Real, surreal, and virtual

Jan Marek

Great Ormond Street Hospital
Professor of Cardiology
Institute of Cardiovascular Sciences,
University College London

“It is the supreme art of the teacher to awaken joy in creative expression and knowledge”

„Nejvýznamnějším uměním učitele je probouzet v žácích radost, tvořit a poznávat.“ A.Einstein

Transitioning from Analogue to Digital Life

radically rethinking of the human-computer interactive experience

4th Industrial Revolution & Digital Medicine

Digital medicine is amongst the fastest developing disciplines recently further accelerated by:

- **Covid pandemics**
- **Climate change**
- **Energy crisis**

Enormous changes occur during geopolitical instability

Digital Medicine

- **Digitalisation of health care systems** (*electronic patients registry* – EPR, *massive data storage* and *data transfer pathway* for digital communication)
- **3D/4D modelling** (anatomical, functional)
- **Virtual reality** (VR/AVR), virtual simulation
- **Artificial Intelligence** (AI) for automated decision making

Transparent, patient specific (personalised) medicine

Digitalisation of National Health Service (NHS)

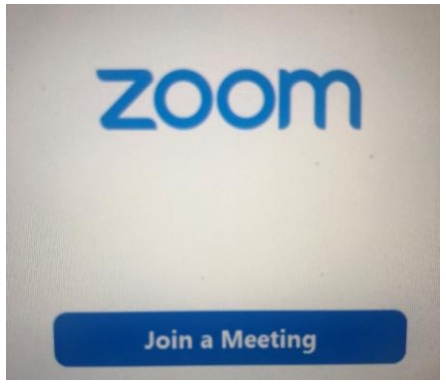
- In 2015, government decided to make all NHS hospitals and outpatient services fully digital
- Estimated costs up to £13bn
- GOSH fully digital from 2018 (completely paperless)

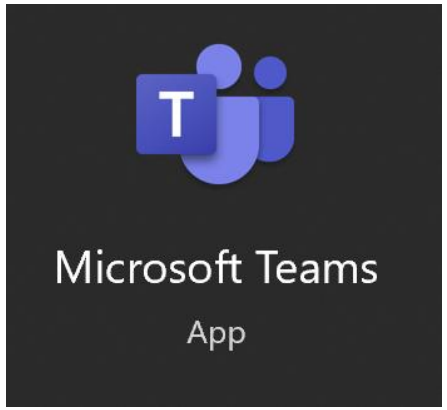
Digitalisation of National Health Service (NHS)

- In 2015, government decided to make all NHS hospitals and outpatient services fully digital
- Estimated costs up to £13bn
- **GOSH fully digital from 2018 (completely paperless)**

Covid lockdown

(2020, Western Bohemia)



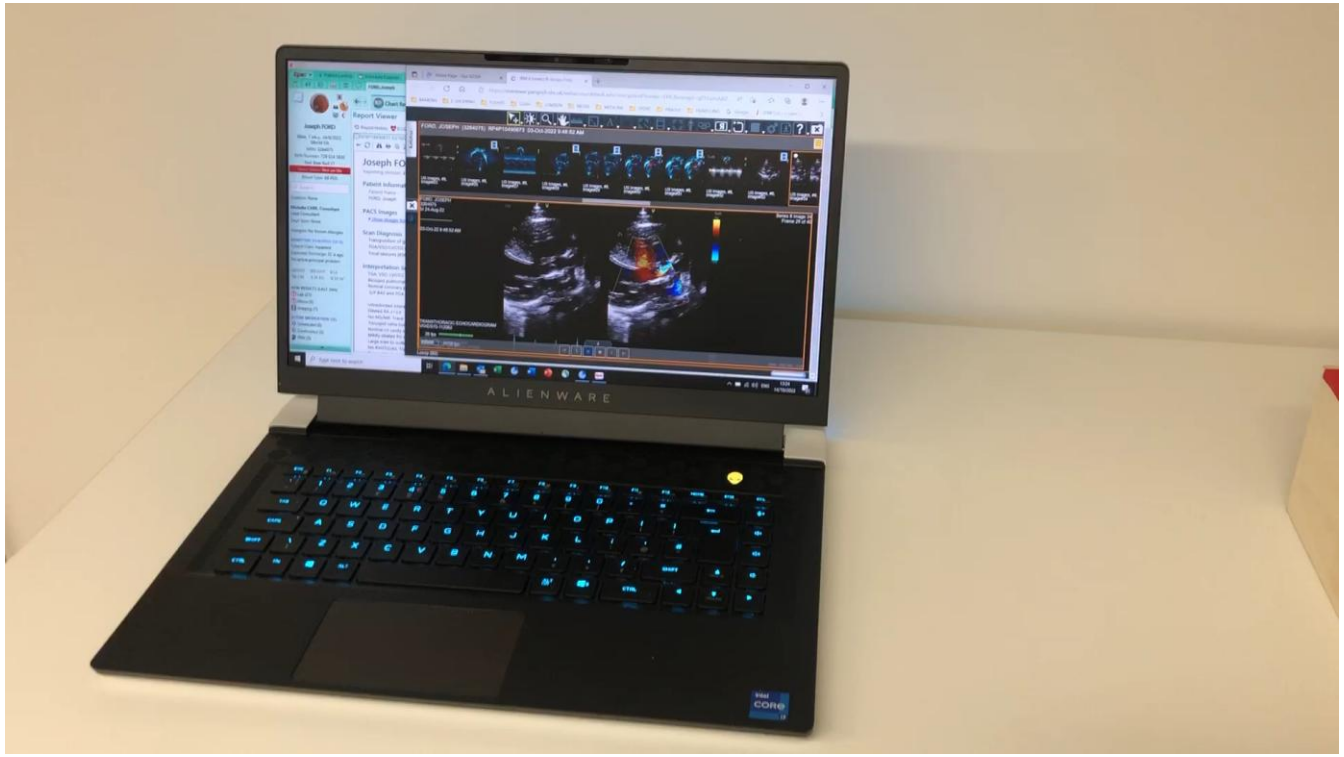


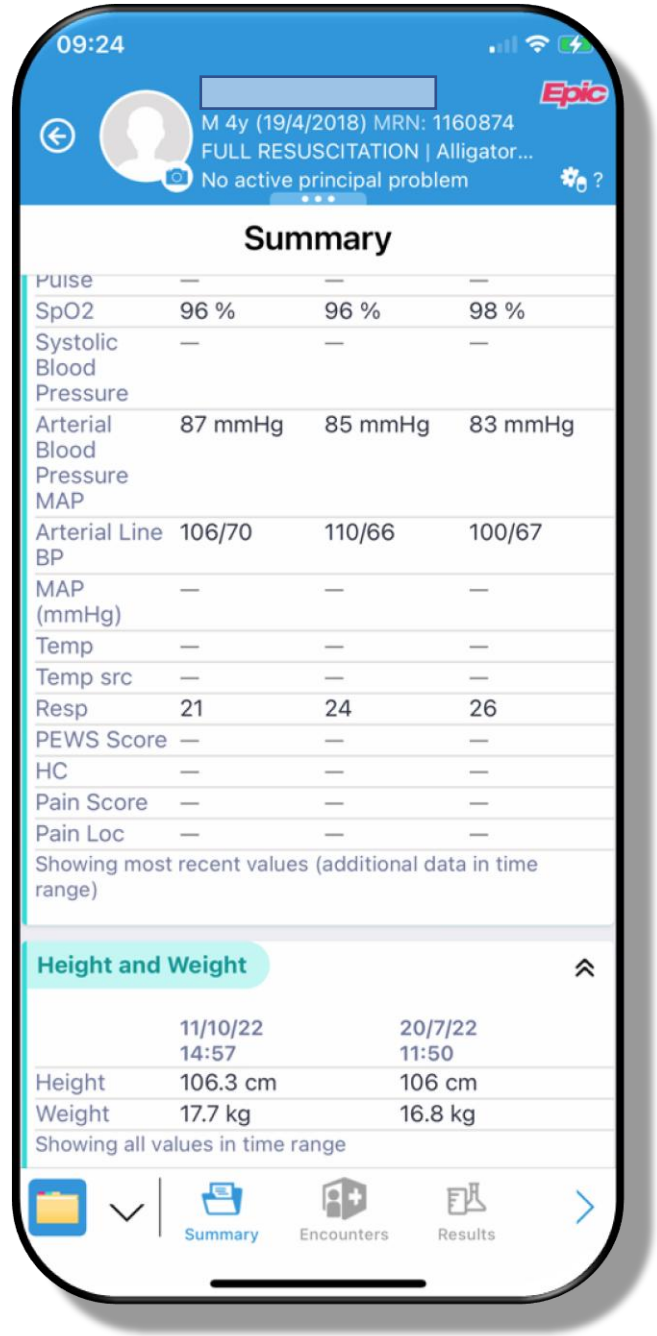
NHS
Great Ormond Street Hospital for Children
NHS Foundation Trust

User name: Marekj

Password: ••••••••••••

MFA Required for logon.

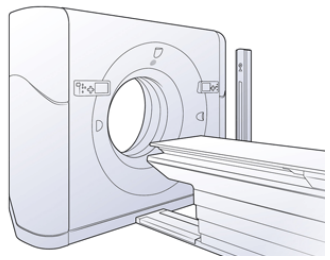


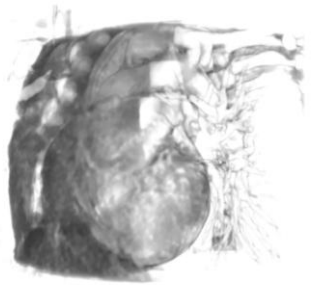


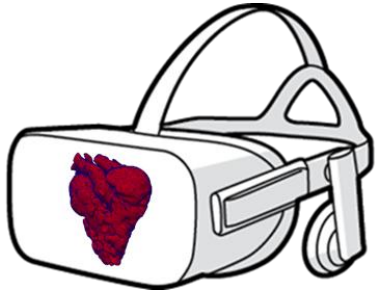
3D Modelling
&
Virtual Reality

Patient-specific heart models

From medical images to 3D Models





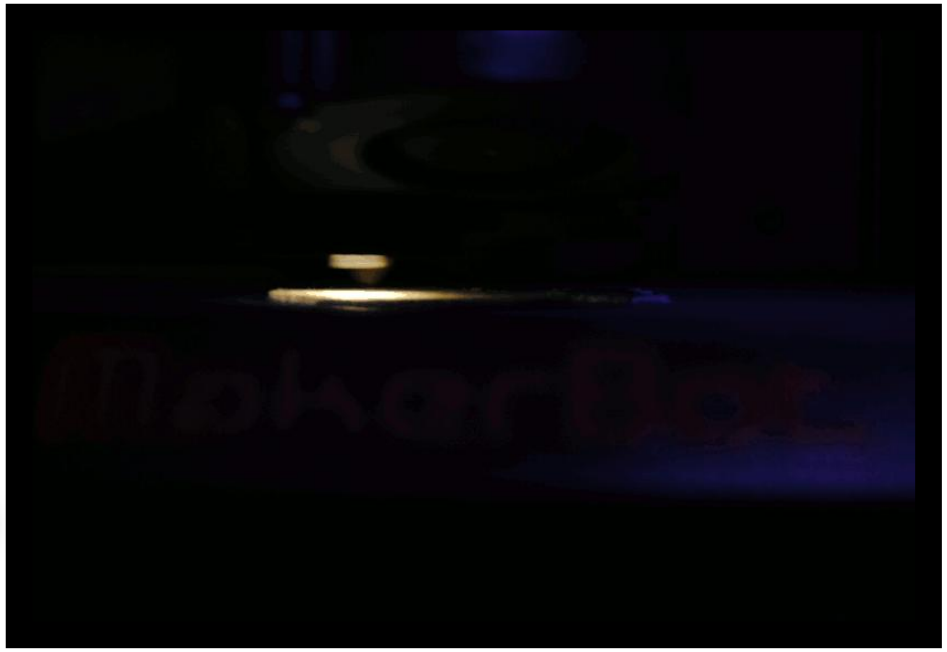


Medical Scan

Medical Images

3D Model

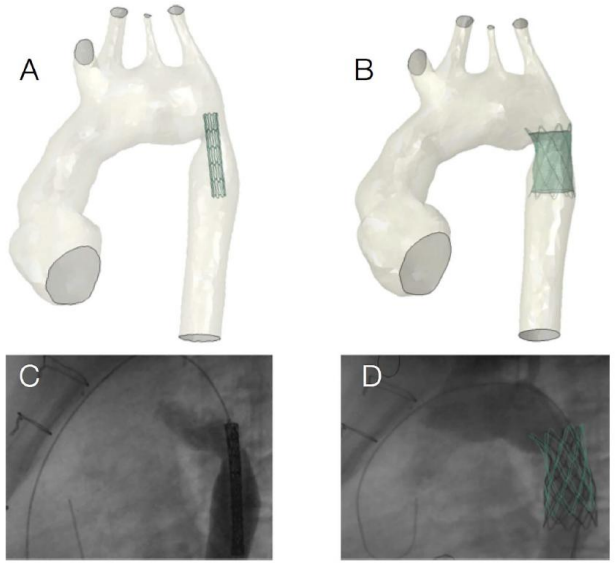
Virtual Reality

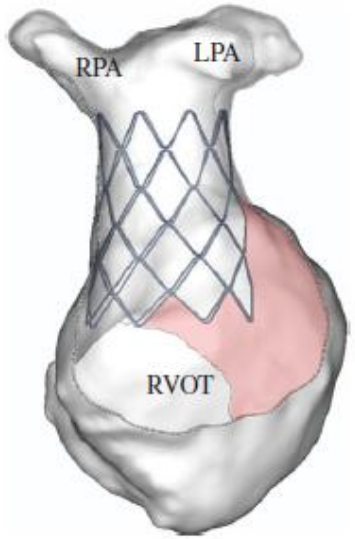


Virtual and Augmented Reality

Biomechanical modelling for **research**
& **clinical application**

- **Complex DORV / TOF / TGA**
- **Coronary a. (AAOCA)**
- **Complex aortic arch** (stent, patch)
- **Post repair RVOT** (PPVI)

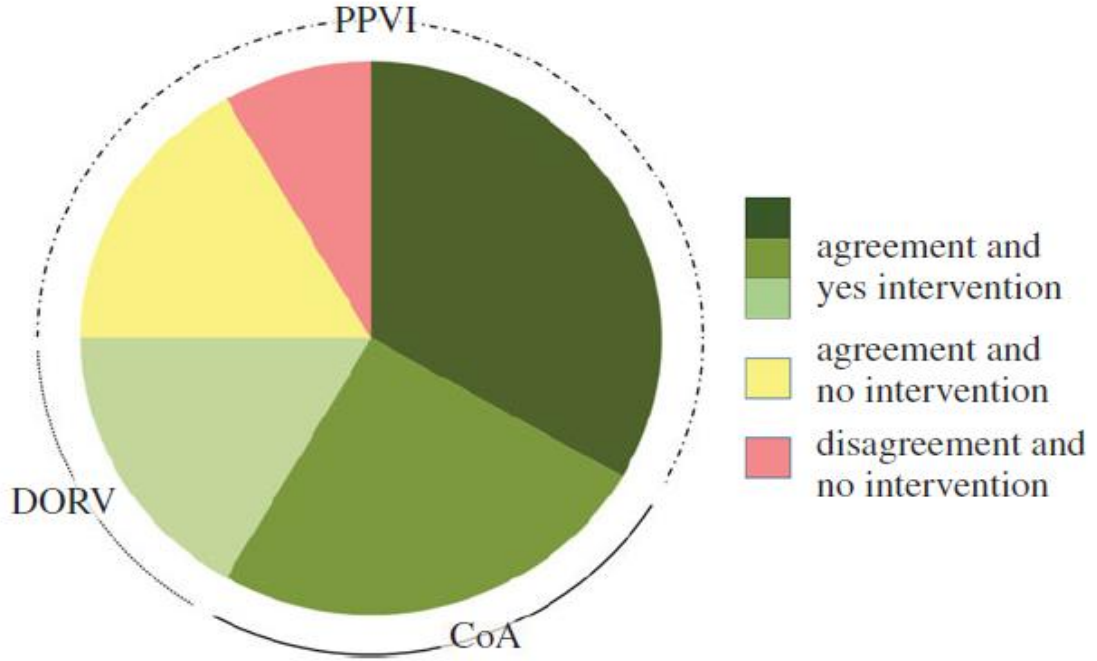




Patient-specific simulations for planning treatment in congenital heart disease

Claudio Capelli[1,2], Emilie Sauvage[1,2], Giuliano Giusti[2,3], Giorgia M. Bosi[2,4], Hopewell Ntsinjana[5], Mario Carminati[3], Graham Derrick[2], Jan Marek[1,2], Sachin Khambadkone[2], Andrew M. Taylor[1,2] and Silvia Schievano[1,2]

Interface focus 2018
Heart 2017
Circ CVI 2020



Circulation: Cardiovascular Imaging

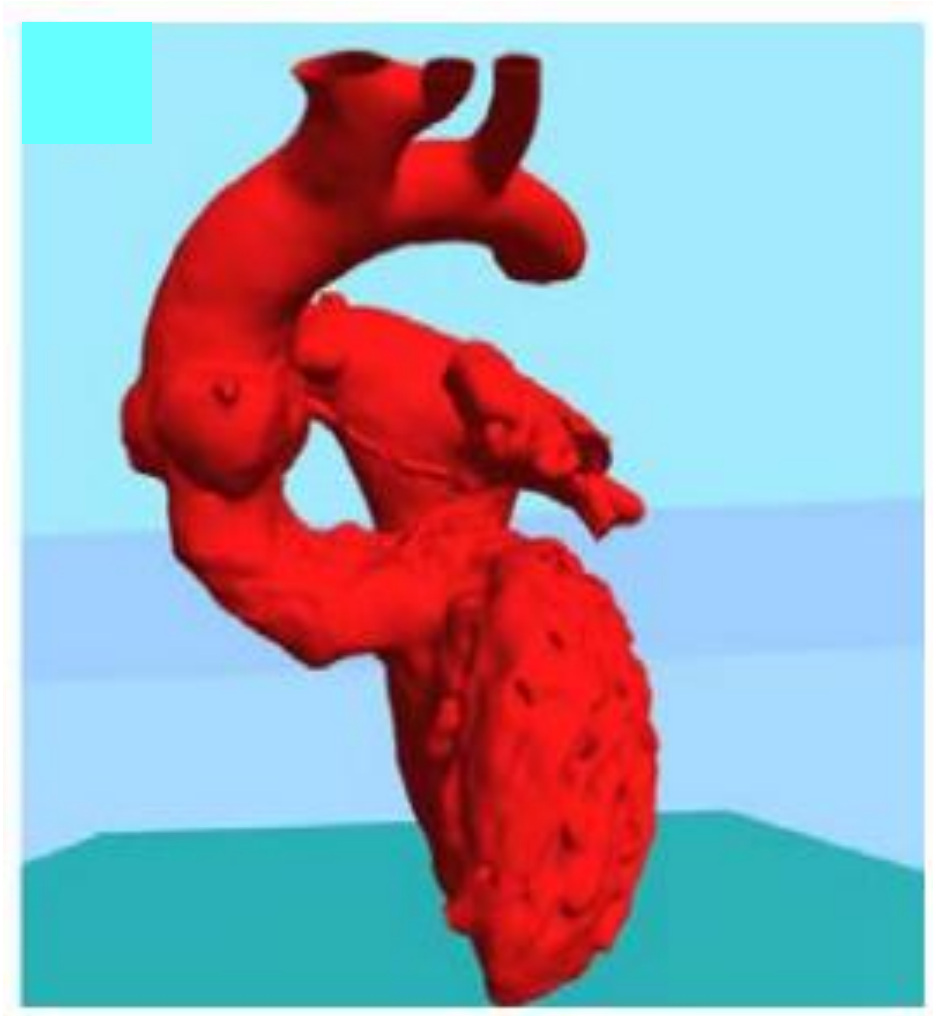
2019

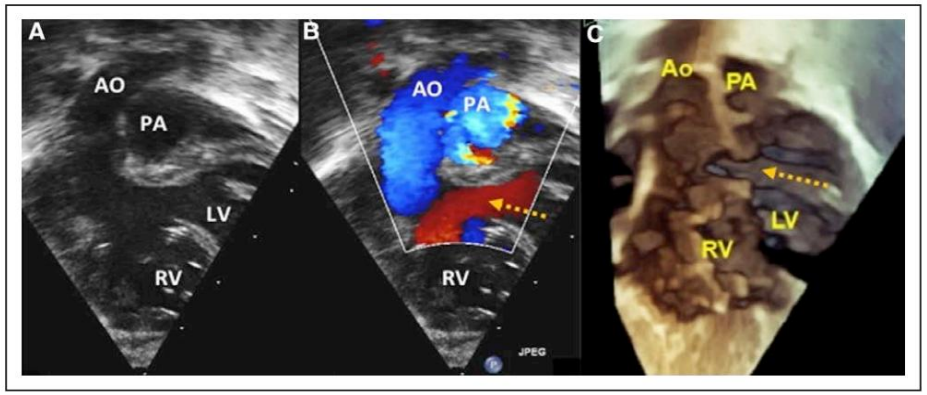
CARDIOVASCULAR IMAGES

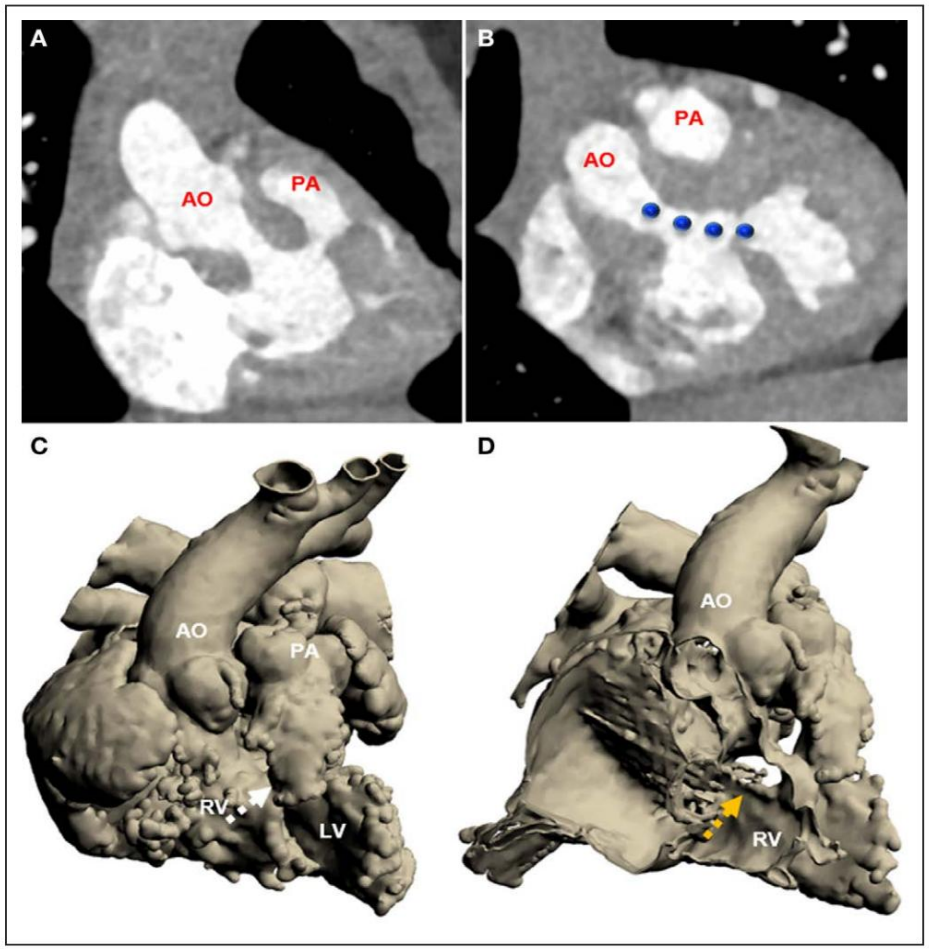
Taking Surgery Out of Reality

A Virtual Journey Into Double Outlet Right Ventricle

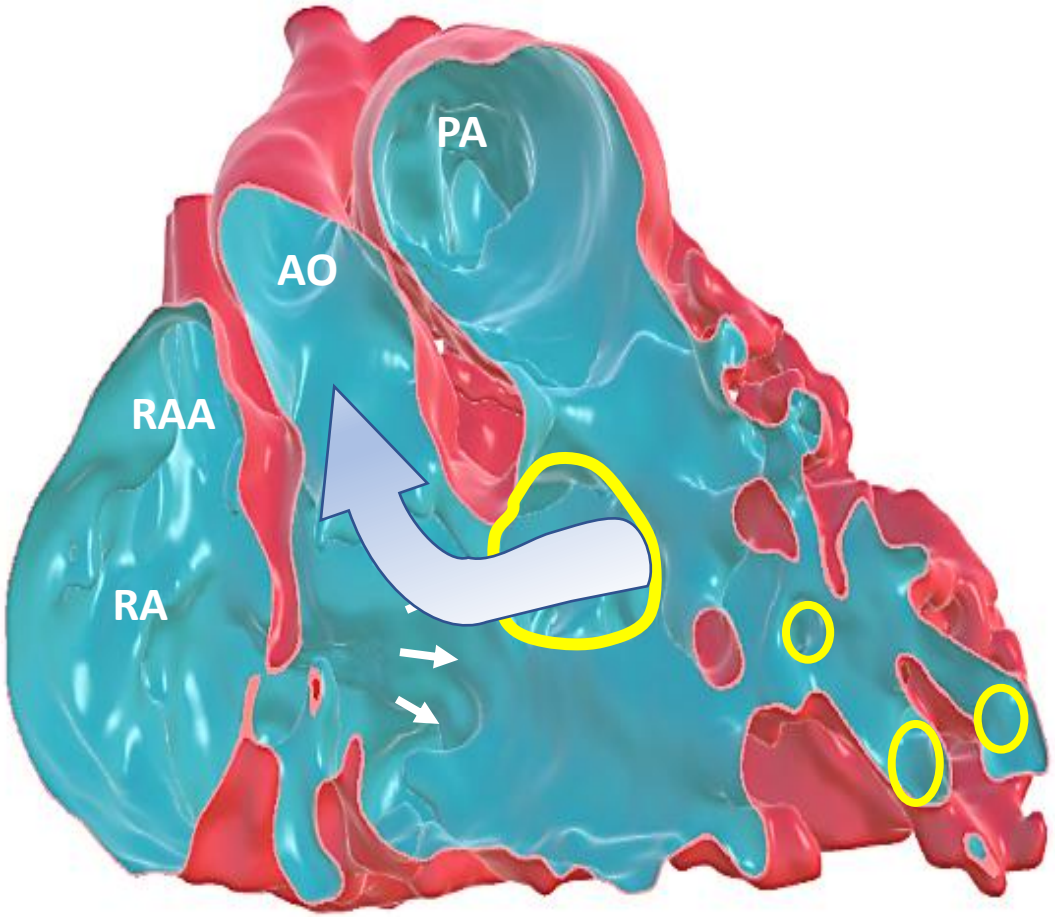
Elena Giulia Milano, MD
Endrit Pajaziti, BEng
Emilie Sauvage, PhD
Andrew Cook, PhD
Silvia Schievano, PhD
Kristian H. Mortensen, MD, PhD
Andrew M Taylor, MD, PhD
Jan Marek, MD, PhD
Martin Kostolny, MD
Claudio Capelli, PhD

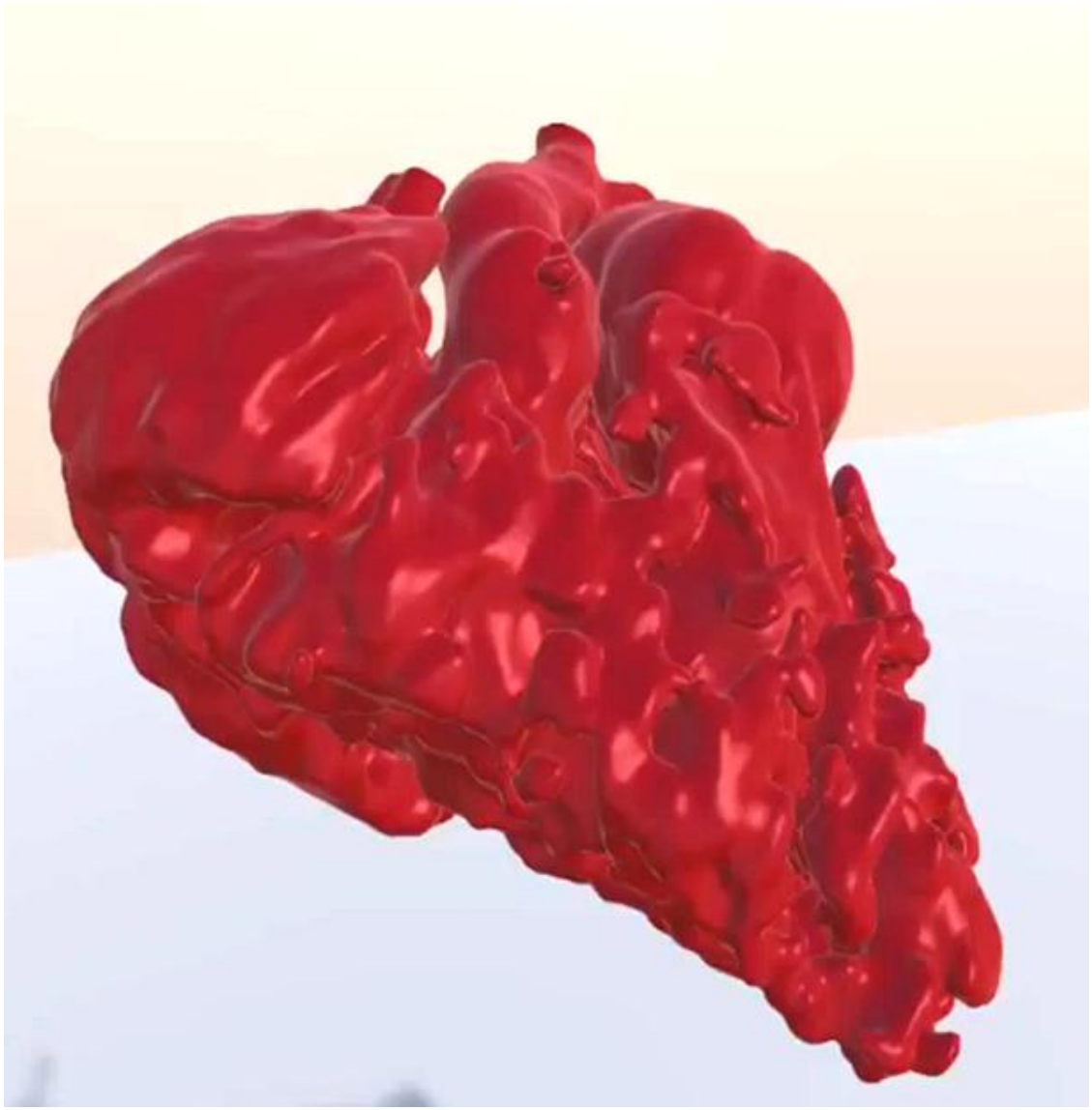






VR in clinical practise



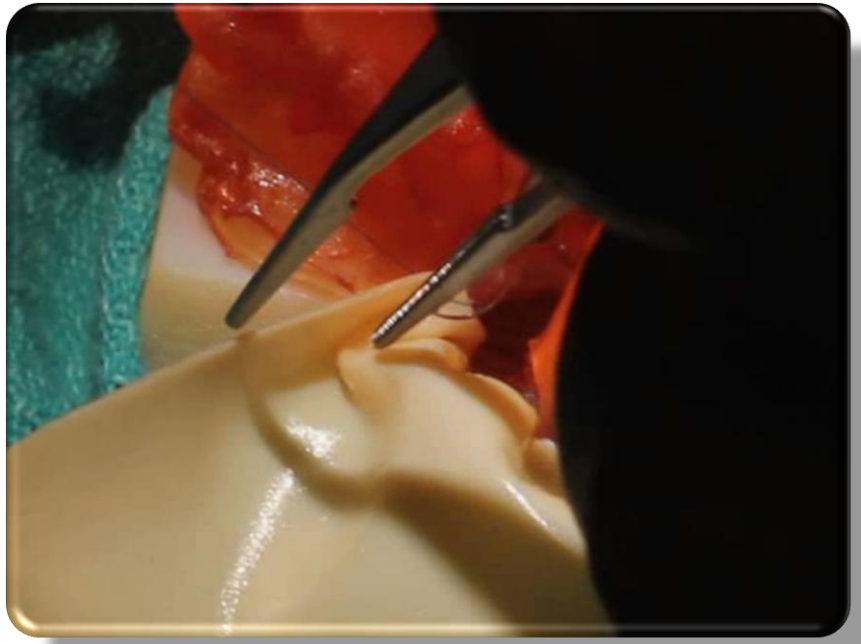


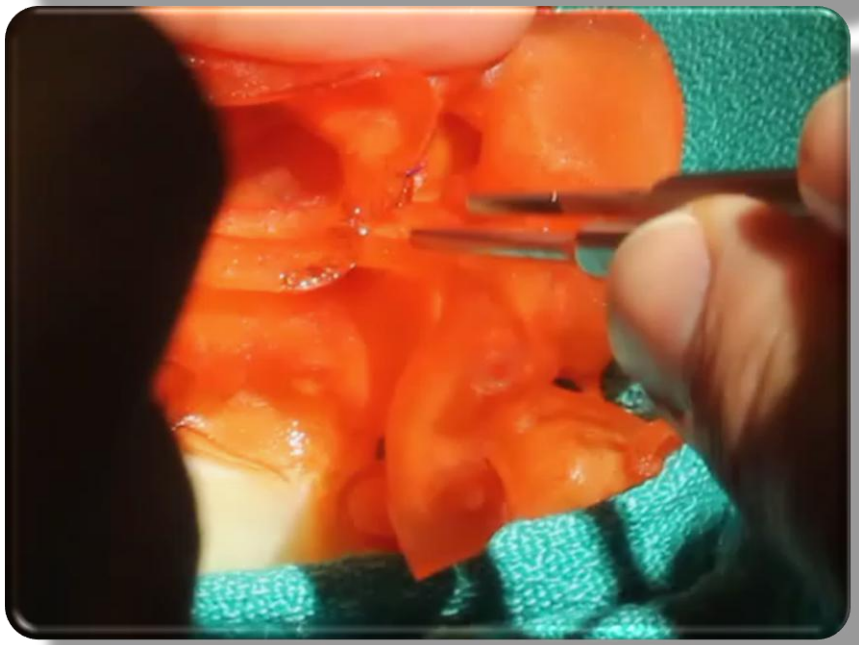
3D Printing: practising operation

- Preparing for complex operations
- Teaching young surgeons

…. but

- Surgeons have no spare time
- Costly





Curtesy Glen van Arsdell

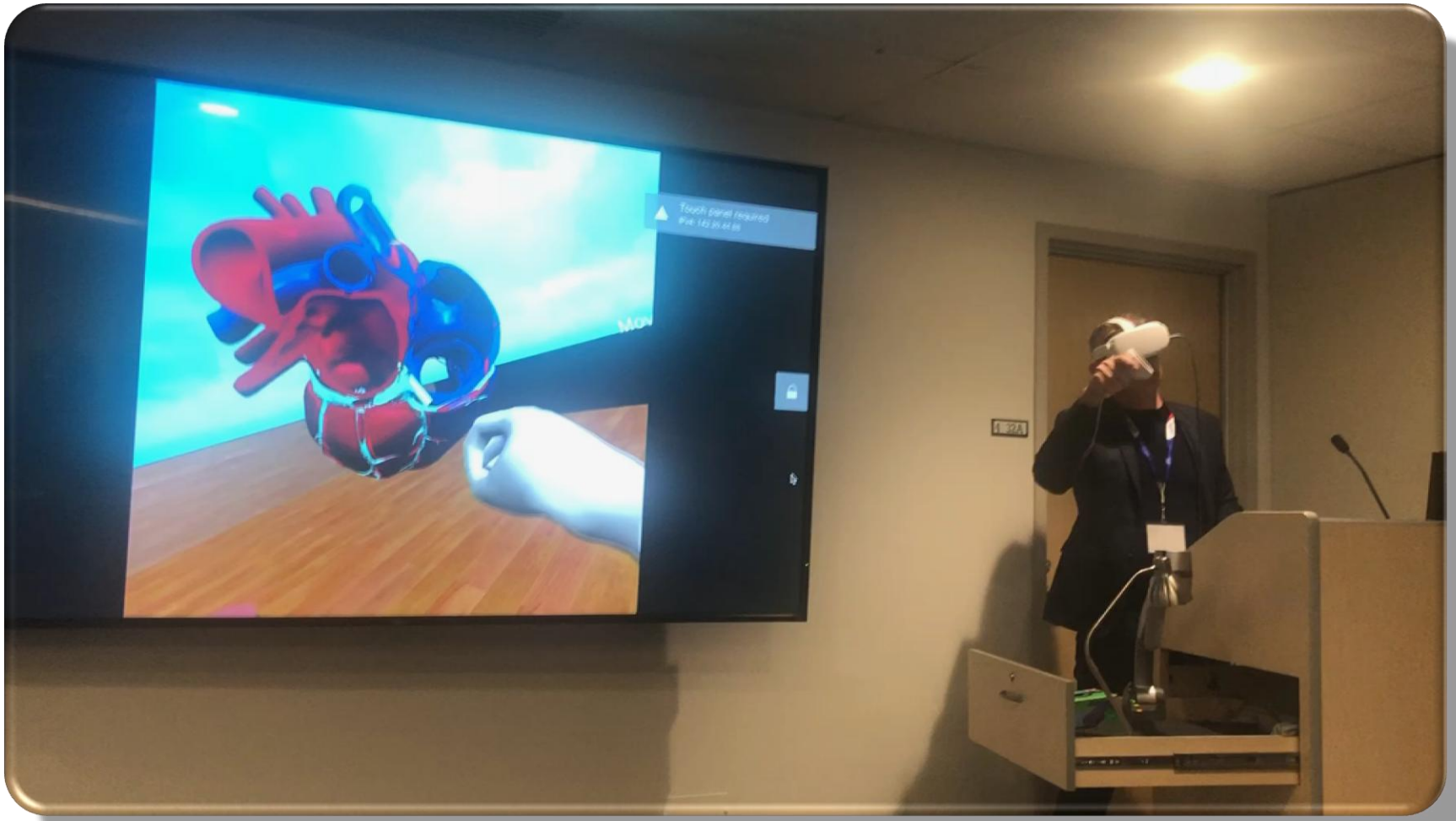
3D printed patient specific model: For patients & Students

- Anxious patients (Asymptomatic teenagers)
- Anxious parents

Cas. Tema 2019

Virtual Teaching & Education

Teaching through VR lectures



Virtual teaching & Education

Teaching through practical simulation using VR

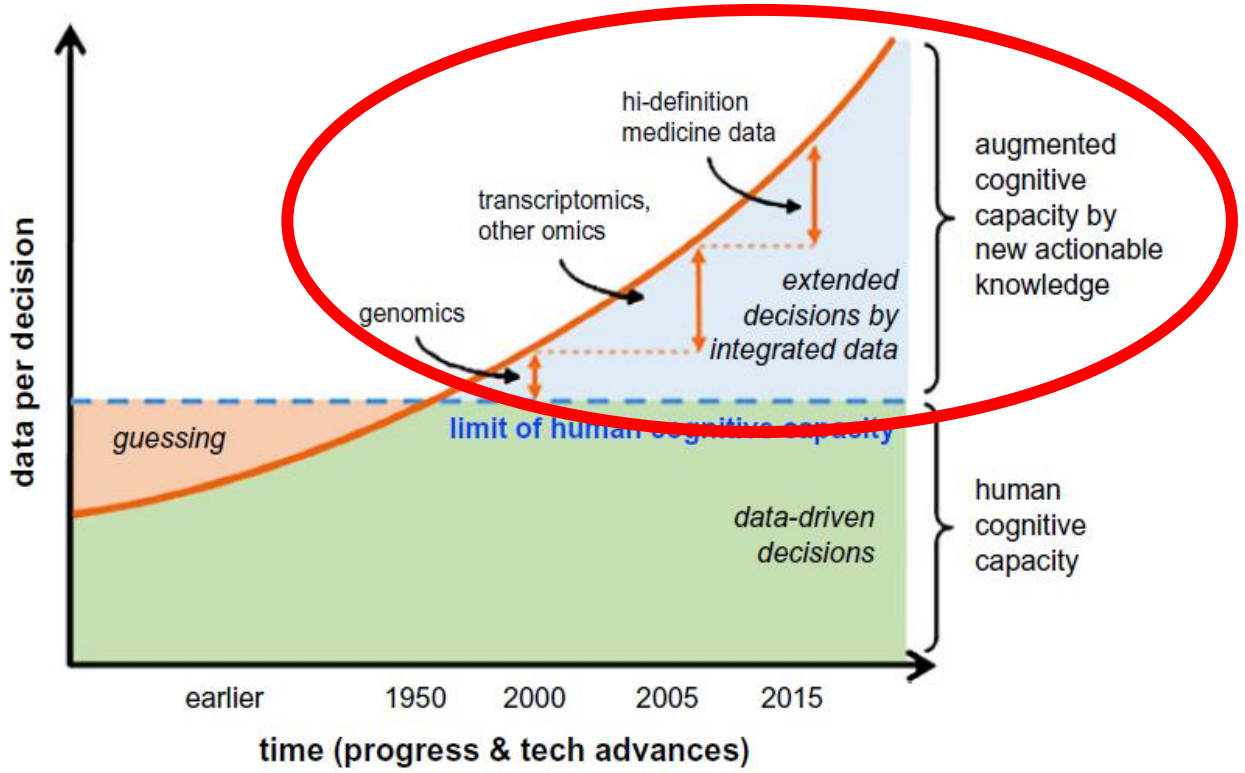
www.echocardiography-course.com

Deep Machine Learning & Artificial Intelligence

Artificial Intelligence: Why?

Patients **medical data** production
750 quadrillion bytes of data daily
(**30% of the world's data production**)

Accelerated rate of data production **supersedes 200-times limits of human cognitive capacity**



Escalating volumes of data offer **TRUE evidence based medicine** resulting in changing decision-making process

Gearhart A, Cardiol young 2020
Rossi RL. Front Digit Humanit 2020

Existing experience in cardiology

- ECG
- Chest X-Ray
- Echocardiography
- Cross-section imaging

Diagnosis
&
Proposed treatment
including surgical technique

AI algorithms can outperform cardiologists

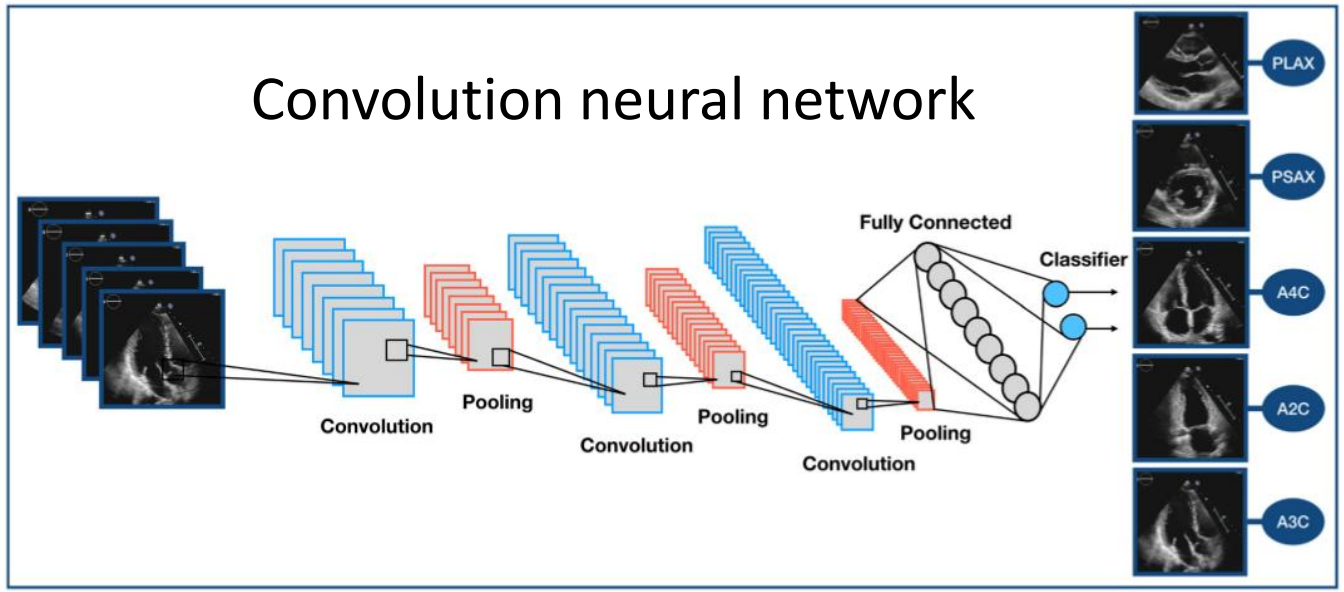
- **Patients with CHD could benefit** from data based medicine evidence
- **Randomised controlled trials difficult to conduct** and often fail to provide definitive solutions because of a *small number of subjects*, *complexity*, and *heterogeneity*

Eynde JV, Froniers in Cardiovac Med 2021

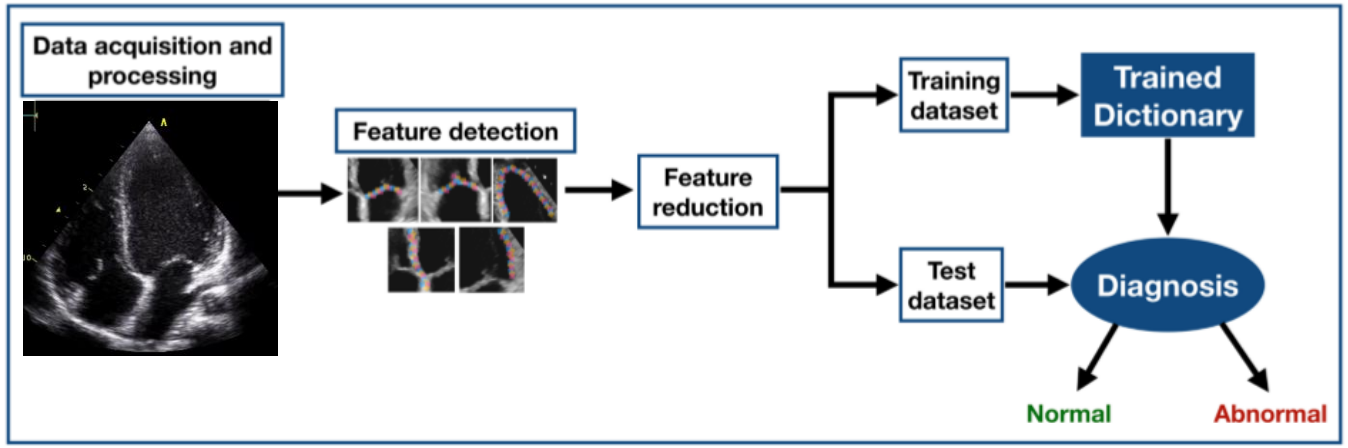
Gaffar S, Pediatr Clin North Am. 2020

Artificial Intelligence: How?

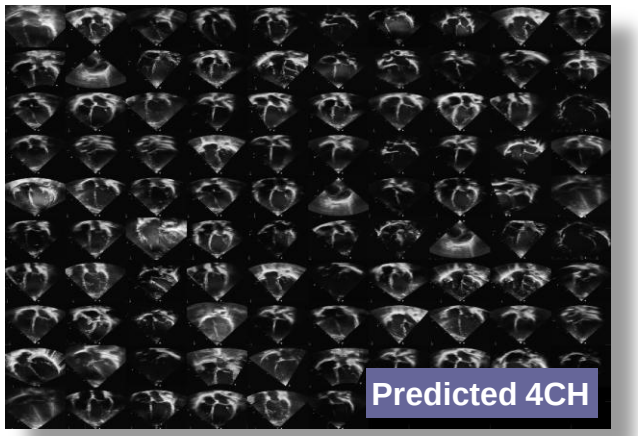
Supervised & Unsupervised Learning

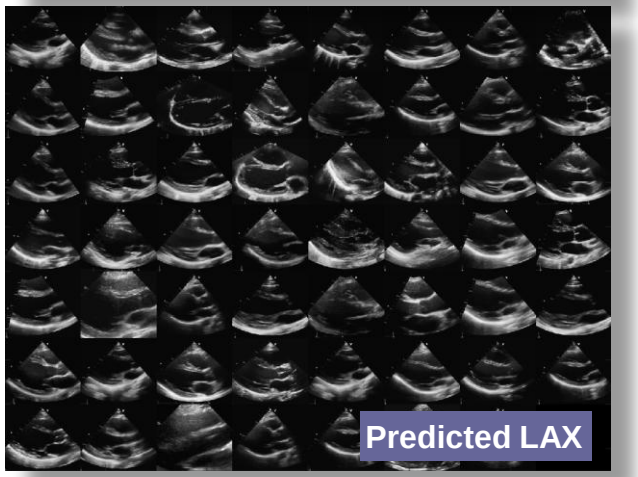


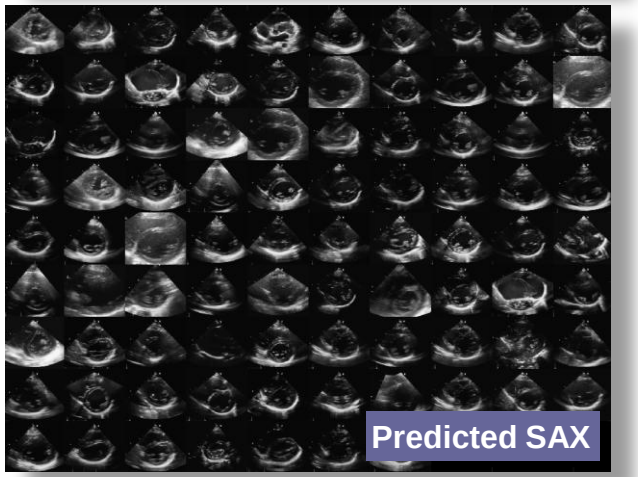
Deep Machine Learning



Alsharqi M, Echo Res and Practice, 2018

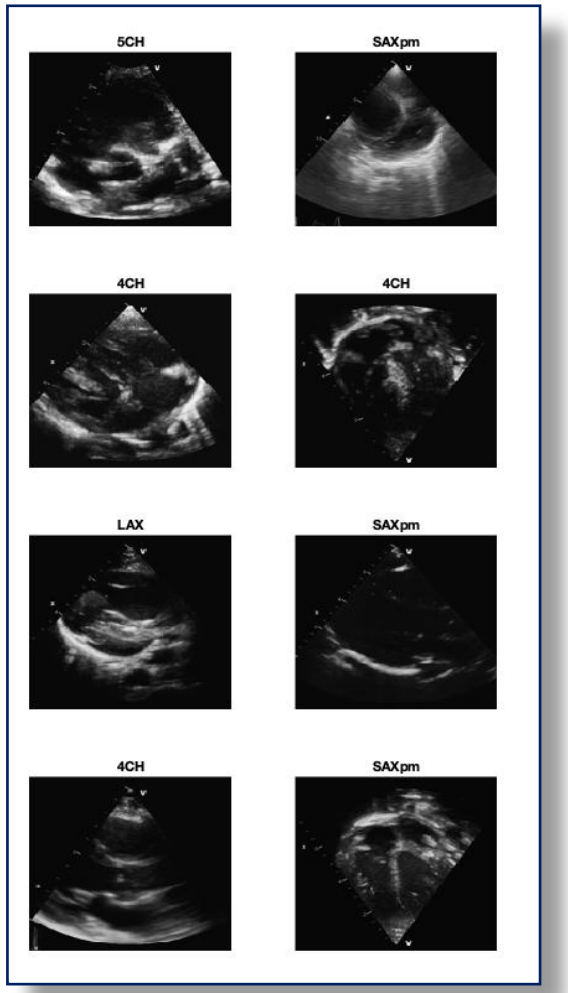






Deep Machine Learning

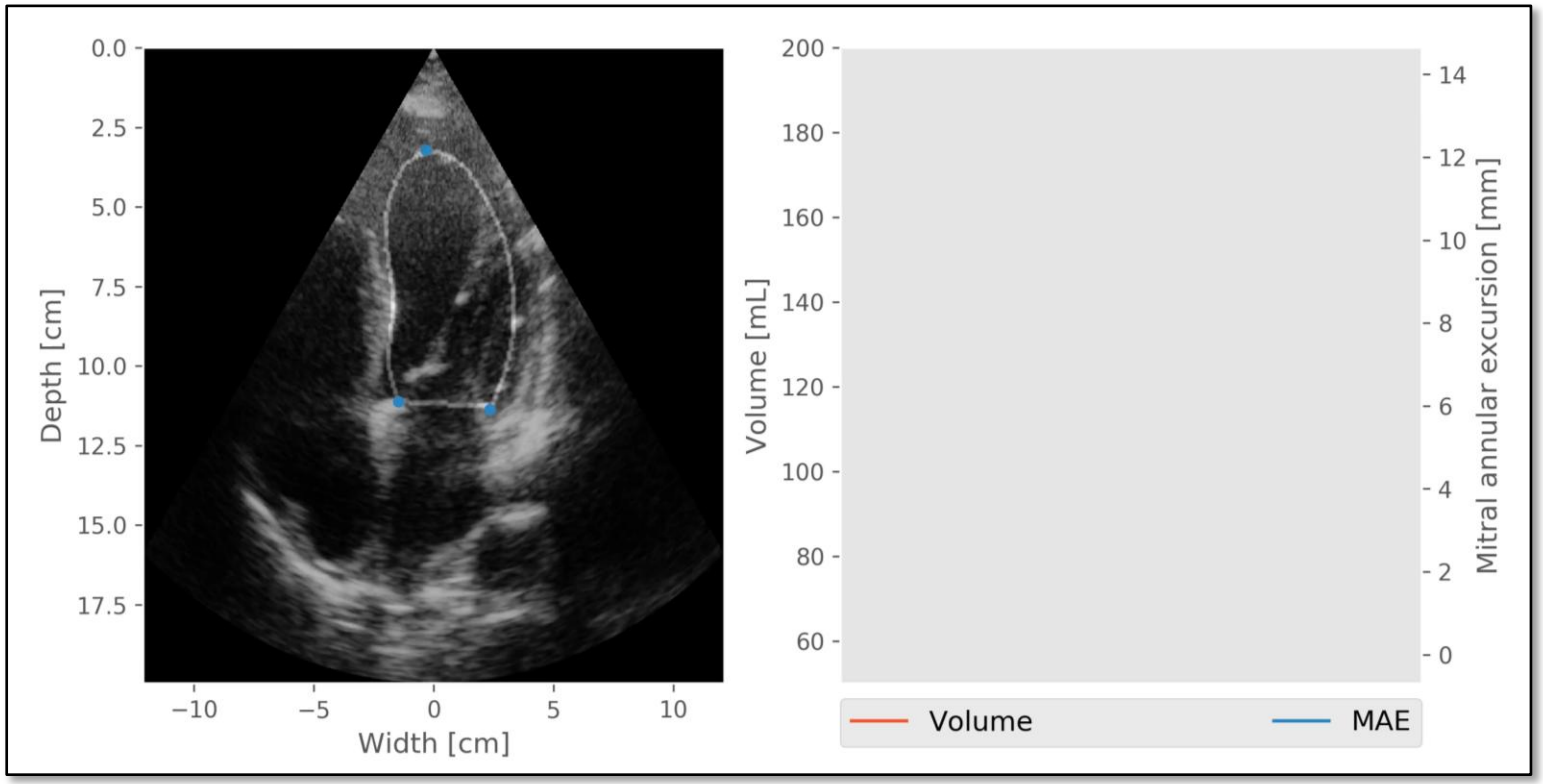
- Convolution neural network
- Trained on 700 images
- 95% accuracy on validation dataset
- Needs testing on larger datasets



Failure examples

Marek J, Muthurangu V GOSH 2021

Automated Real-time Measurement



Fully automated assessment of LV volumes and EF is feasible and gives **precise results within seconds** that are comparable to manual determination

Narula S, JACC 2016
Knacksted C, JACC 2015

Borderline Small Left Ventricle

(risk stratification Bi- vs Univentricular Circulation)

- **651 neonates** with critical left heart obstruction

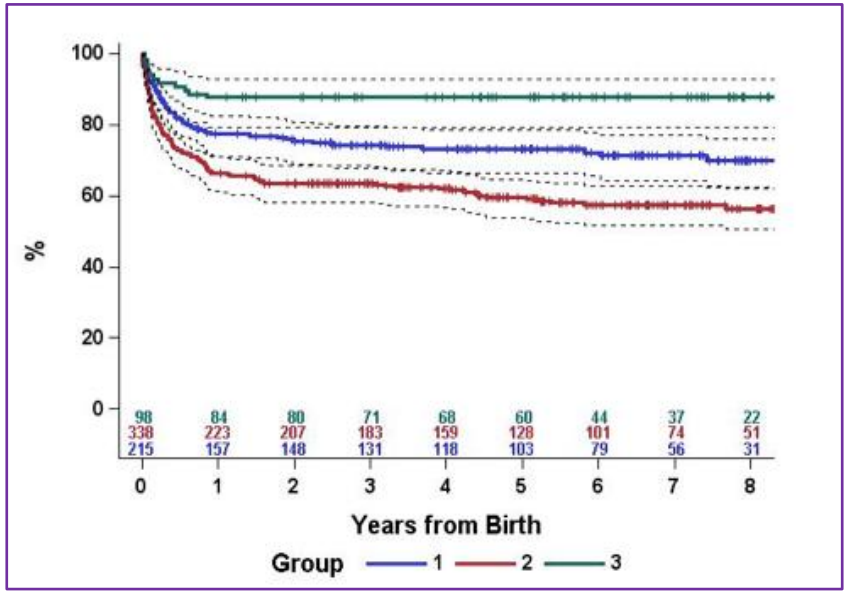
  Unsupervised **136 echocardiographic parameters**

  = 88,536 variables

- **Key measures differentiating groups** identified
- **Cluster analysis** = data-driven approach instead of pre-conceptualization and pre-grouping of data

Meza JM et al, Comput Methods Programs Biomed 2018

Data-driven models may improve prognostication



	Group I. (N=215)	Group II. (N=338)	Group III. (N=98)	
LVED area	1.35	0.69	2.47 cm^2	$p < 0.0001$
Aortic atresia	11%	87%	8%	$p < 0.0001$
Balloon VP	9%	2%	61%	$p < 0.0001$
Single ventricle	90%	98%	58%	$p < 0.0001$
Mortality	27%	41%	12%	$p < 0.0001$

- Allows **unbiased approach to large datasets**
- Can provide **better predictions of outcomes for individual patients**
- Will need **further prospective validation**

Challenges

Data storage

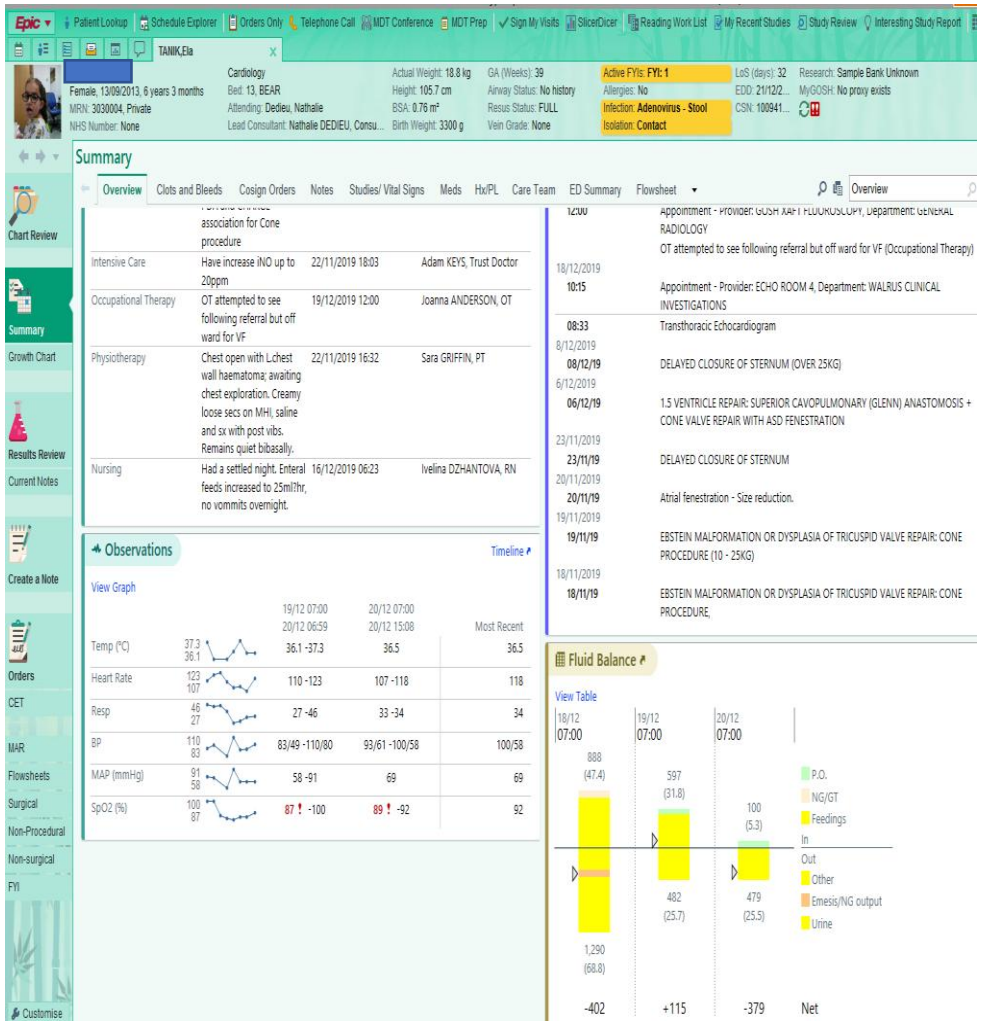
Data protection

Expert opinion

Energy !?

Digital Meedicine

- **Virtual clinics**
  - Routine for HF/HTx, PAH
  - Virtual nurse visits
- **Distant review & Consultation**
  - Imaging, ECG
- **Virtual clinical meetings**
  - Clinical (JCC, MDT, urgent review)
  - Education (simulation)
  - Patient/family access (limited)



Predictive modelling of EPR data has achieved 70–72% accuracy in predicting individualized treatment response at baseline

Centerstone research institute

Artificial Intelligence: WHY?

- Medical assistance devices
- More accuracy in diagnosis
- Better predictions in treatment plan
- More prevention of disease
- Decrease medical costs

Evidence in health care:

- Chatbots in the field of mental health
- Brain-computer Interfaces (BCI)
- Virtual nursing assistants
- Robot-assisted surgery
- Administrative workflow assistance

- Fraud detection
- Dosage error reduction
- Connected machines
- Clinical trial participant identifier
- Preliminary diagnosis
- Automated image diagnosis