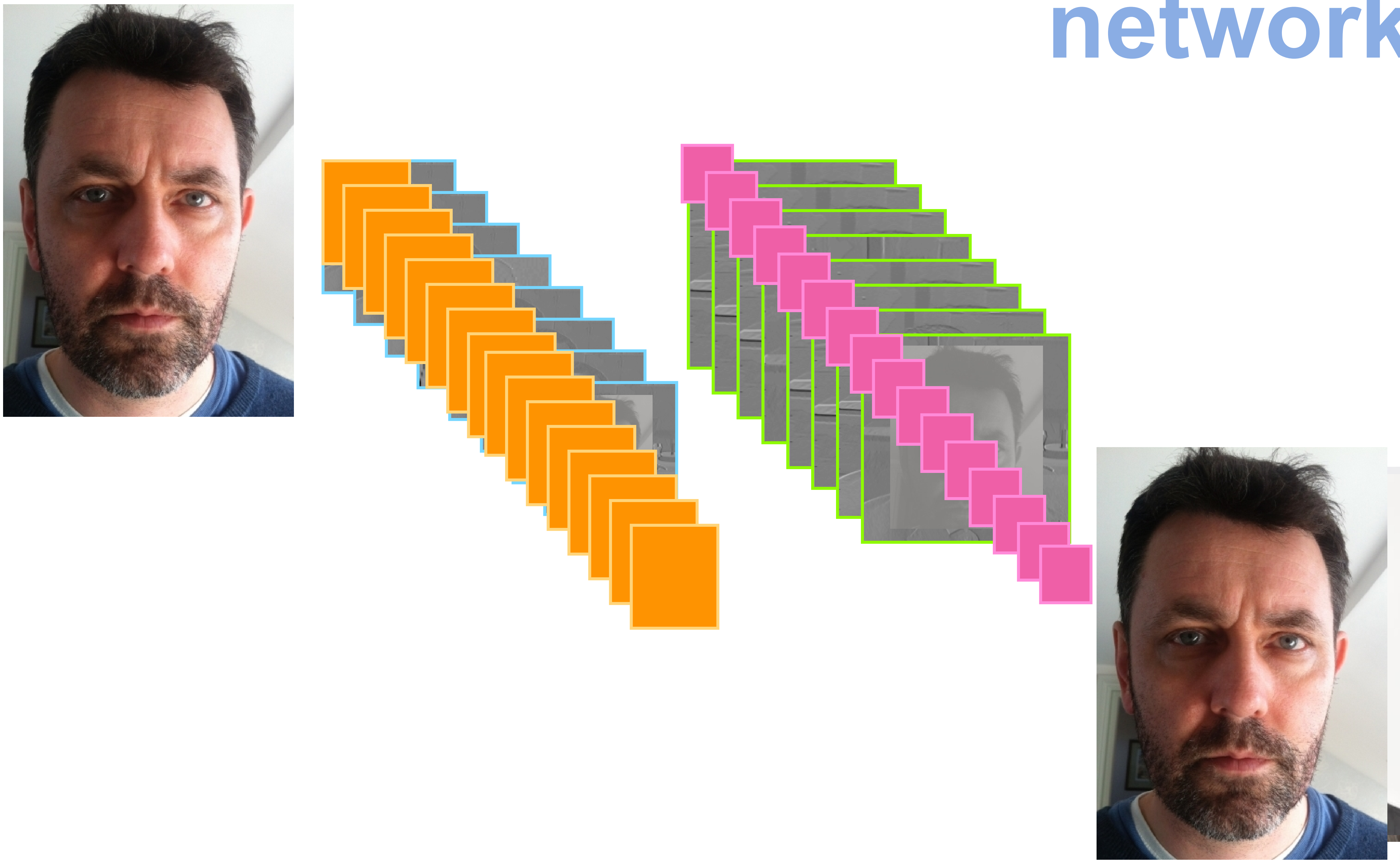
Convolutional neural network



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The simple chest x-ray

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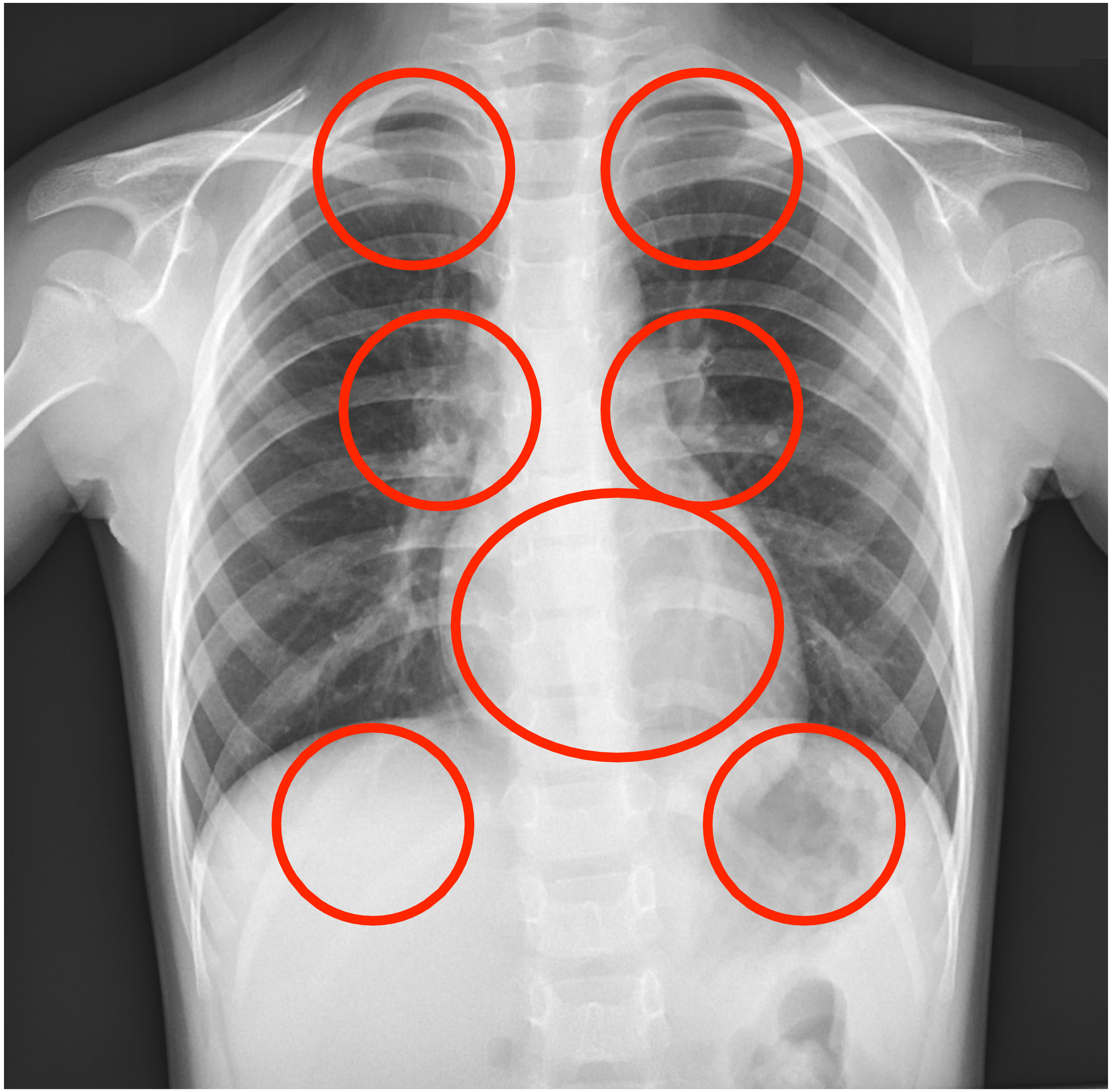
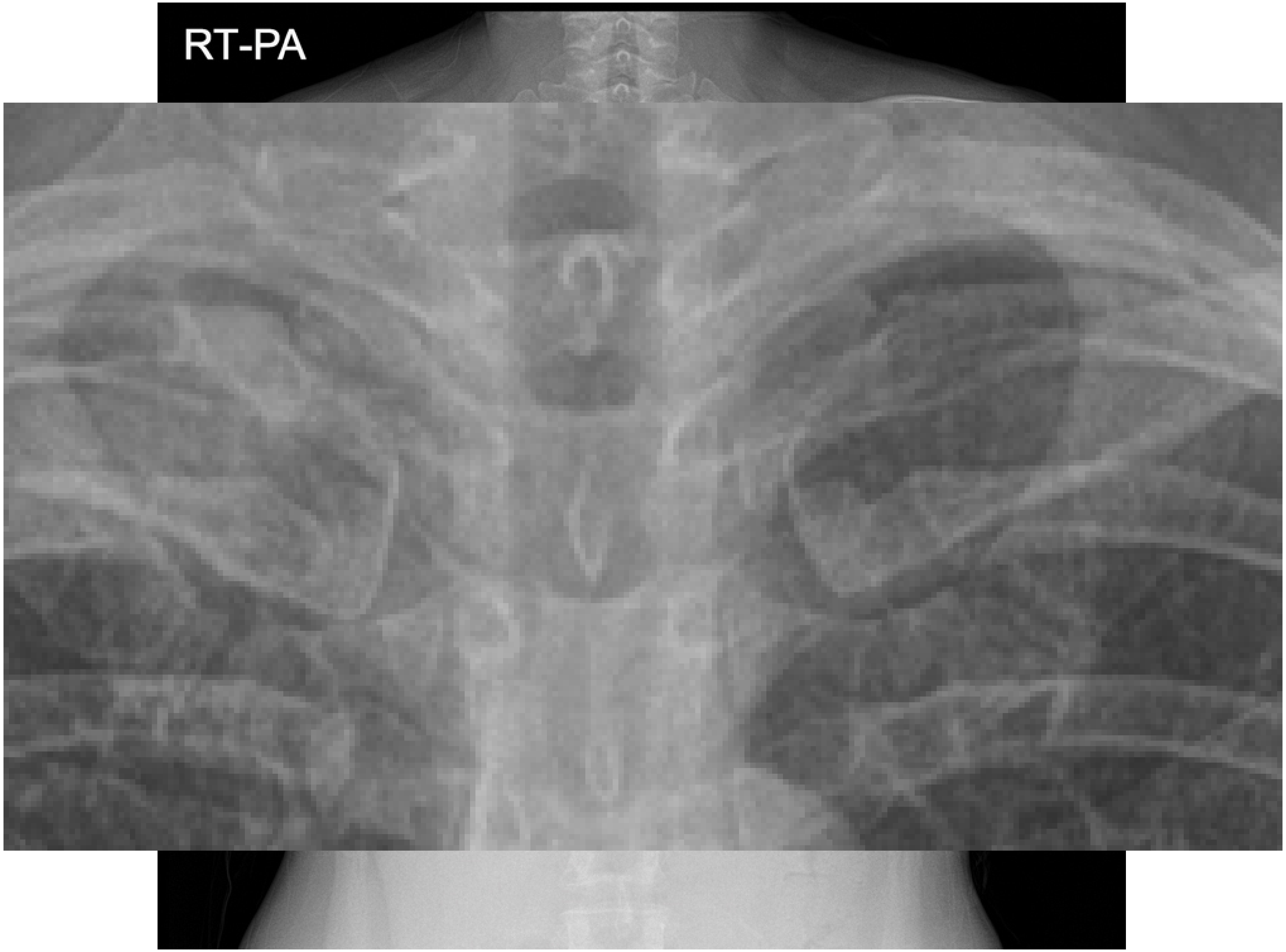
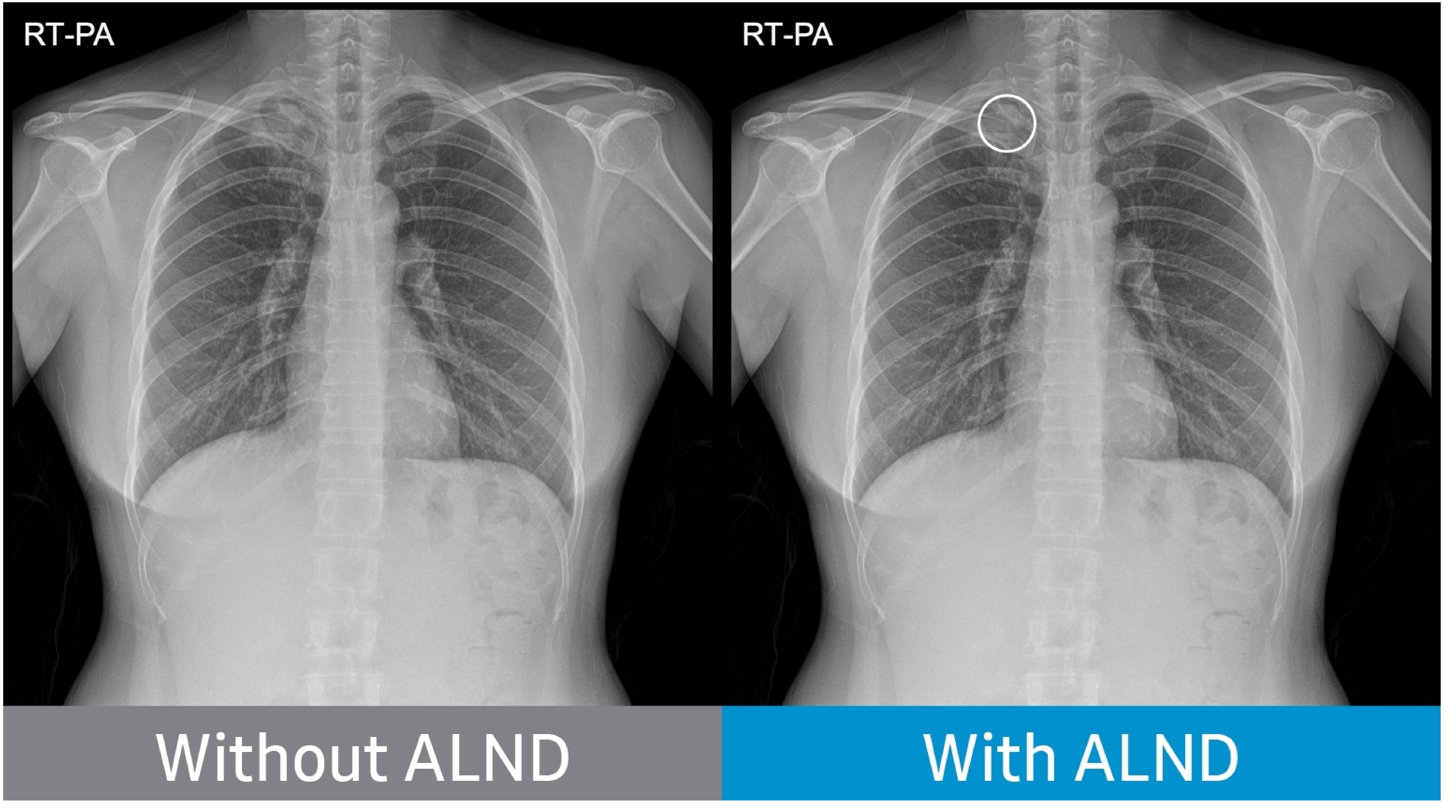
Defining normal



Single glance



AI as decision support



Auto Lung Nodule Detection

AI and radiology

"This FDA clearance is a huge milestone for Samsung and is the result of our tireless work to design diagnostic solutions that empower providers to deliver patients the absolute best care possible"

AI for decision support

Sensitivity of this algorithm is about 80%

Important question is not whether is replaces me - my accuracy is 95% (97.5% if double reported - but does it improve my accuracy?

AI shouldn’t be scary

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My imaging pathway

Patient scheduling → Image acquisition → Scanning → Image analysis → Reporting → Big data

Patient scheduling
- Automated test request
- Automated patient scheduling
- Automated scan protocol generation

Image acquisition
- Increased speed
- De-noising
- De-alisaising
- Super-resolution

Scanning
- Automated scan protocol loading
- Automated scan planning
- Scanning at a distance

Image analysis
- Automated quantification of: ventricular function; vessel flow; tissue characterisation
- Automated diagnosis

Reporting
- Automated report template
- Automated speech recognition
- Automated follow-up booking

Big data
- Images, reports, patient flow data
- Combined with other patient data
- Research & precision medicine

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Better scheduling, reporting, scanning

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Ordering tests

At **least 80% of imaging** requests do not have the relevant clinical information

AI tools can extract clinical information from the clinical electronic patient record (EPR) to improve imaging modality selection and then drive protocolisation

An ML tool was able to analyse unstructured text for clinical indications for neurological MRI requests and appropriately protocolise the MR scan, **with an accuracy of 95%**

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Better processes

Algorithms can also be used to support optimisation of scheduling to:

- define optimal times for appointment bookings
- predict which patients may not attend
- define optimal follow-up times
- automatically book follow-up imaging

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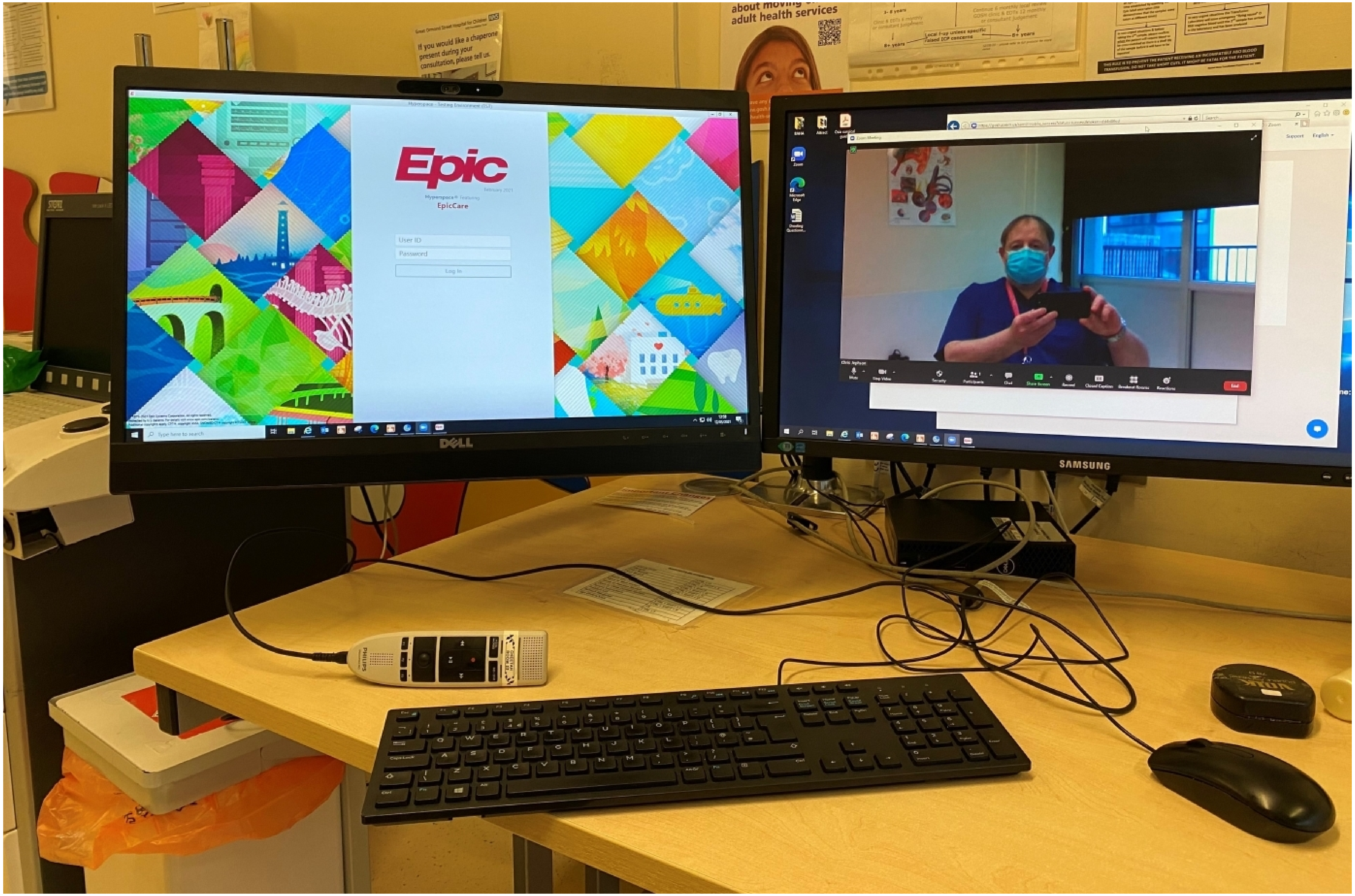

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Faster image acquisition

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Be fast - acquisition

Walheim *et al. Journal of Cardiovascular Magnetic Resonance* (2019) 21:42
https://doi.org/10.1186/s12968-019-0549-0

Journal of Cardiovascular Magnetic Resonance

TECHNICAL NOTES Open Access

Multipoint 5D flow cardiovascular magnetic resonance - accelerated cardiac- and respiratory-motion resolved mapping of mean and turbulent velocities

Jonas Walheim*, Hannes Dillinger and Sebastian Kozerke

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Be fast - acquisition

- **Aim** - To develop a 5D Flow CMR framework which combines undersampled data acquisition, including multipoint velocity encoding with low-rank image reconstruction of cardiac- and respiratory-motion
- **Method** - 9 subjects comparing 5D flow with 4D flow for the assessment of velocity maps and turbulent kinetic energy
- **Results** - Net scan time of 5D Flow CMR was **4 min vs. 17.8 ± 3.9 min** for 4D flow protocol. On average, peak velocities assessed with 5D Flow CMR were higher than for the 4D protocol (3.1 ± 4.4%)

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Be fast - reconstruction

ARTICLES
https://doi.org/10.1038/s42256-020-0165-6

nature machine intelligence

Check for updates

Deep variational network for rapid 4D flow MRI reconstruction

Valery Vishnevskiy[1,2], Jonas Walheim[1,2] and Sebastian Kozerke[1]

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Be fast - reconstruction

- The network is shown to reconstruct under-sampled 4D flow MRI data in under a minute on standard consumer hardware
- Remarkably, the network was trained on images from 11 reference scans while generalising well to retrospective and prospective under-sampled data for various acceleration factors and anatomies

Table 1 | Model complexities and typical reconstruction time for 4D flow reconstruction

Method	Reconstruction time	No. of parameters
CS-LLR	10 min 24 s	2
HamVN	89 s	62,742
FlowVN	21 s	63,583

Typical reconstruction times are shown for four-point velocity encoded data compressed to five virtual coils and reconstructed on a 113 × 113 × 25 grid. CS-LLR was executed on a six-core Intel CPU; FlowVN and HamVN were implemented in Tensorflow and evaluated on a NVIDIA Titan RTX system.

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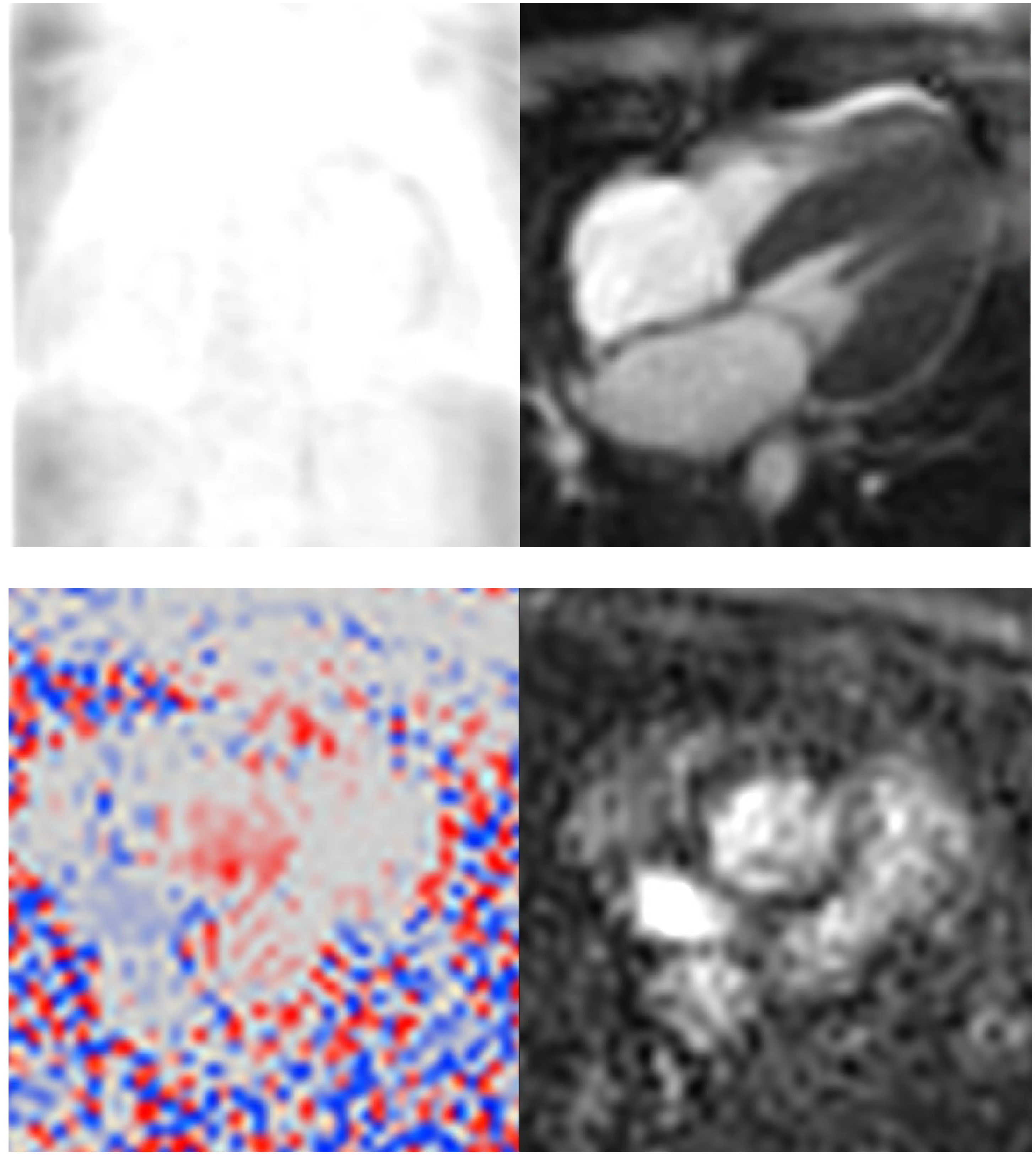
Real-time imaging in PH



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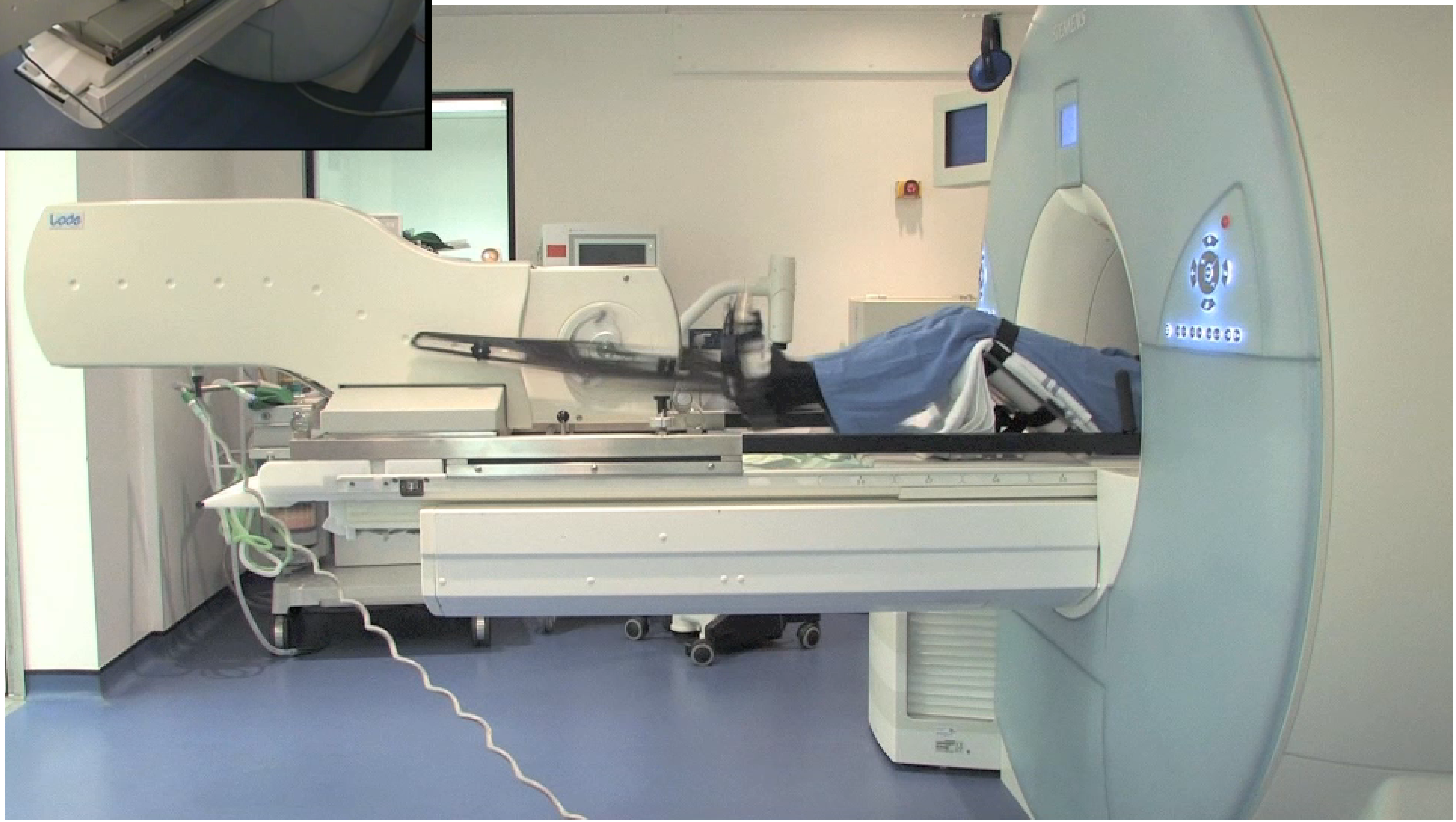
Exercise CMR



Faster image analysis

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Quantify size and shape

Schievano S, et al. *Radiology* 2007; 242:490-7

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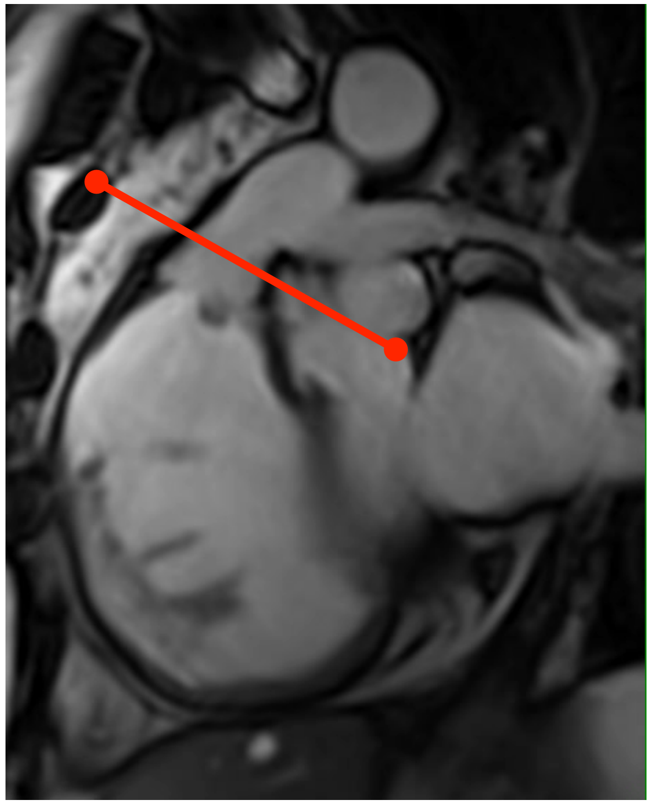
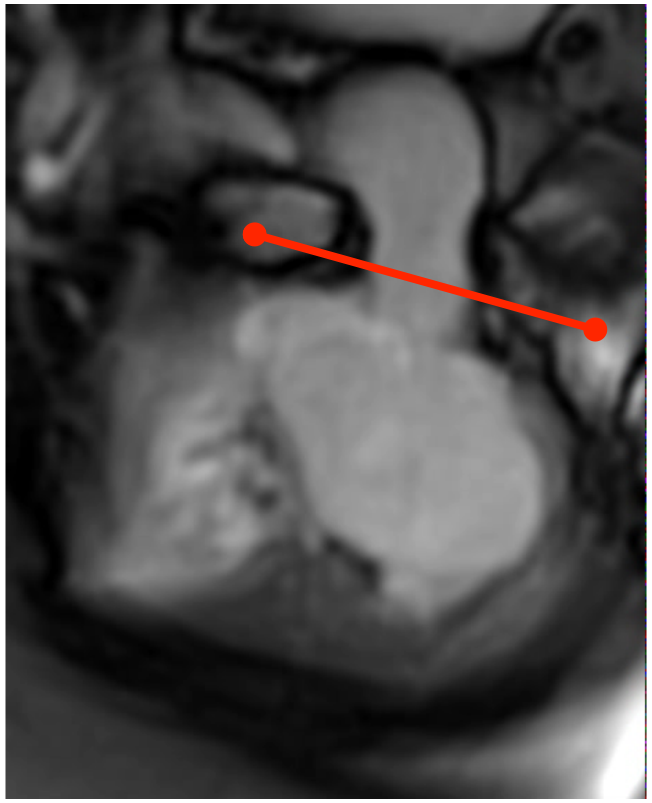
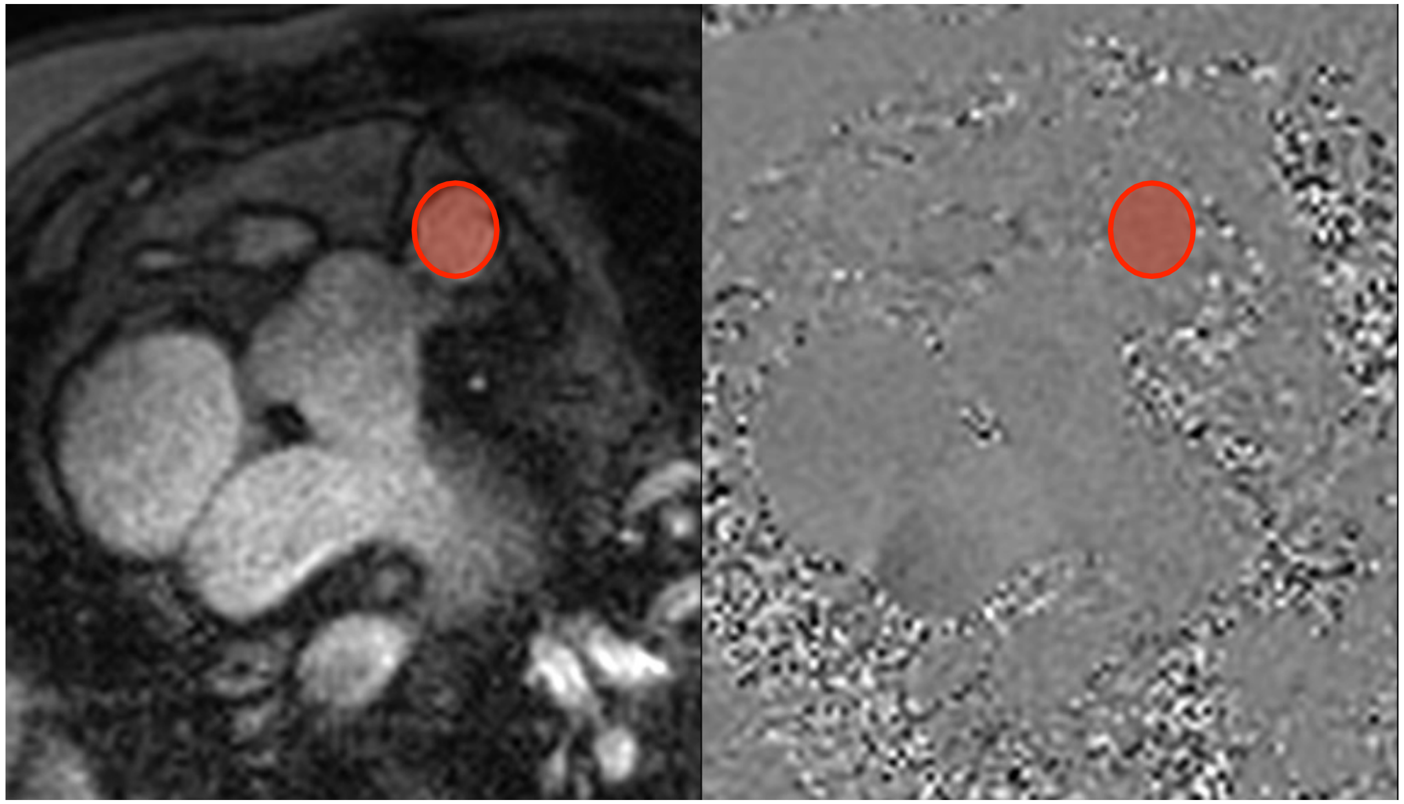
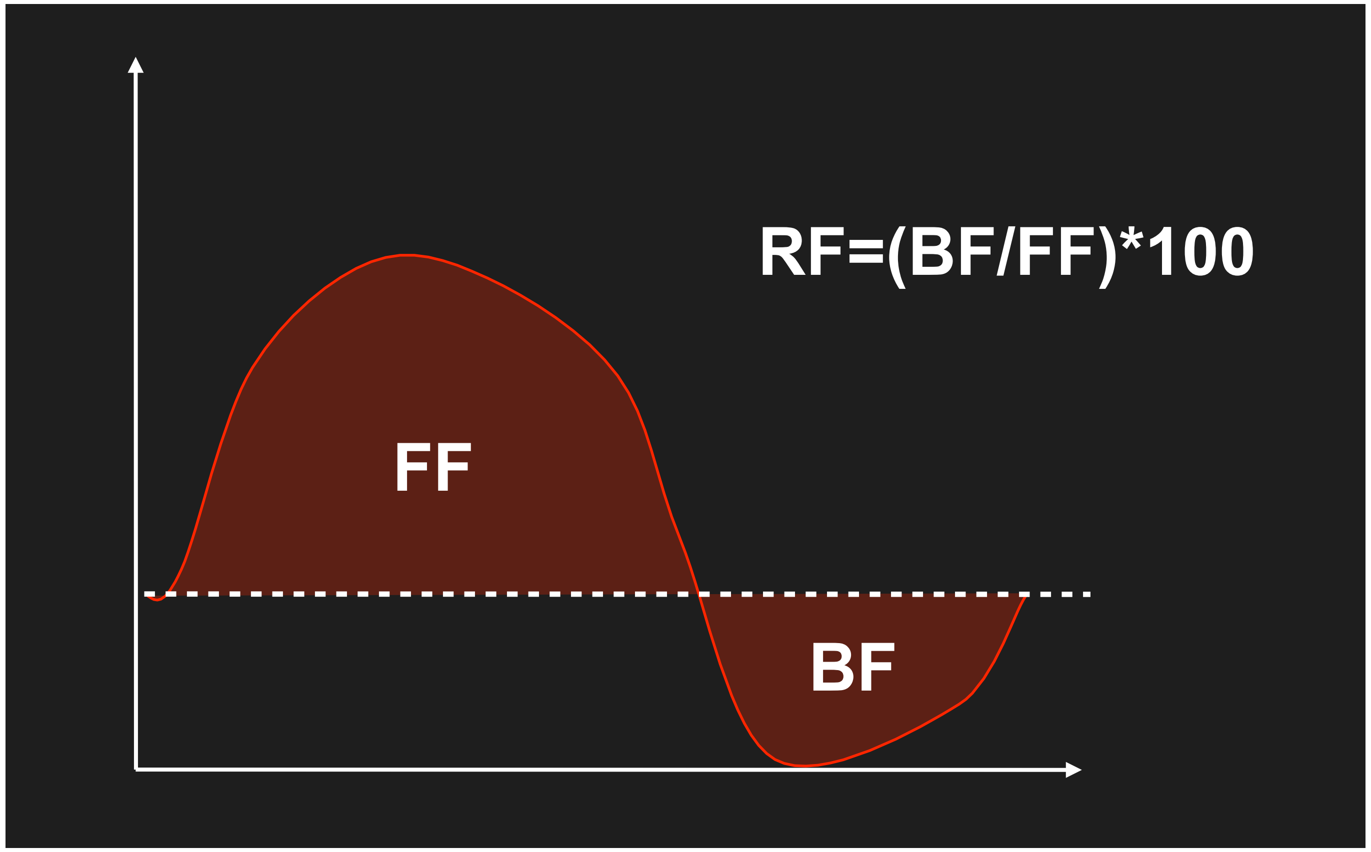
Quantify flow









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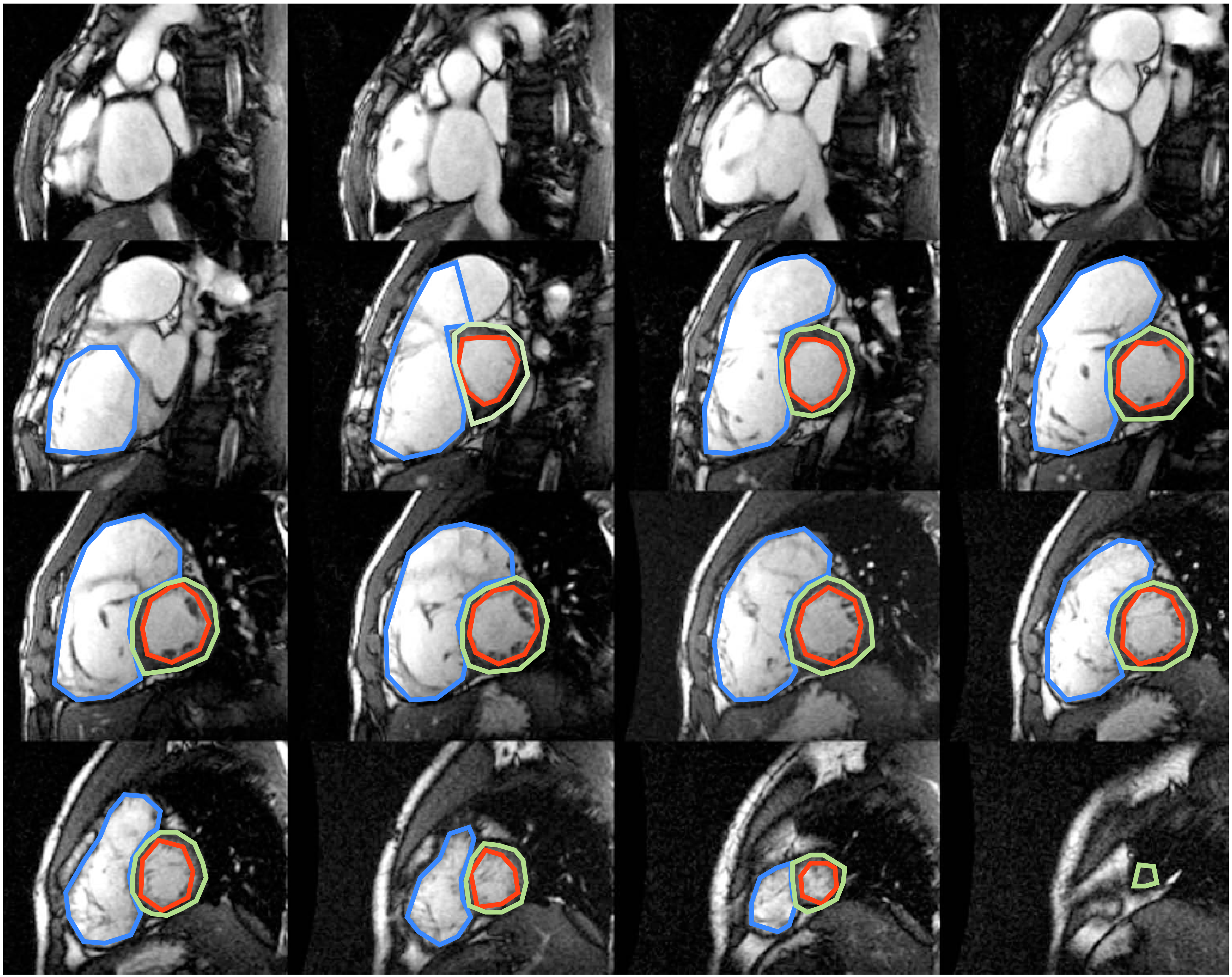
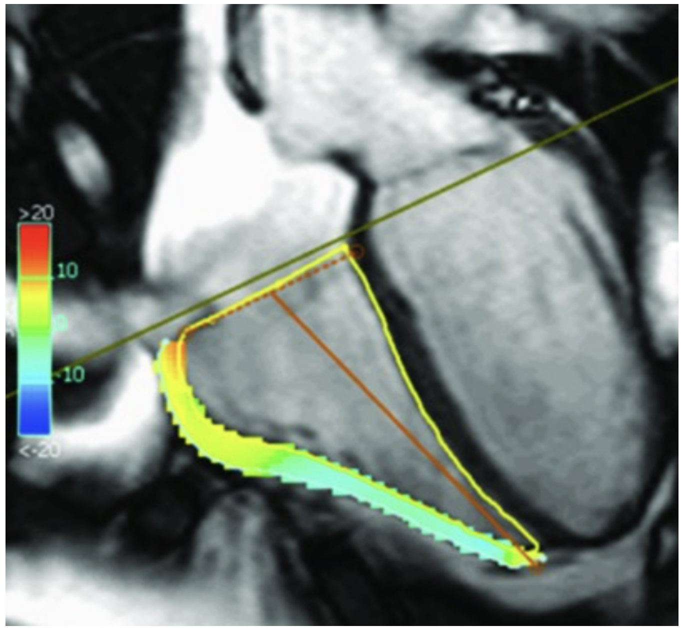
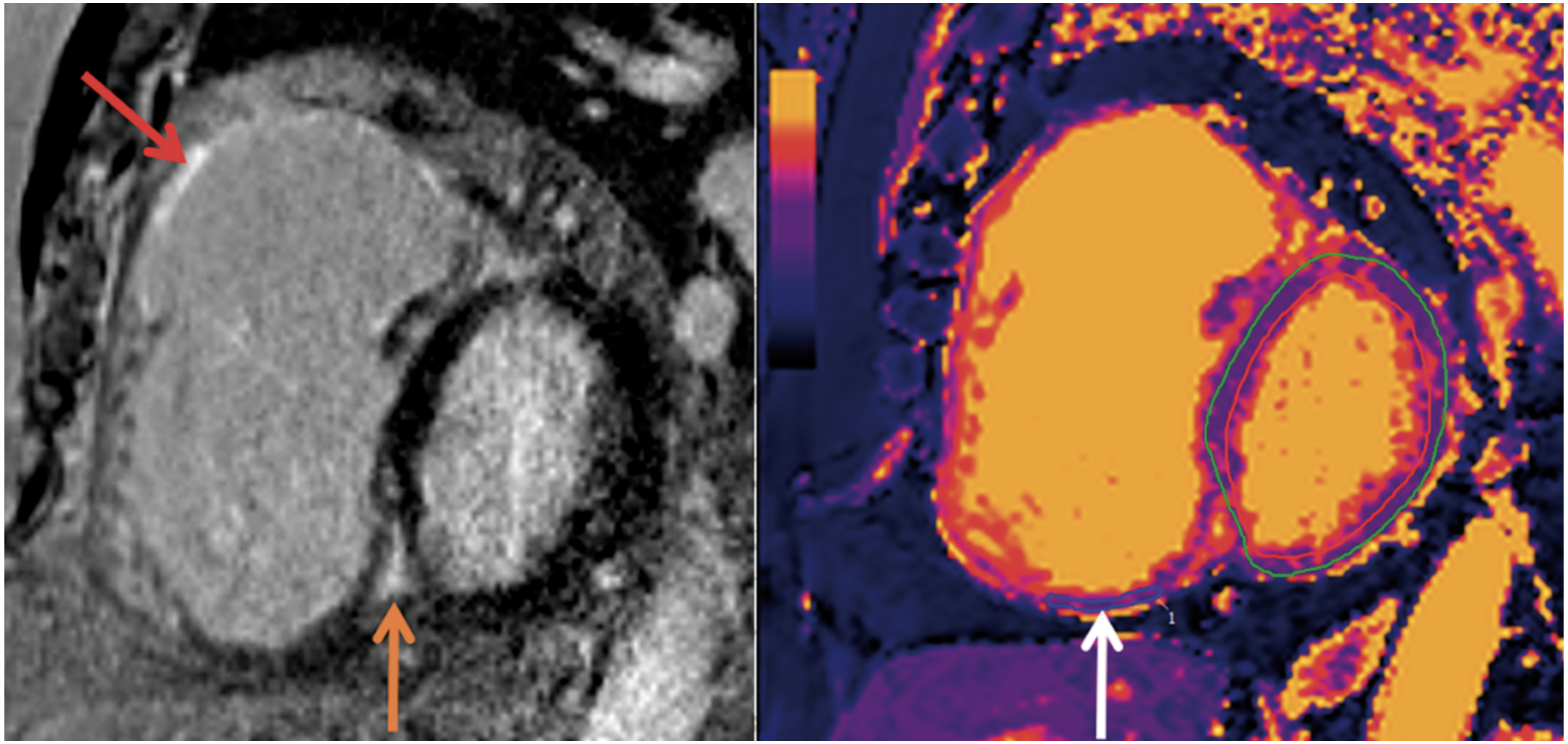
Quantify volumes



Quantify tissue characterisation





Hanneman et al. EHJ CVI 2018

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Automated flow analysis

Bratt et al. Journal of Cardiovascular Magnetic Resonance (2019) 21:1
https://doi.org/10.1186/s12968-018-0509-0

Journal of Cardiovascular Magnetic Resonance

RESEARCH Open Access

Machine learning derived segmentation of phase velocity encoded cardiovascular magnetic resonance for fully automated aortic flow quantification

Alex Bratt[1], Jiwon Kim[1,2], Meridith Pollie[2], Ashley N. Beecy[2], Nathan H. Tehrani[2], Noel Codella[3], Rocio Perez-Johnston[4], Maria Chiara Palumbo[2], Javid Alakbarli[2], Wayne Colizza[1], Ian R. Drexler[1], Clerio F. Azevedo[5], Raymond J. Kim[5], Richard B. Devereux[2] and Jonathan W. Weinsaft[1,2,4,6*]

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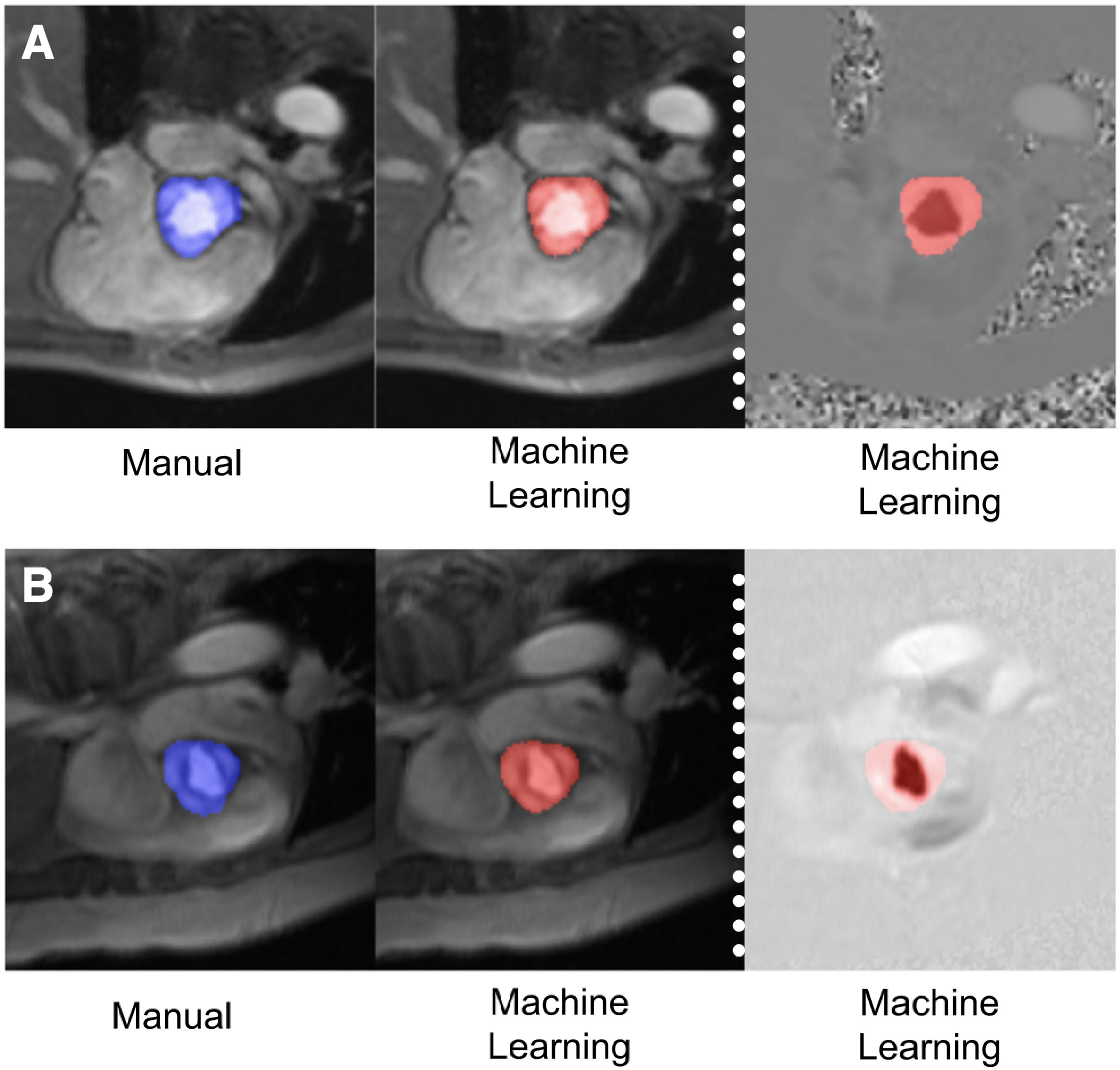
Automated flow analysis



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Automated flow analysis

- **Method** - A machine learning model was designed to track aortic valve borders based on neural network approaches. The model was trained on 150 patients who underwent clinical PC-CMR then compared to manual and commercially-available automated segmentation in a prospective validation cohort of 190 patients.

- **Results** - Machine learning segmentation was uniformly successful, requiring no human intervention: Segmentation time was **< 0.01 min/case** (1.2 min for entire dataset); manual segmentation required **3.96 ± 0.36 min/case** (12.5 h for entire dataset).

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Automated volume analysis

Karimi-Bidhendi *et al.*
J Cardiovasc Magn Reson (2020) 22:80
https://doi.org/10.1186/s12968-020-00678-0

Journal of Cardiovascular Magnetic Resonance

RESEARCH Open Access

Check for updates

Fully-automated deep-learning segmentation of pediatric cardiovascular magnetic resonance of patients with complex congenital heart diseases

Saeed Karimi-Bidhendi[1], Arghavan Arafati[2], Andrew L. Cheng[3], Yilei Wu[1], Arash Kheradvar[2*] and Hamid Jafarkhani[1*]

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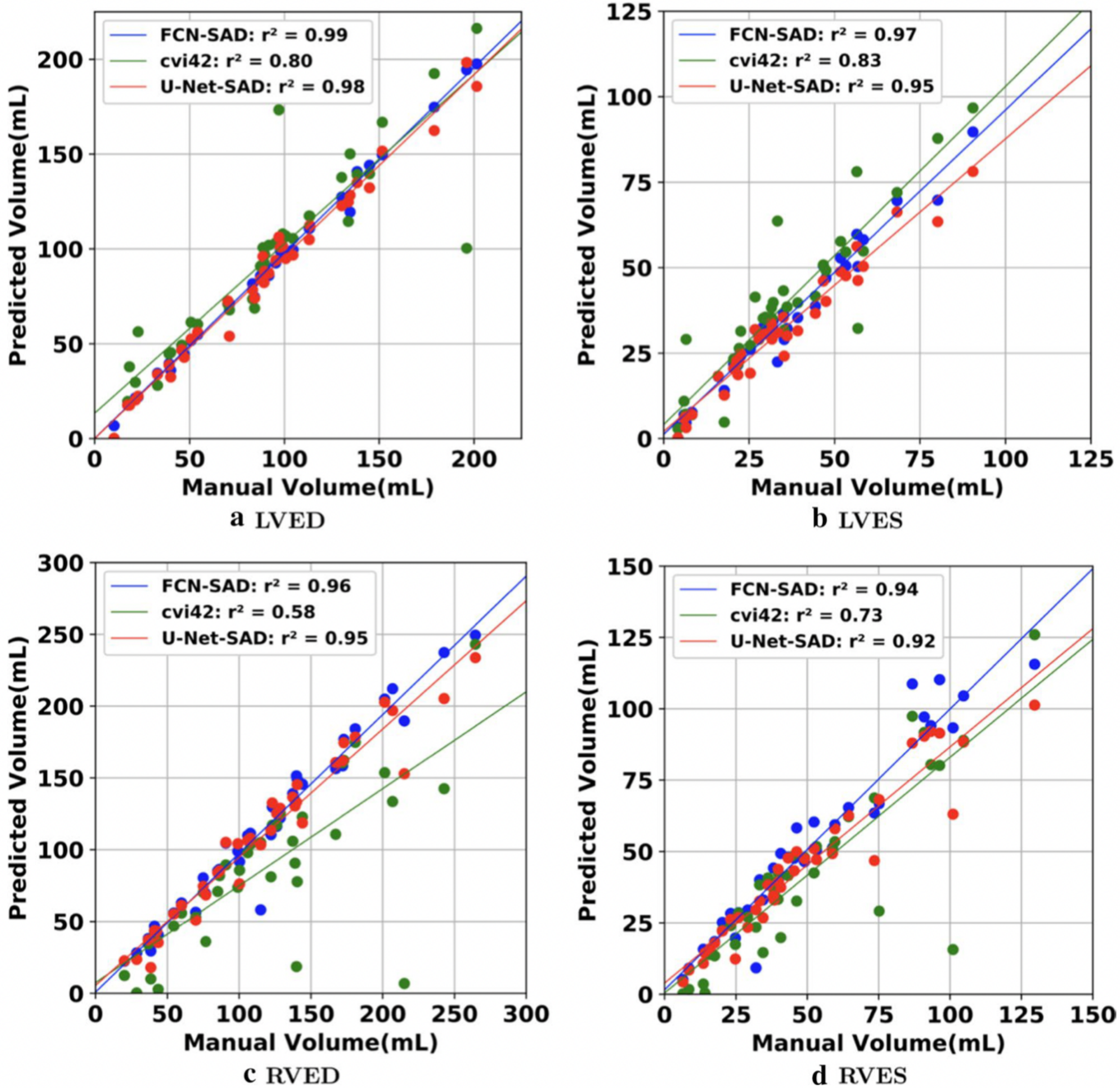
Automated volume analysis



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Automated volume analysis

- **Conclusions** - The chambers' segmentation results from our fully-automated method showed strong agreement with manual segmentation and **no significant statistical difference was found by two independent statistical analyses**.

- Relying on these outcomes, it can be inferred that by taking advantage of generative adversarial networks (GAN), the method is clinically relevant and can be used for pediatric and congenital CMR segmentation and analysis.

Automated 4D flow analysis

HHS Public Access

Author manuscript

Magn Reson Med. Author manuscript; available in PMC 2021 April 01.

Published in final edited form as:

Magn Reson Med. 2020 October ; 84(4): 2204–2218. doi:10.1002/mrm.28257.

Fully automated 3D aortic segmentation of 4D flow MRI for hemodynamic analysis using deep learning

Haben Berhane[1], Michael Scott[2,3], Mohammed Elbaz[2,3], Kelly Jarvis[3], Patrick McCarthy[4], James Carr[2], Chris Malaisrie[3], Ryan Avery[3], Alex J. Barker[5], Joshua D. Robinson[1], Cynthia K. Rigsby[1], Michael Markl[2,3]

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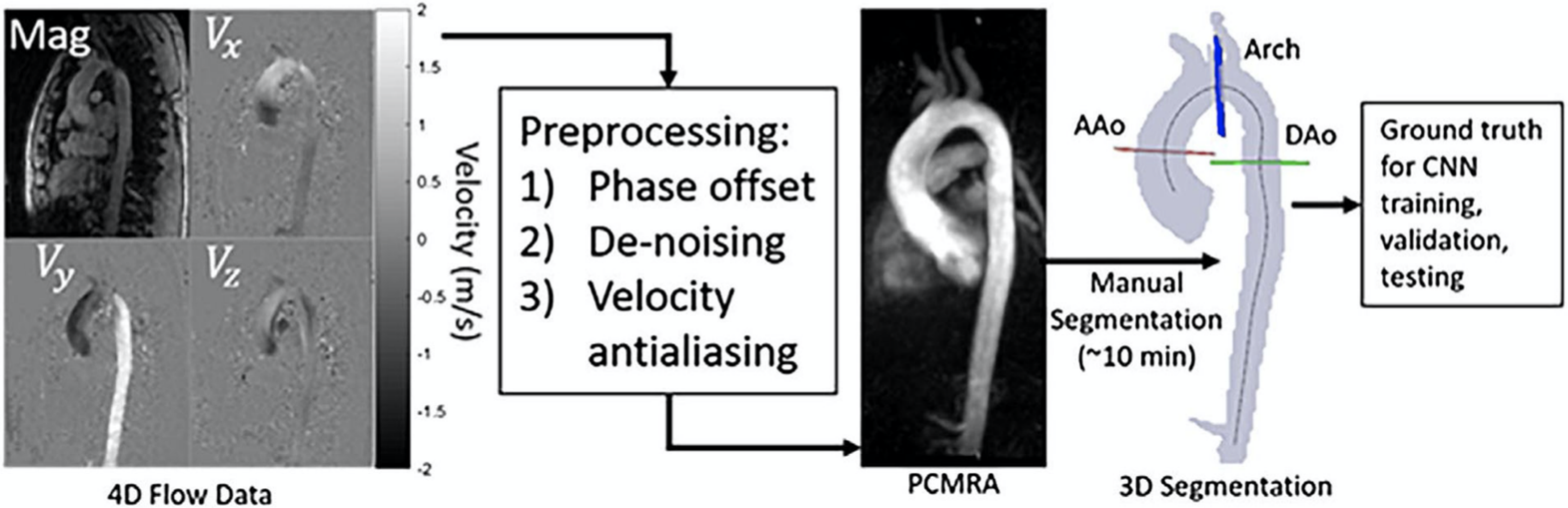
Automated 4D flow analysis



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Automated 4D flow analysis

- **Aim** - To generate fully automated and fast 4D-flow MRI-based 3D segmentations of the aorta using deep learning for reproducible quantification of aortic flow, peak velocity, and dimensions
- **Subjects** - 1018 subjects with aortic 4D-flow MRI (528 with bicuspid aortic valve, 376 with tricuspid aortic valve and aortic dilation, 114 healthy controls)
- **Results** - Convolutional neural network segmentation required **0.438 ± 0.355 s vs 630 ± 254 s** for manual analysis, with excellent agreement for flow, peak velocity, and dimensions

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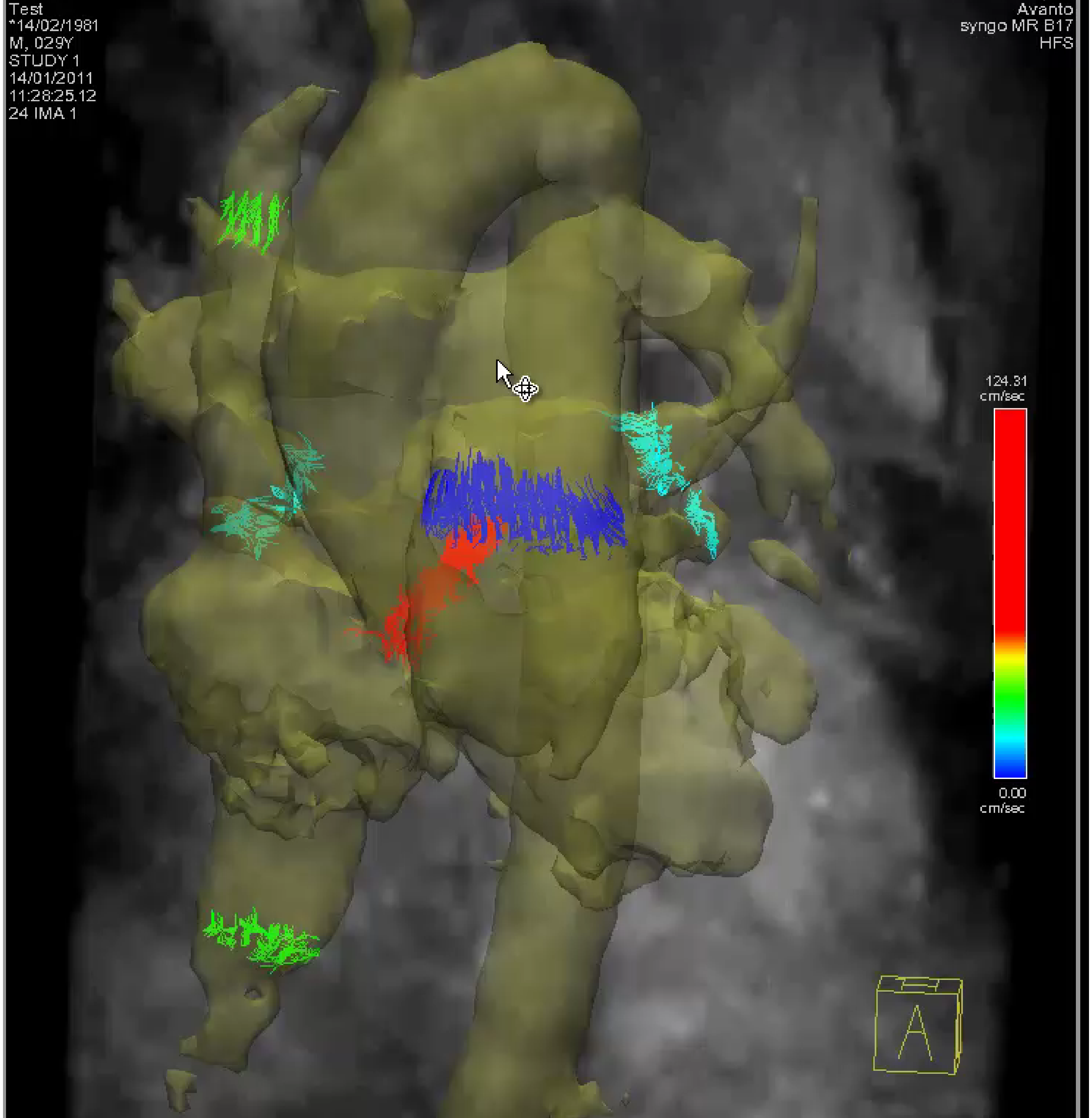
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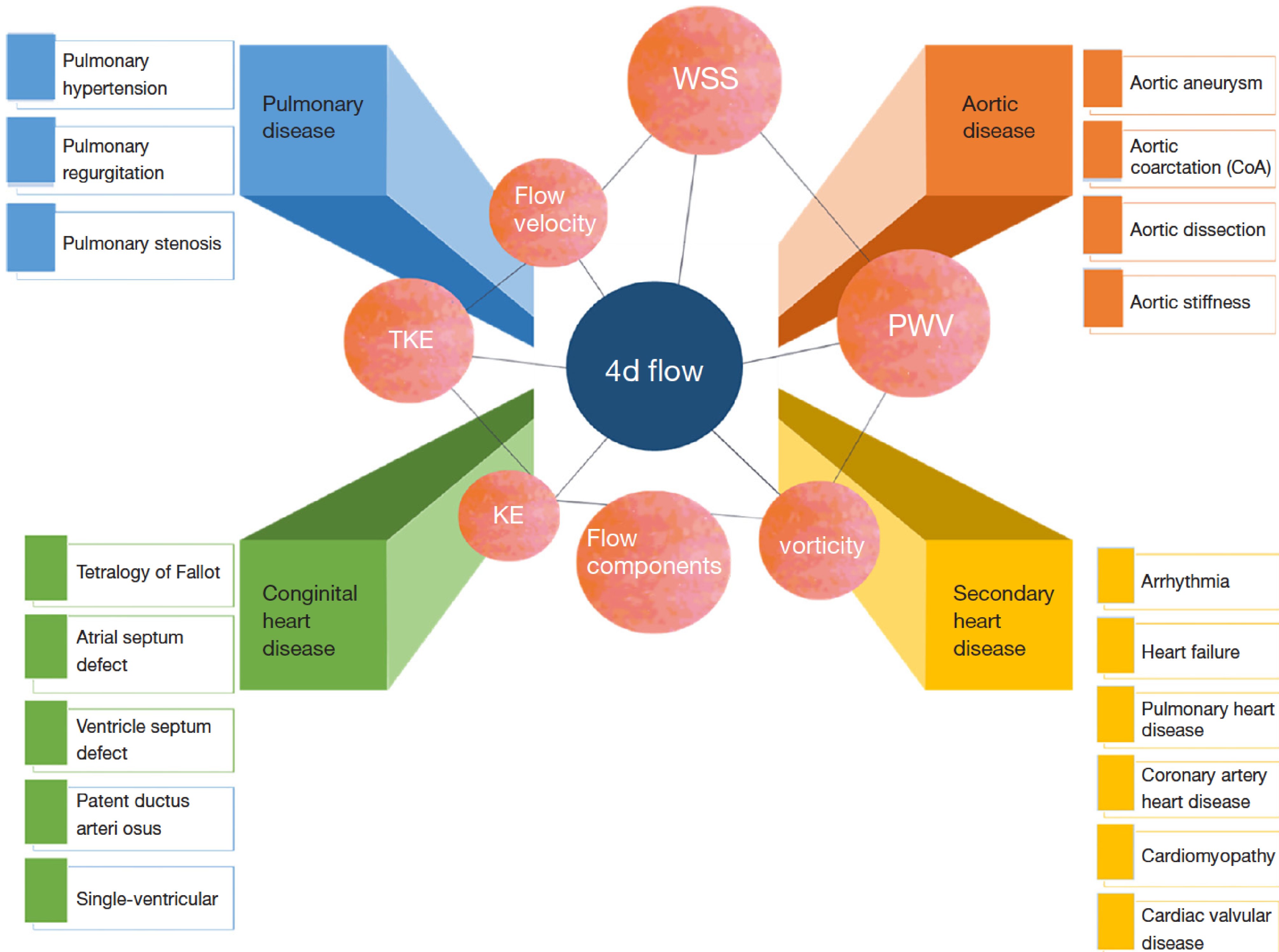
New applications



From: Zhuang B, Sirajuddin A, Zhao S, Lu M. *Quant Imaging Med Surg* 2021;**11(9)**:4193-4210.

Automated diagnosis

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Computer-aided diagnosis

Medical Image Analysis 26 (2015) 185–194

Contents lists available at ScienceDirect

Medical Image Analysis

journal homepage: www.elsevier.com/locate/media

Voxelwise atlas rating for computer assisted diagnosis: Application to congenital heart diseases of the great arteries

Maria A. Zuluaga [a,1,*], Ninon Burgos [a,1], Alex F. Mendelson [a], Andrew M. Taylor [b,c], Sébastien Ourselin [a]

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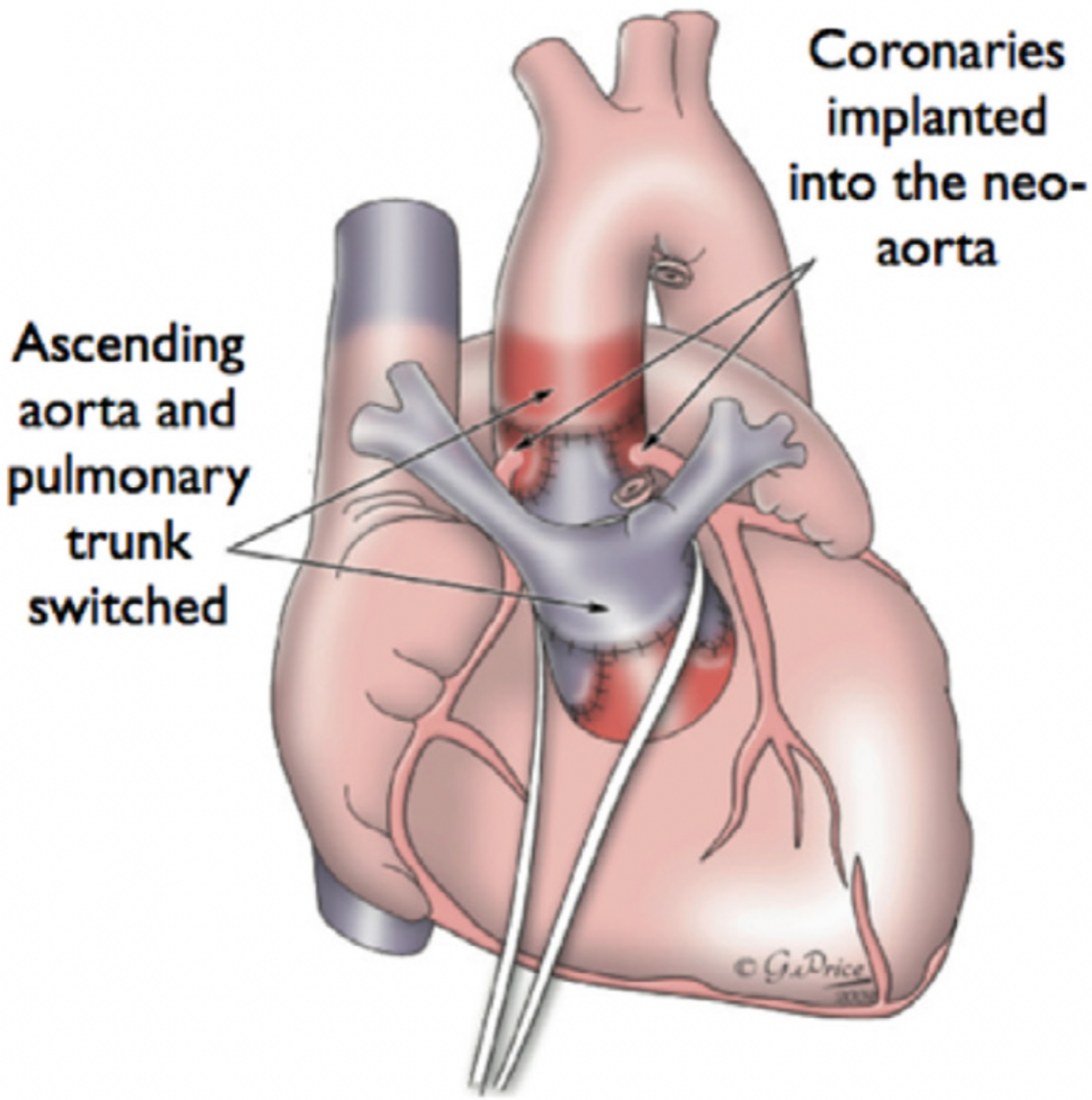
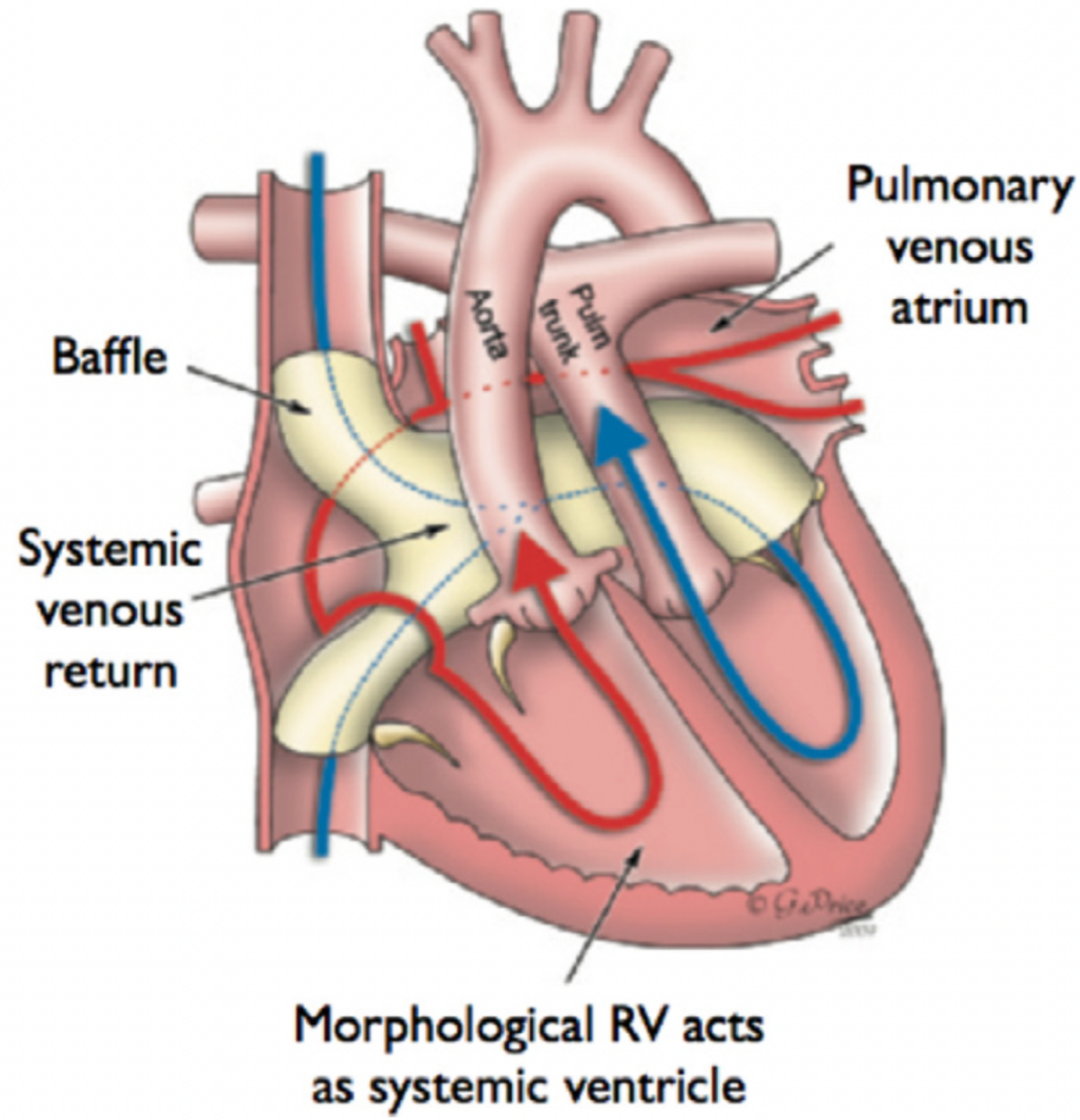
TGA diagnosis



Post arterial switch operation



Post atrial switch

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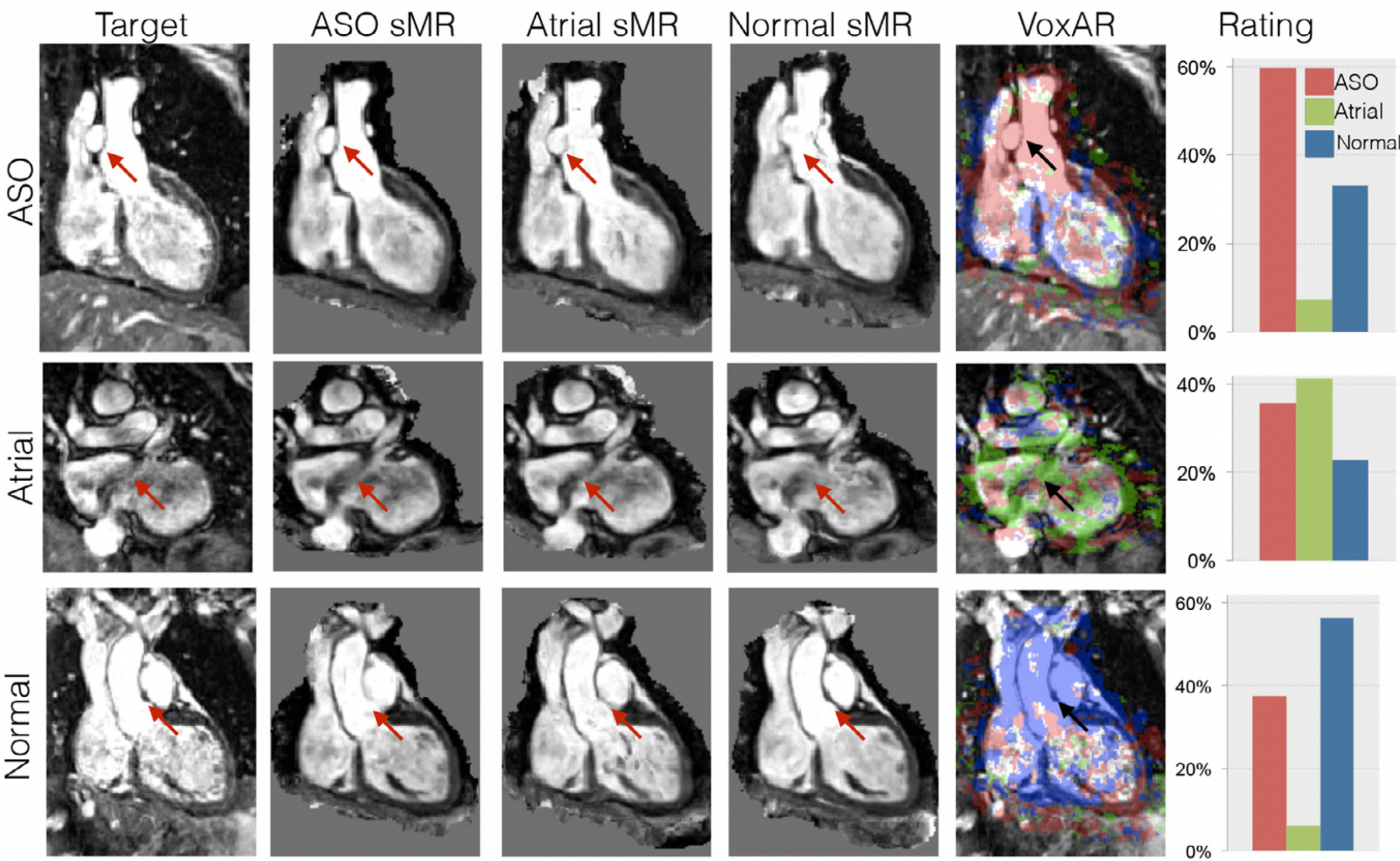
Computer-aided diagnosis



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Computer-aided diagnosis

- **Aim** - To use atlas based analysis to define similarity between the atlas and target images. A rating map displaying for each voxel the condition of the atlases most similar to the target was defined. The final diagnosis was established by assigning the condition of the database the most represented in the rating map
- **Results** - The proposed approach outperforms other state-of-the-art methods using annotated images, with an accuracy of **97.3%** when evaluated on a set of 60 whole heart MR images containing healthy and pathological subjects using cross validation.

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Big data
Precision medicine

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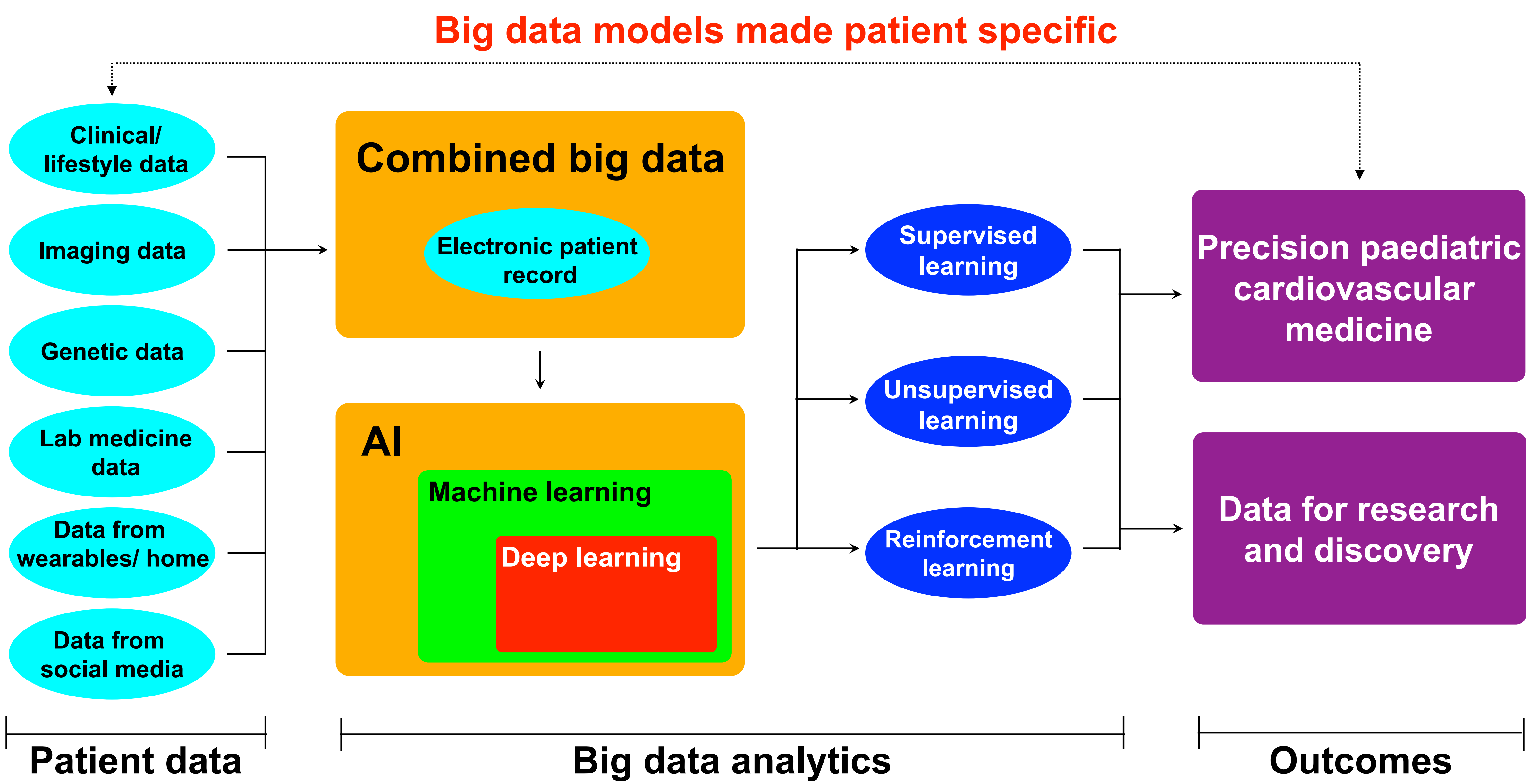
Potential for precision medicine



Trusted research environment

Bring your data

- Lab
- Social
- Longit
- Genomic
- Imaging
- Clinical
- Sensor
- Time
- Service KPI

Invite your multi-disciplinary team

- Clinician
- Researcher
- Doctor
- Academic
- Programme director
- Industry partner

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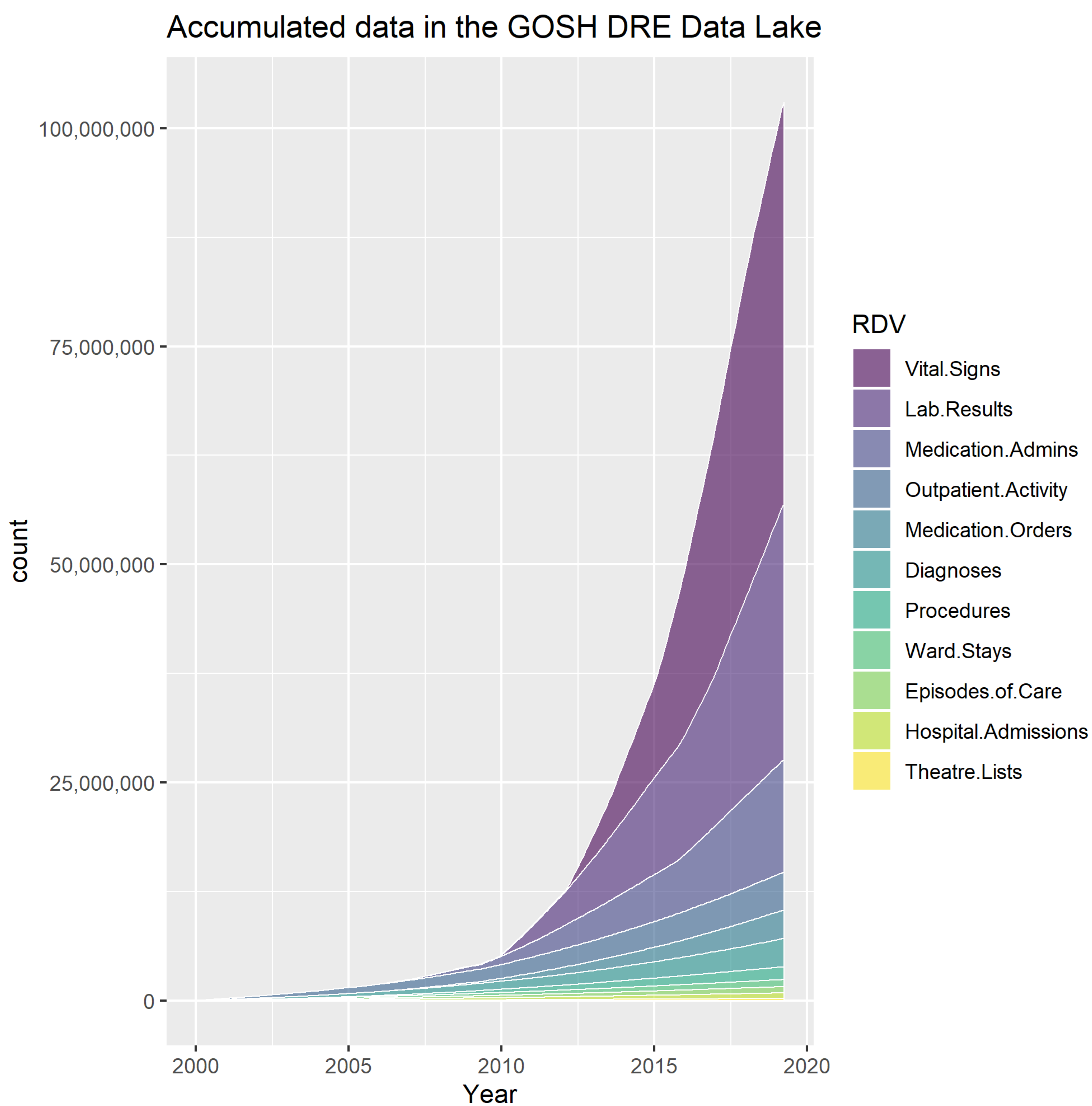
Data in data lake



Data is:

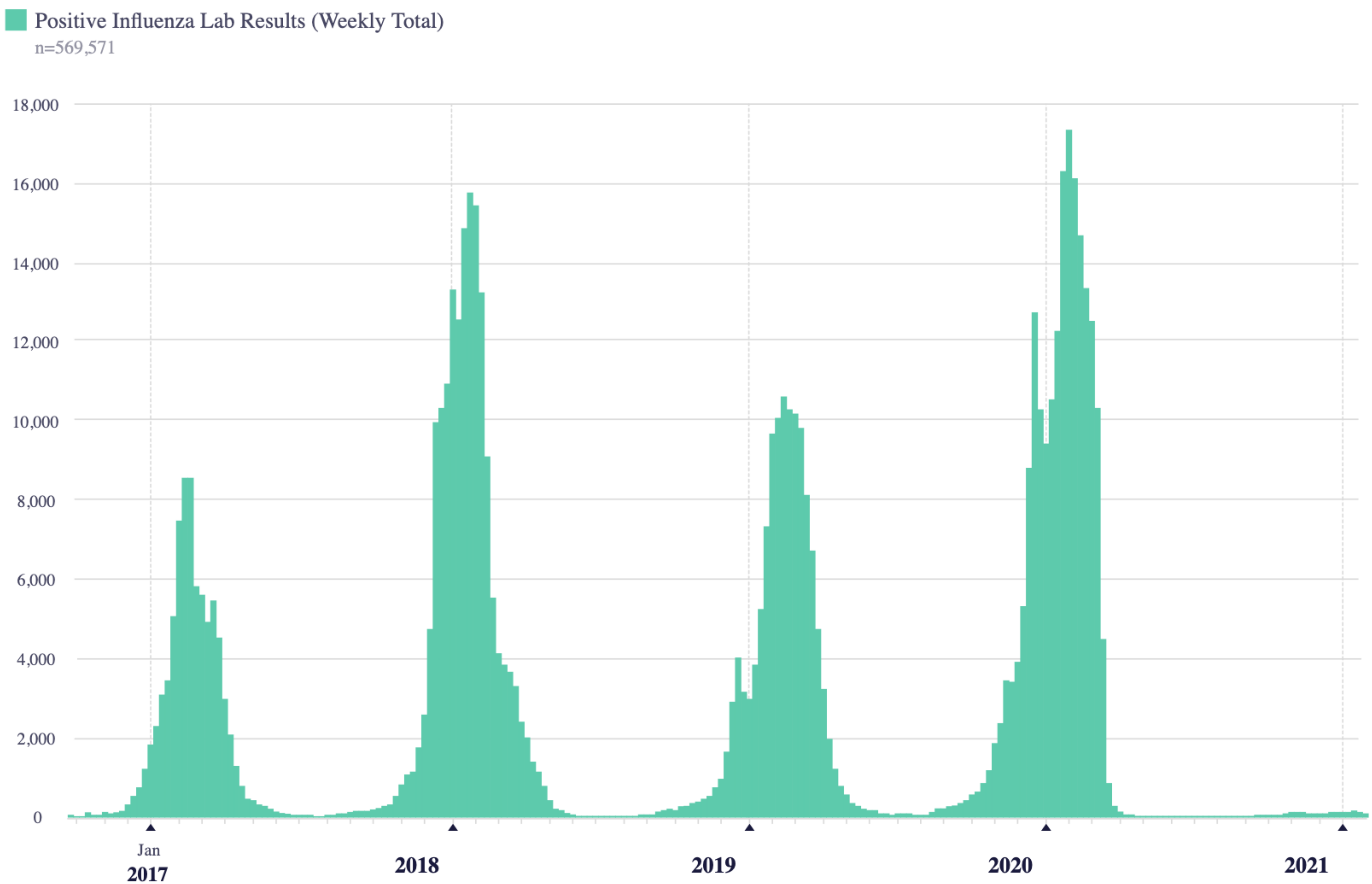
- Anonymised
- Curated
- Research workspaces
- Common analytics
- Auditable
- Refreshed daily

TRE query around lost appointments

18,556 appointments were missed across 2020/21

Greater than 720 weekdays (2.75 years) would be required to achieve all out-patient catch-up activity, if weekday hospital activity were able to increase by 10% with respect to pre-COVID 19 activity

Power of big data



"Seasonal Influenza Rates Drop to Historic Lows During the COVID-19 Pandemic." 2021. Epic Health Research Network (EHRN.org)

Issues

Issues

- Change to the way care is delivered
- Build good quality (excellent data in) large data sets
- Move from single centre validation to universal applicability
- Understand data issues - Confidentiality/ Ownership
- Value – What is the worth of healthcare data?
- Importance of regulation for ethical use of data, but not over-regulation that will stifle crucial innovation
- Importance of understanding the role of decision support tools/ models of care, and where AI information does not make sense
- Connectivity to link disparate data sets, coming from the home, primary care & the hospital setting

Conclusions

- This field will expand significantly over the next decade
- Improving targeted patient care
- Reducing mundane tasks for radiologists
- Enhancing our diagnostic capabilities and accuracy
- By combining data from many sources this will further improve care

AI will drive much of this change in the next decade, though won't be a panacea for everything

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Wait. Will AI Replace Radiologists After All?

| February 18, 2020 | Artificial Intelligence

YES. NO. MAYBE. IT DEPENDS.

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“My guess is that in 10 to 20 years, most imaging studies will be read only by machines…(with)…The results transmitted directly to the referring physician without input from a human radiologist”

“AI allows radiologists to pull information that would otherwise be left on the table…(with)…AI enhancing the value of medical imaging, which is great for patients as well as the filed of radiology”

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Any questions

The child first and always