



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)



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zoom

Join a Meeting

Microsoft Teams

Арр

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Covid lockdown

(2020, Western Bohemia)

	User name:	Marekj				
NHS	Password:					
Great Ormond Street Hospital for Children NHS Foundation Trust		⊘ MFA Required for logon.				



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© 🤇	FULL RESI	/2018) MRN: 11 JSCITATION A principal proble	lligator			
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Arterial Blood Pressure MAP	87 mmHg	85 mmHg	83 mmHg			
Arterial Line BP	106/70	110/66	100/67			
MAP (mmHg)	-	_	_			
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	Summary I		esults			

3D Modelling &

Virtual Reality

Patient-specific heart models

From medical images to 3D Models



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)





DORV

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 Ntsinjana⁵, Mario Carminati³, Graham Derrick², Jan Marek^{1,2}, Sachin Khambadkone², Andrew M. Taylor^{1,2} and Silvia Schievano^{1,2}



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



Deep Machine Learning

Artificial Intelligence

8

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

Al 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



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.	Group II.	Group III.	
	(N=215)	(N=338)	(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



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)

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D		and Bleeds Cosign	-	Studies/ Vital Sig	ins Meds Hx/PL	Care Team	ED Summary		• ment - Provider: GUSH		Overview JPY, Department: GEN	IEKAL
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a.	Intensive Care	Have increase iN 20ppm	O up to 22/11/20	019 18:03	Adam KEYS, Trust Do	10	/12/2019 10:15		mpted to see following Iment - Provider: ECHO			
	Occupational Therapy	OT attempted to following referral		019 12:00	Joanna ANDERSON, G	- II.	08:33	INVESTI	GATIONS pracic Echocardiogram			
contrary	Physiotherapy	ward for VF Chest open with wall haematoma;	awaiting	019 16:32	Sara GRIFFIN, PT	8/	8/12/2019 8/12/2019 08/12/19 DELAYED CLOSURE OF STERNUM (OVER 25KG) 6/12/2019					
Ł		chest exploration. Creamy loose secs on MHI, saline and sx with post vibs.						1.5 VENTRICLE REPAIR: SUPERIOR CAVOPULMONARY (GLENN) ANASTOMOS CONE VALVE REPAIR WITH ASD FENESTRATION				SISOMC
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¥	- Observations	no vommits over	ngn.		Tin	neline A	/11/2019 19/11/19		I MALFORMATION OR DURE (10 - 25KG)	DYSPLASIA OF TRI	CUSPID VALVE REPAIF	E CONE
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445	Temp (°C)	37.3	36.1 -37.3	36.5	muserv	26.5	Fluid Bala	nce č				_
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)ET	Resp	46 27	27 -46	33 -34		34 18	w Table 1/12 7:00	19/12	20/12	1		
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M N												
Customise							-402	+115	-379	Net		

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