AI and Echocardiography
A Brave New World

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Canadian Society of Echocardiography

St. Michael's Inspired Care. Inspiring Science.

UNIVERSITY OF TORONTO

USquareSoft

Objectives

- To go over what is AI, deep learning & machine learning?

- Practical examples on how AI is used in echocardiography

- How is AI going to affect the way we practice cardiology and medicine

Declaration

Founder and Owner

Cardio Sq

&

USquareSoft

His love is real.

But he is not.

A STEVEN SPIELBERG FILM

ARTIFICIAL INTELLIGENCE

1996

Man Won

Deep Blue vs. Kasparov

Deep Blue

IBM chess computer

Garry Kasparov

World Chess Champion

1997

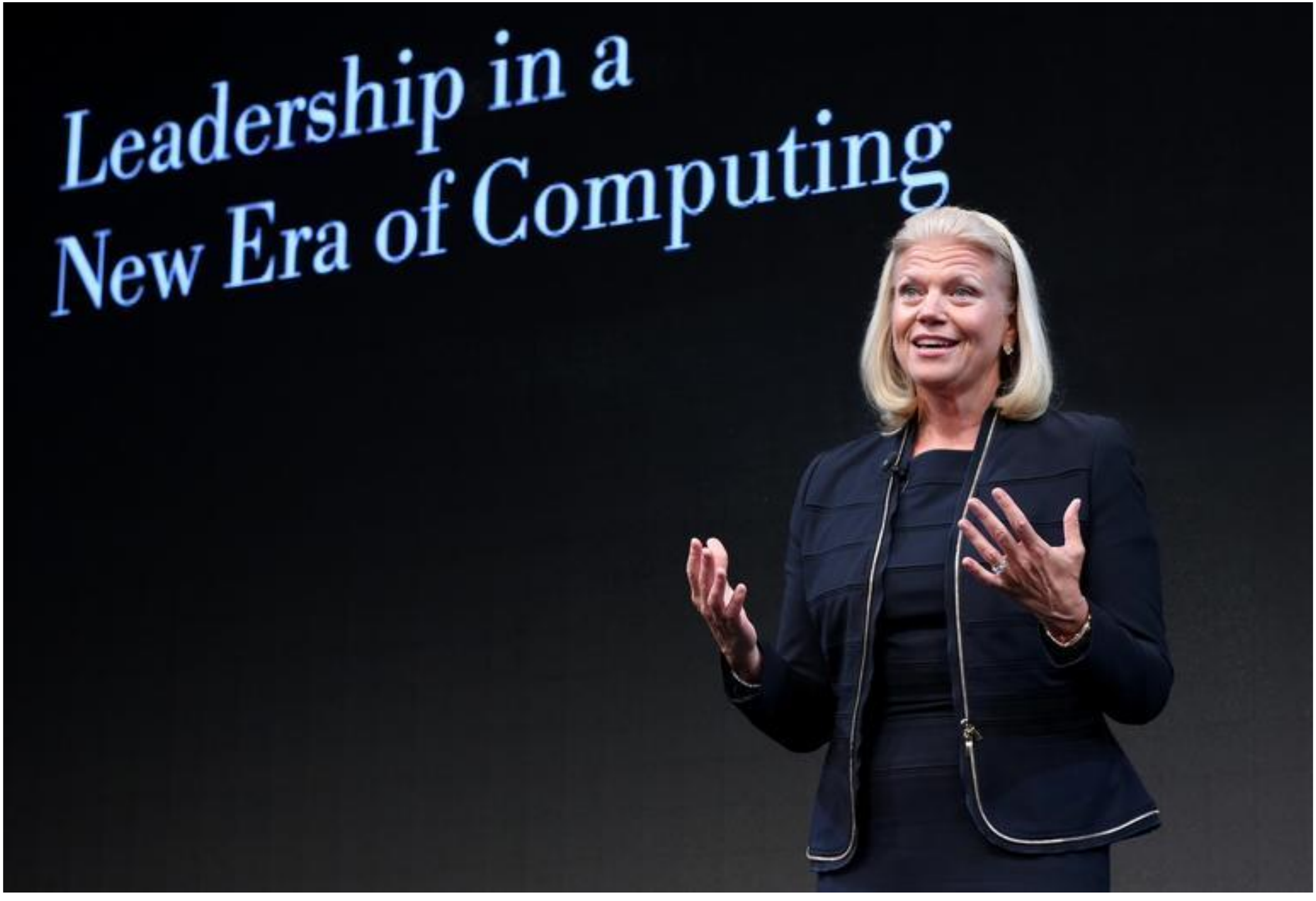
Machine Won

2011 Machine Won

World's best Go player flummoxed by Google's "godlike" Alpha Go AI

The Guardian May 23, 2017

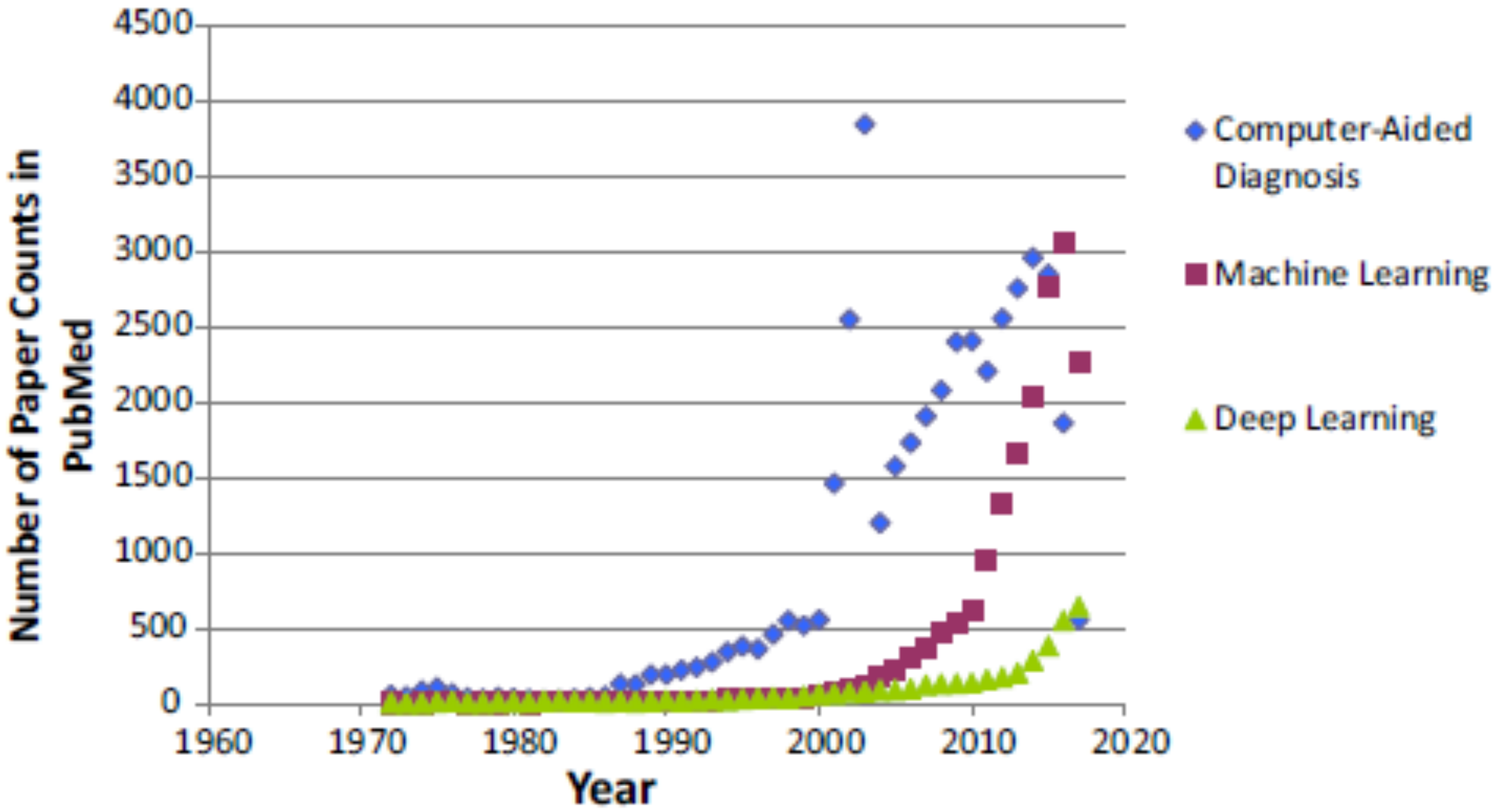
Ginni Rometty



November 10, 2016

How 3D Printing and IBM Watson Could Replace Doctors

PubMed Radiology Papers 1972-2017



Giger M. J Am Coll Radiol 2018;15:512-520

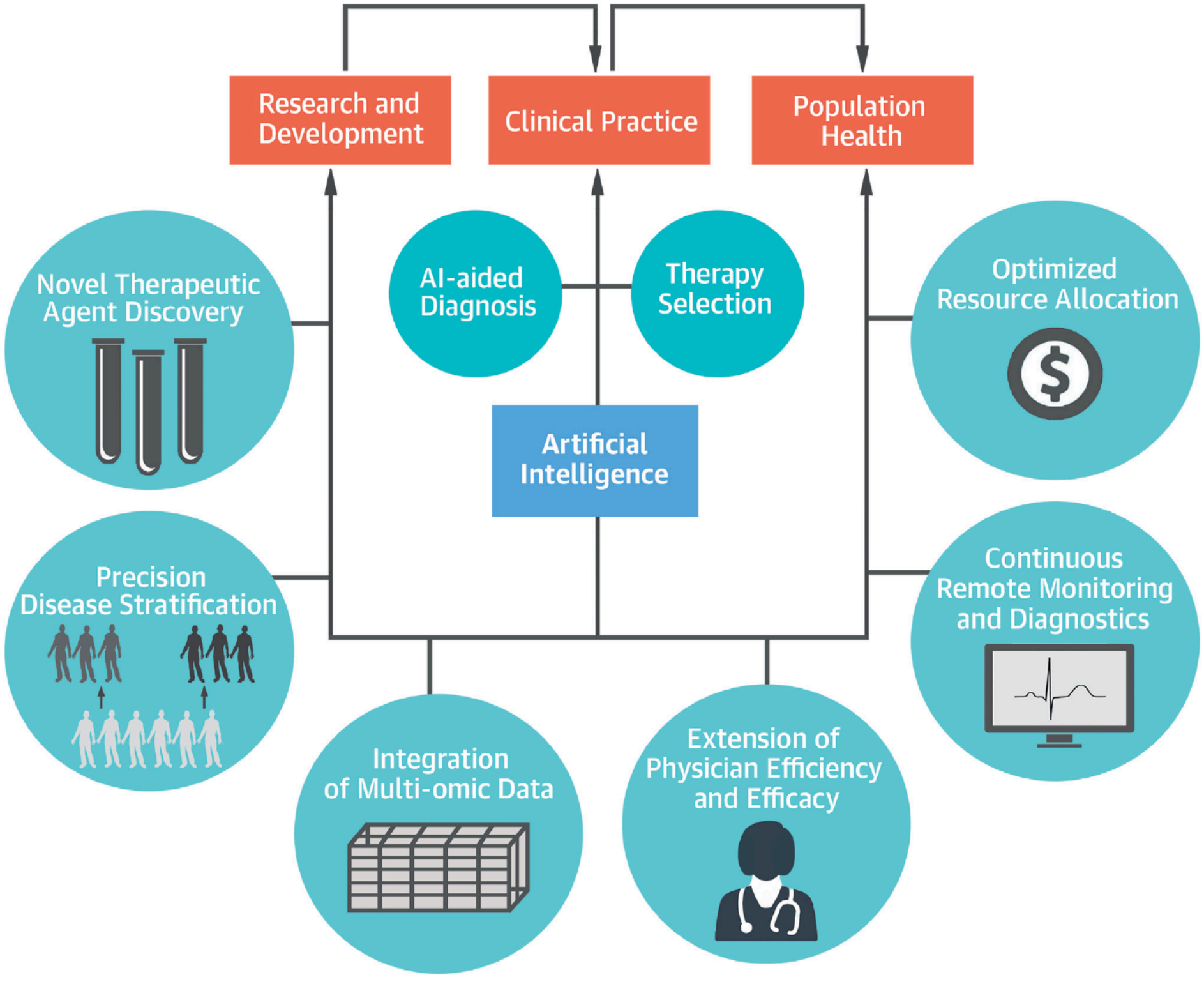
Why now?

Google AI

Amazon AI

NVIDIA®

CENTRAL ILLUSTRATION Role of Artificial Intelligence in Cardiovascular Medicine



Johnson, K.W. et al. J Am Coll Cardiol. 2018;71(23):2668-79.

The incorporation of artificial intelligence (AI) into cardiovascular medicine will affect all aspects of cardiology, from research and development to clinical practice to population health. This illustration demonstrates selected applications within all 3 domains of cardiovascular care.

REVIEW

WILEY Echocardiography

Automation, machine learning, and artificial intelligence in echocardiography: A brave new world

Sumeet Gandhi MD[1,2] | Wassim Mosleh MB BCh BAO[3] | Joshua Shen PhD[2] | Chi-Ming Chow MD[2]

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[2]St. Michael's Hospital, University of Toronto, Toronto, Ontario, Canada

[3]University of Buffalo, Buffalo, NY, USA

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Automation, machine learning, and artificial intelligence (AI) are changing the landscape of echocardiography providing complimentary tools to physicians to enhance patient care. Multiple vendor software programs have incorporated automation to improve accuracy and efficiency of manual tracings. Automation with longitudinal strain and 3D echocardiography has shown great accuracy and reproducibility allowing the incorporation of these techniques into daily workflow. This will give further experience to nonexpert readers and allow the integration of these essential tools into more echocardiography laboratories. The potential for machine learning in cardiovascular imaging is still being discovered as algorithms are being created, with training on large data sets beyond what traditional statistical reasoning can handle. Deep learning when applied to large image repositories will recognize complex relationships and patterns integrating all properties of the image, which will unlock further connections about the natural history and prognosis of cardiac disease states. The purpose of this review article was to describe the role and current use of automation, machine learning, and AI in echocardiography and discuss potential limitations and challenges of in the future.

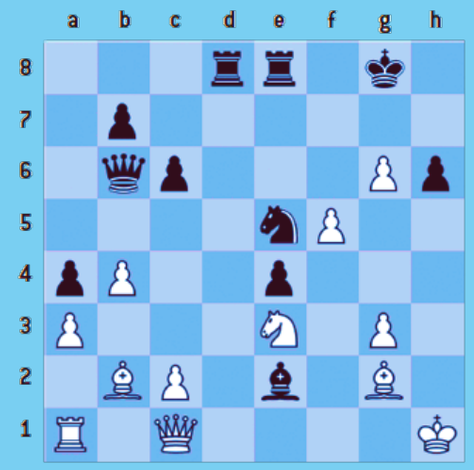
KEYWORDS
algorithm, artificial intelligence, automation, deep learning, echocardiography, machine learning

Echocardiography. 2018 Jul 5. doi: 10.1111/echo.14086. [Epub ahead of print]

Growth of Artificial Intelligence

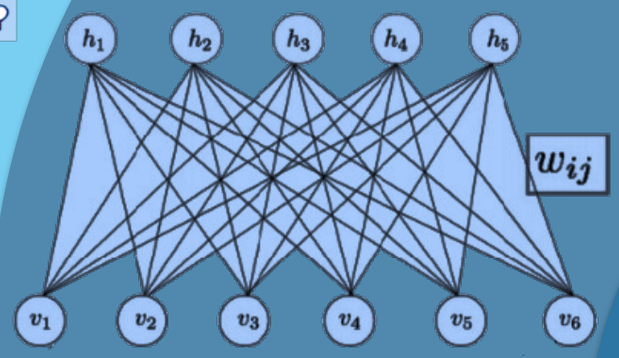
ARTIFICAL INTELLIGENCE

Intelligent agent that makes decisions to maximize chances of achieving its goal



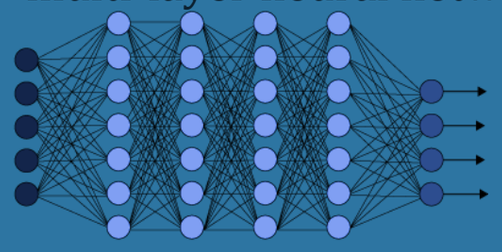
MACHINE LEARNING

Artificial Intelligence that uses statistical methods to improve with experiences



DEEP LEARNING

Machine Learning that uses multi-layer neural networks



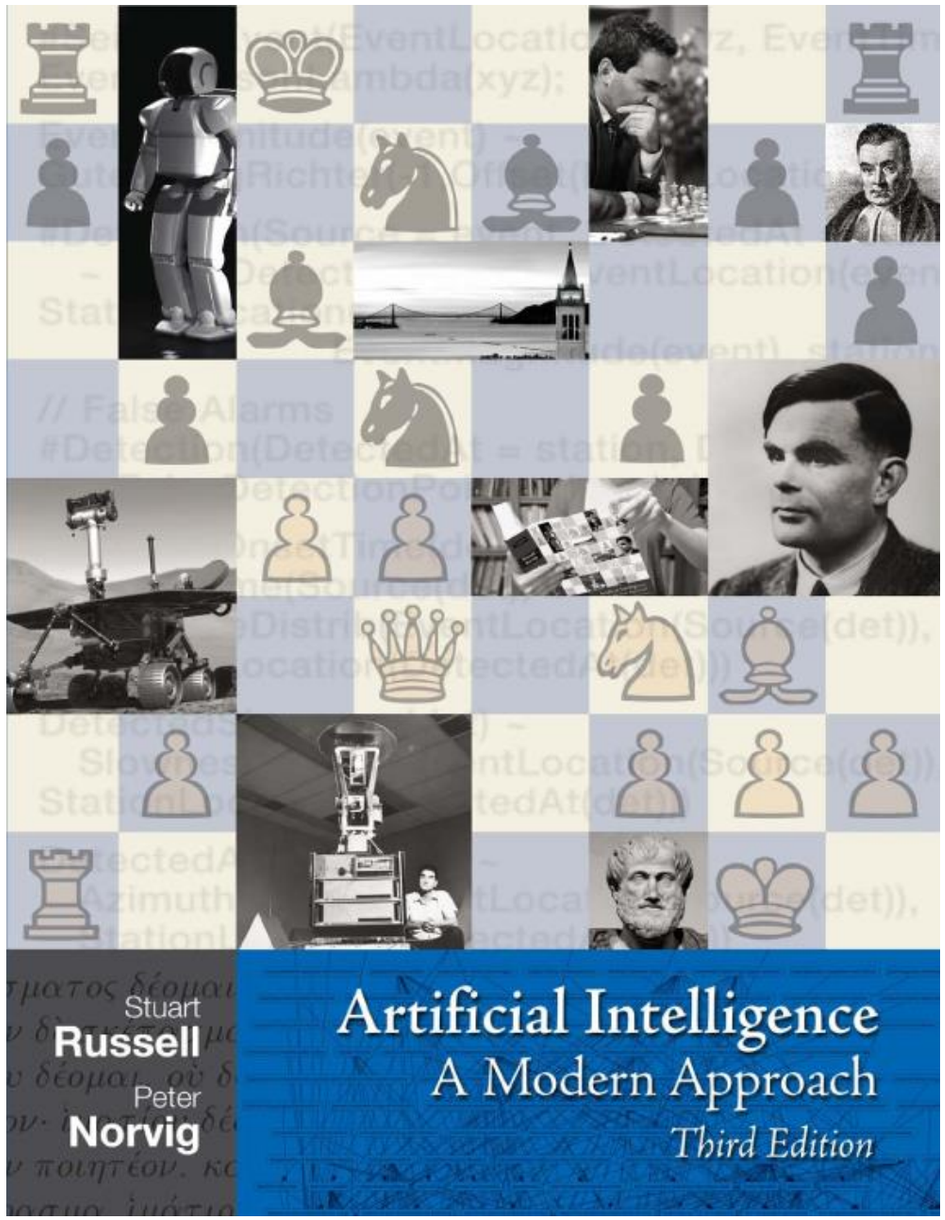
1950 1960 1970 1980 1990 2000 2010

Ghandi S, Chow CM, Echocardiography. 2018 Jul 5. doi: 10.1111/echo.14086. [Epub ahead of print]

What is AI?

What is AI?

Artificial Intelligence (AI) is the ability of a machine to perceive its environment and perform measured actions to maximize its chance of success for a specified goal.



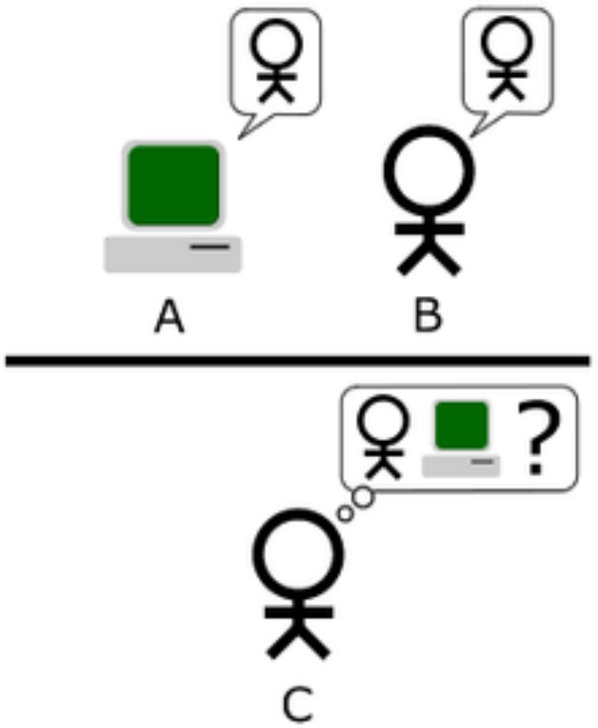
A. M. Turing (1950) Computing Machinery and Intelligence. *Mind 49:* 433-460.

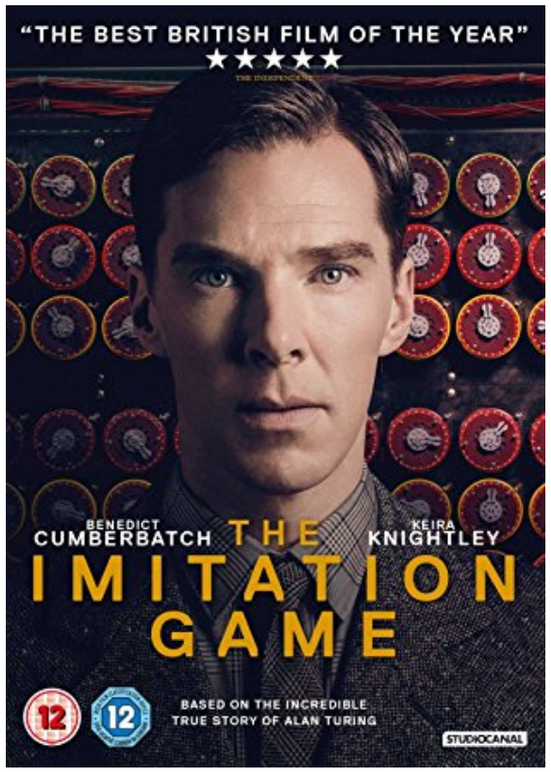
COMPUTING MACHINERY AND INTELLIGENCE

By A. M. Turing

1. The Imitation Game

I propose to consider the question, "Can machines think?" This should begin with definitions of the meaning of the terms "machine" and "think." The definitions might be framed so as to reflect so far as possible the normal use of the words, but this attitude is dangerous, If the meaning of the words "machine" and "think" are to be found by examining how they are commonly used it is difficult to escape the conclusion that the meaning and the answer to the question, "Can machines think?" is to be sought in a statistical survey such as a Gallup poll. But this is absurd. Instead of attempting such a definition I shall replace the question by another, which is closely related to it and is expressed in relatively unambiguous words.





What is Machine Learning?

What is Machine Learning?

- *Machine Learning (ML)* is a component of AI described as the process for a computer to learn from experiences and perform predefined tasks without prior knowledge.

- Supervised, semi-supervised, unsupervised

- Most typical is a neural network

Murphy KP. *Machine Learning: A Probabilistic Perspective*. Cambridge, MA: The MIT Press; 2012.

What is Machine Learning?

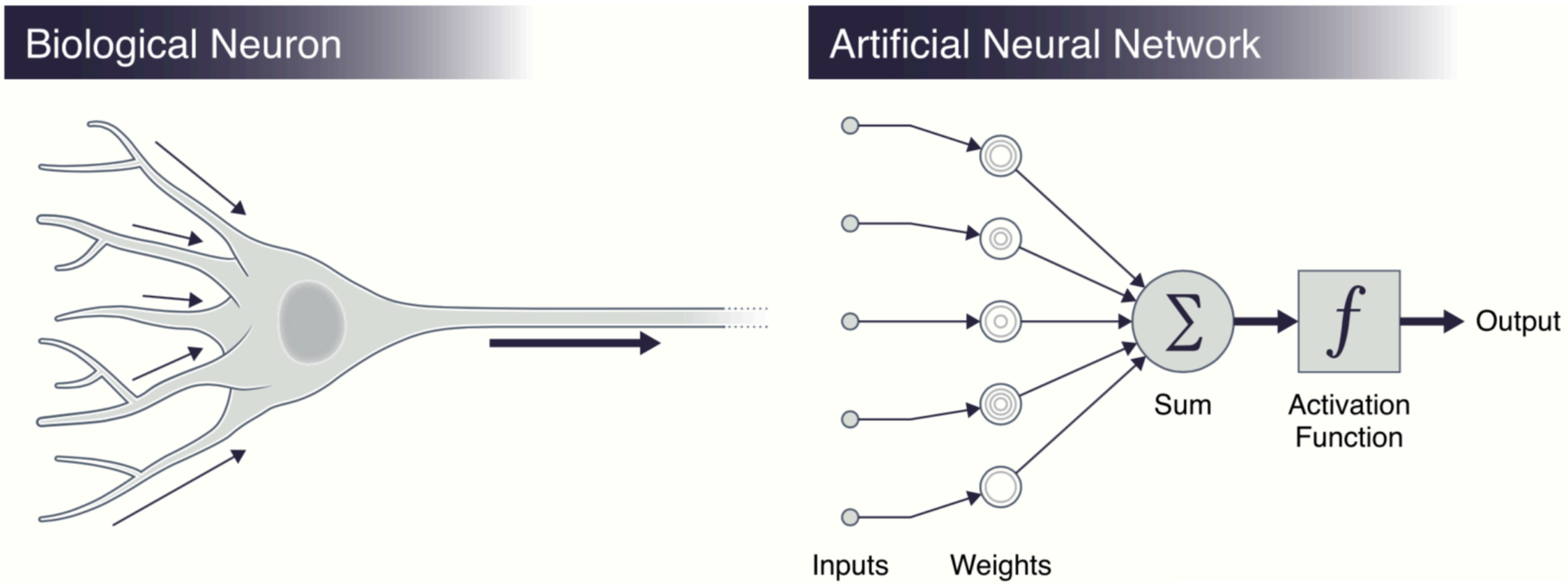
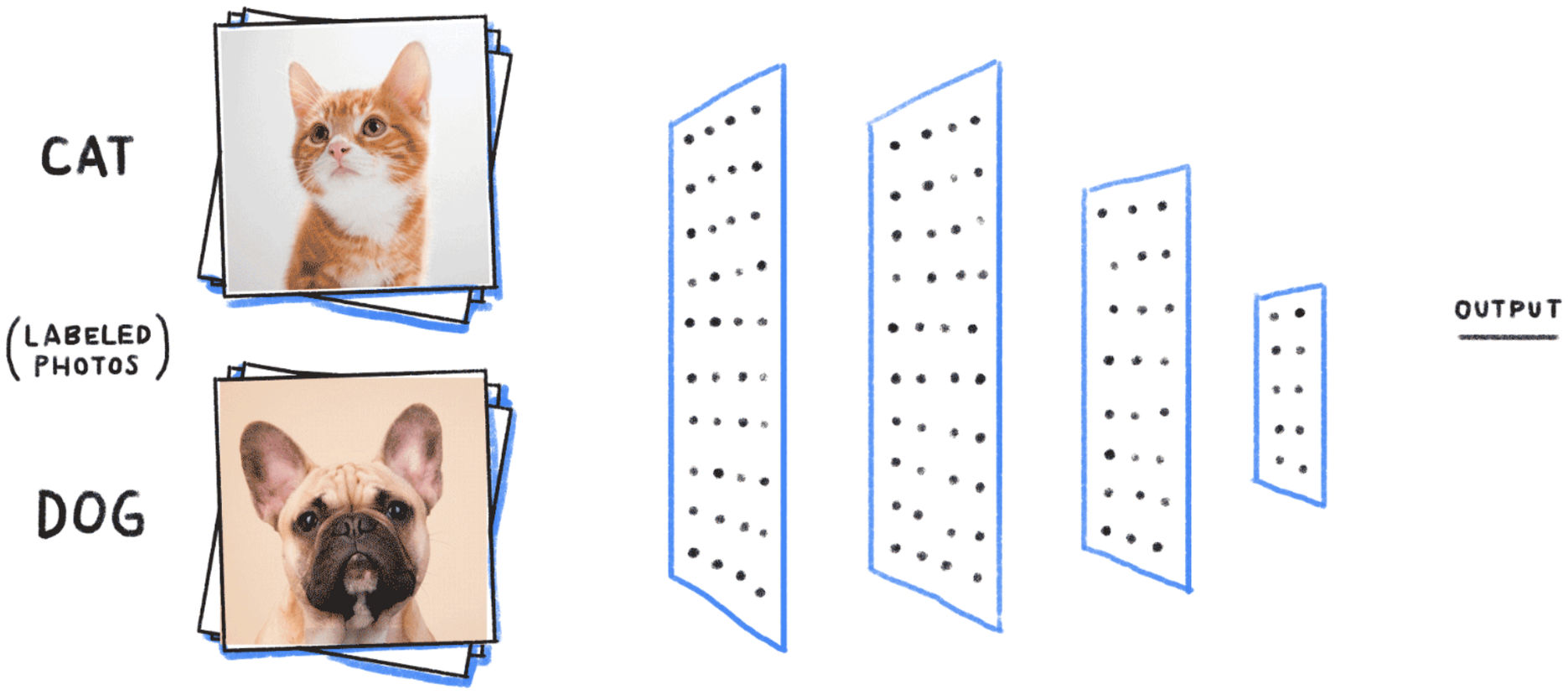


FIGURE 1 Analogy between human neuron and artificial neural network. Illustrated by Kate Campbell

Ghandi S, Chow CM, Echocardiography. 2018 Jul 5. doi: 10.1111/echo.14086. [Epub ahead of print]

What is Machine Learning?



Supervised

What is Deep Learning?

REVIEW

doi:10.1038/nature14539

Deep learning

Yann LeCun[1,2], Yoshua Bengio[3] & Geoffrey Hinton[4,5]

Deep learning allows computational models that are composed of multiple processing layers to learn representations of data with multiple levels of abstraction. These methods have dramatically improved the state-of-the-art in speech recognition, visual object recognition, object detection and many other domains such as drug discovery and genomics. Deep learning discovers intricate structure in large data sets by using the backpropagation algorithm to indicate how a machine should change its internal parameters that are used to compute the representation in each layer from the representation in the previous layer. Deep convolutional nets have brought about breakthroughs in processing images, video, speech and audio, whereas recurrent nets have shone light on sequential data such as text and speech.

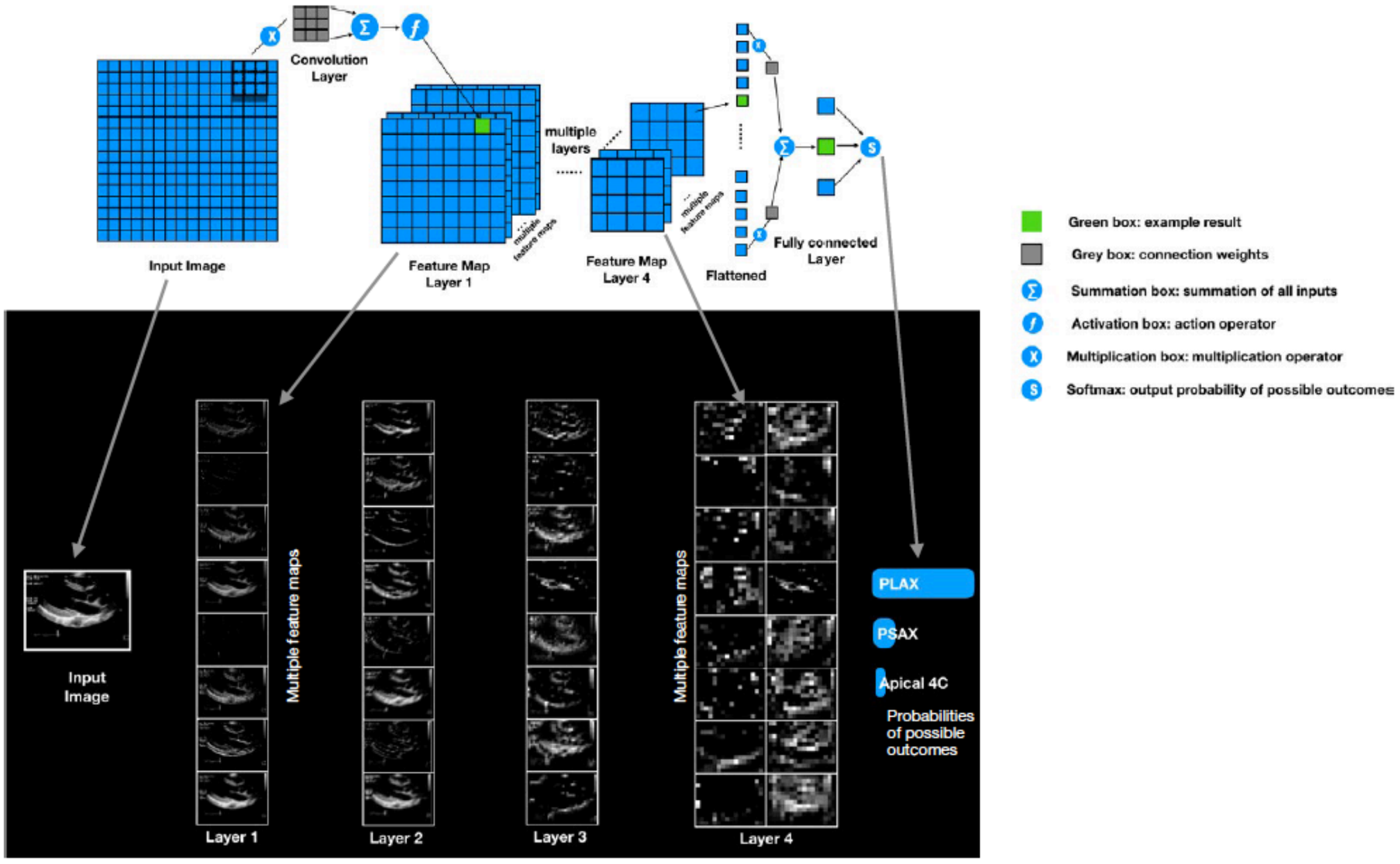
Nature. volume 521, 436–444 (28 May 2015)

What is Deep Learning?

• *Deep learning (DL)* was proposed to address the limitation by automatically learning representations of the samples. To extract optimal features, deep learning uses a cascade of multiple layers of neurons to learn multiple levels of abstraction. With a tailored neuron network structure, deep learning has reached and even exceeded human-level performance in activities such as speech recognition, image recognition, and predicting activity of drug molecules.

LeCun Y, Bengio Y, Hinton G. Deep learning. *Nature*. 2015;521:436–444.

What is Deep Learning?



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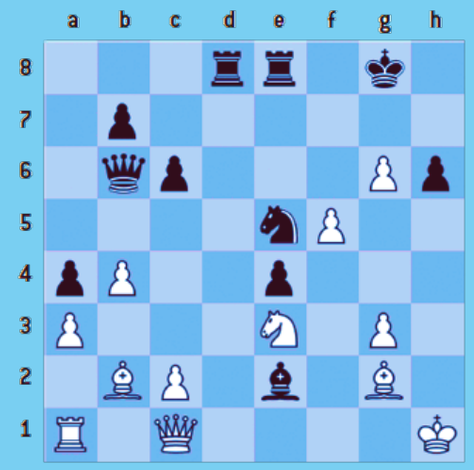

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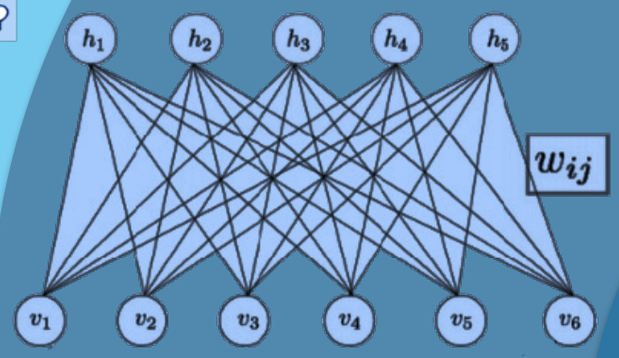

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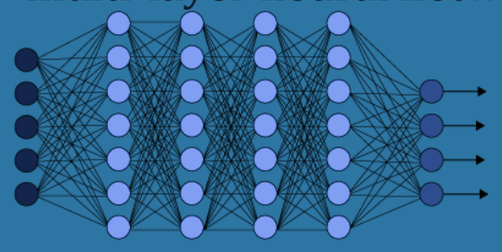

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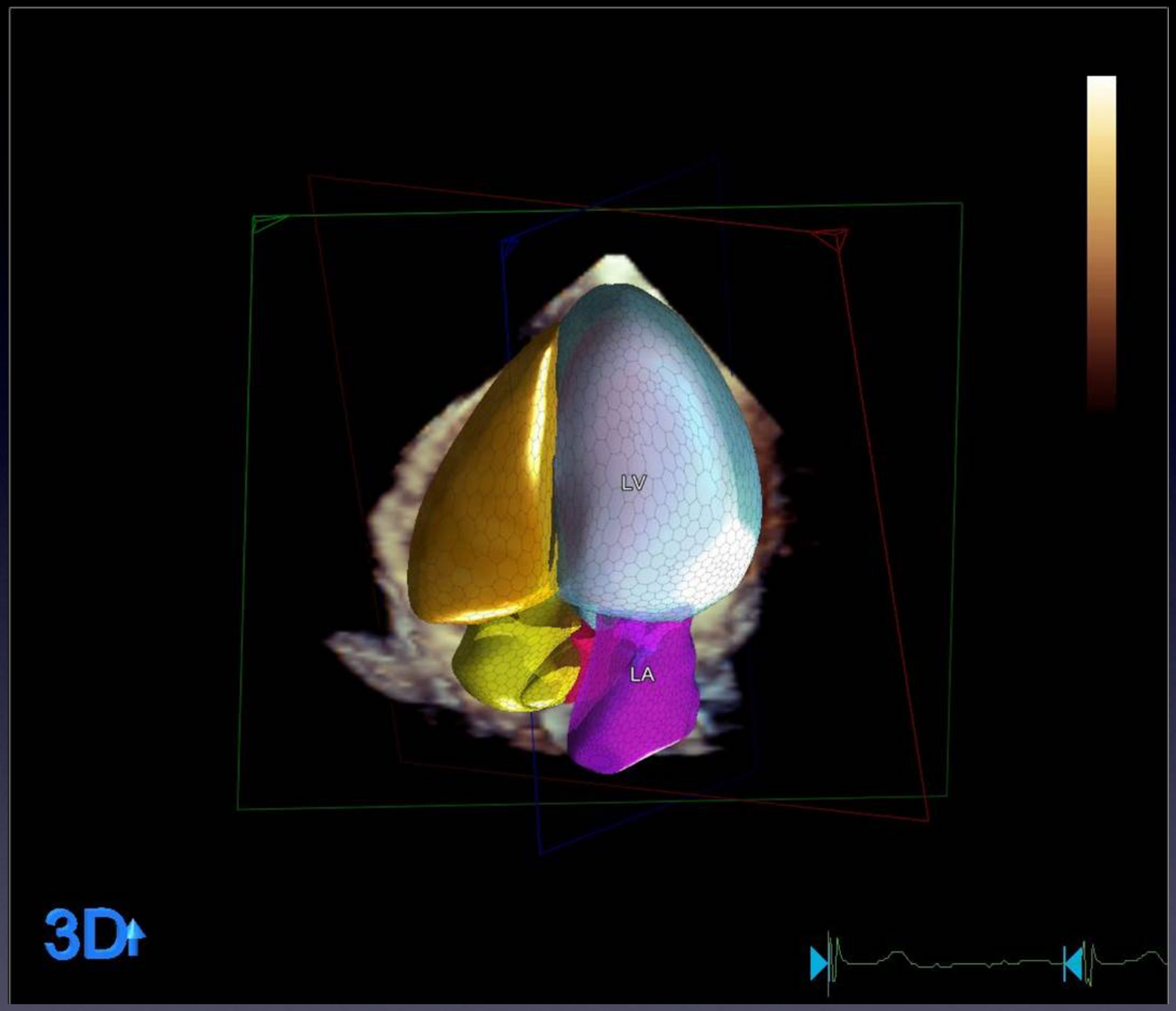
Echo: the essentials

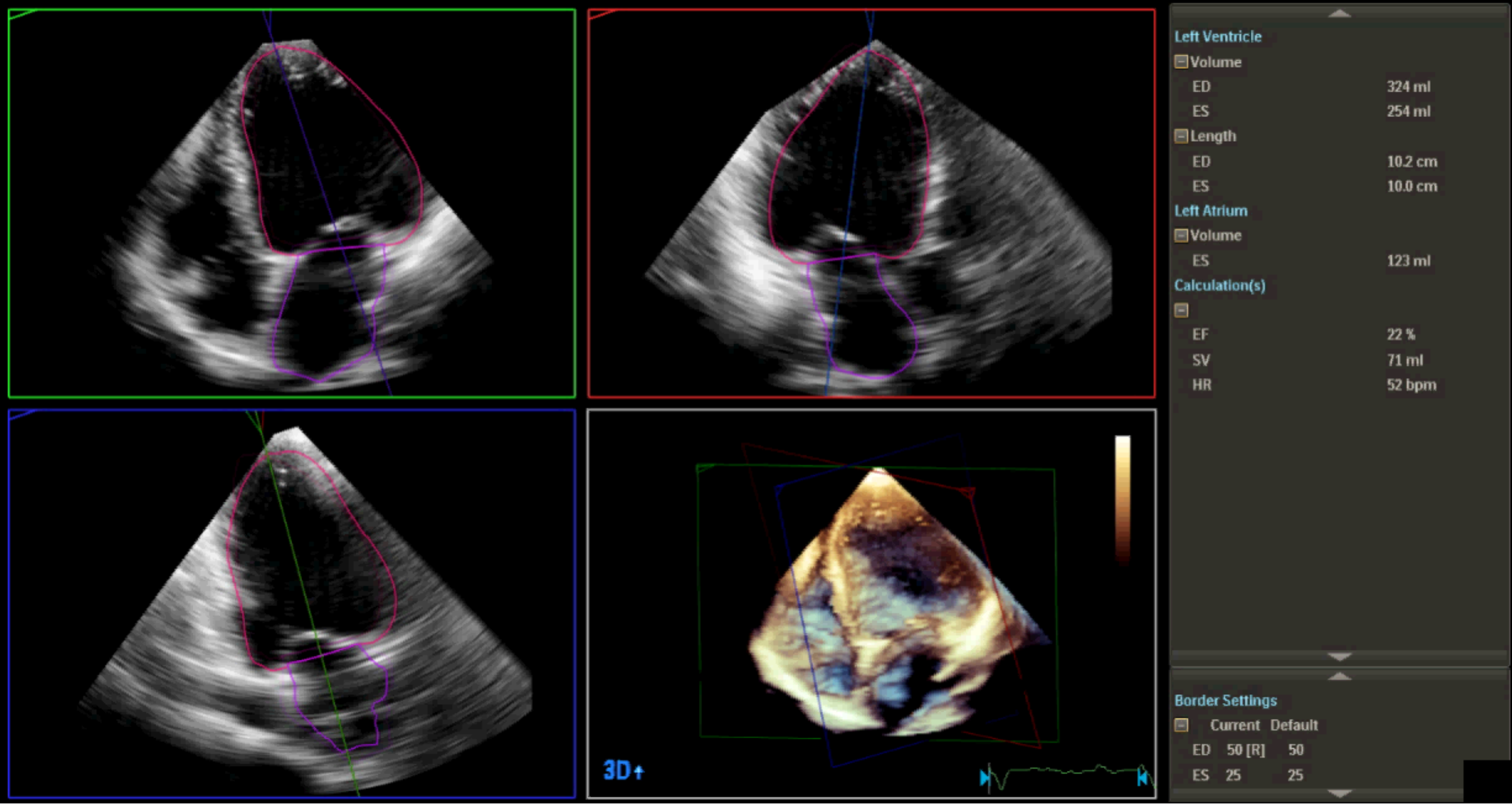
- Image acquisition (30-60 min)
- Image processing and measurements (10-20 min)
- Interpretation (10-20 min)
- Reporting (2-5 min)


THE MACHINES
ARE COMING



Philips Heart Model

Volumes and EF by HeartModel

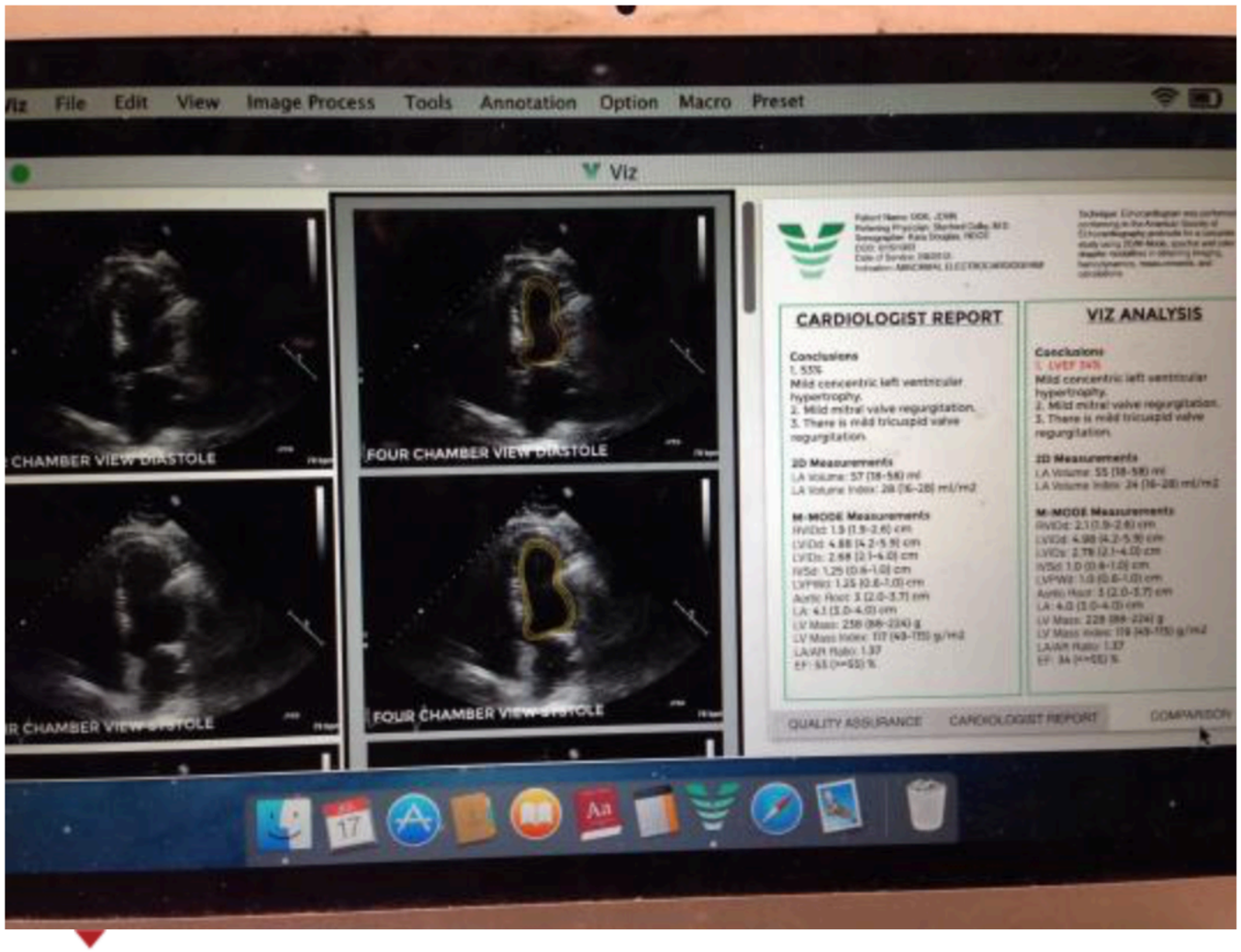


DAIC
Diagnostic and Interventional Cardiology

FEATURE | ARTIFICIAL INTELLIGENCE | MARCH 10, 2017| DAVE FORNELL

How Artificial Intelligence Will Change Medical Imaging

Machine learning software will serve as a very experienced clinical assistant, augmenting the doctor and making workflow more efficient



An example of artificial intelligence from the start-up company Viz. The image shows how the AI software automatically reviews an echocardiogram, completes an automated left ventricular ejection fraction quantification and then presents the data side by side with the original cardiology report. The goal of the software is to augment clinicians and cardiologists by helping them speed workflow, act as a second set of eyes and aid clinical decision support.

Bay Labs' EchoMD AutoEF Software Receives FDA Clearance for Fully Automated AI Echocardiogram Analysis

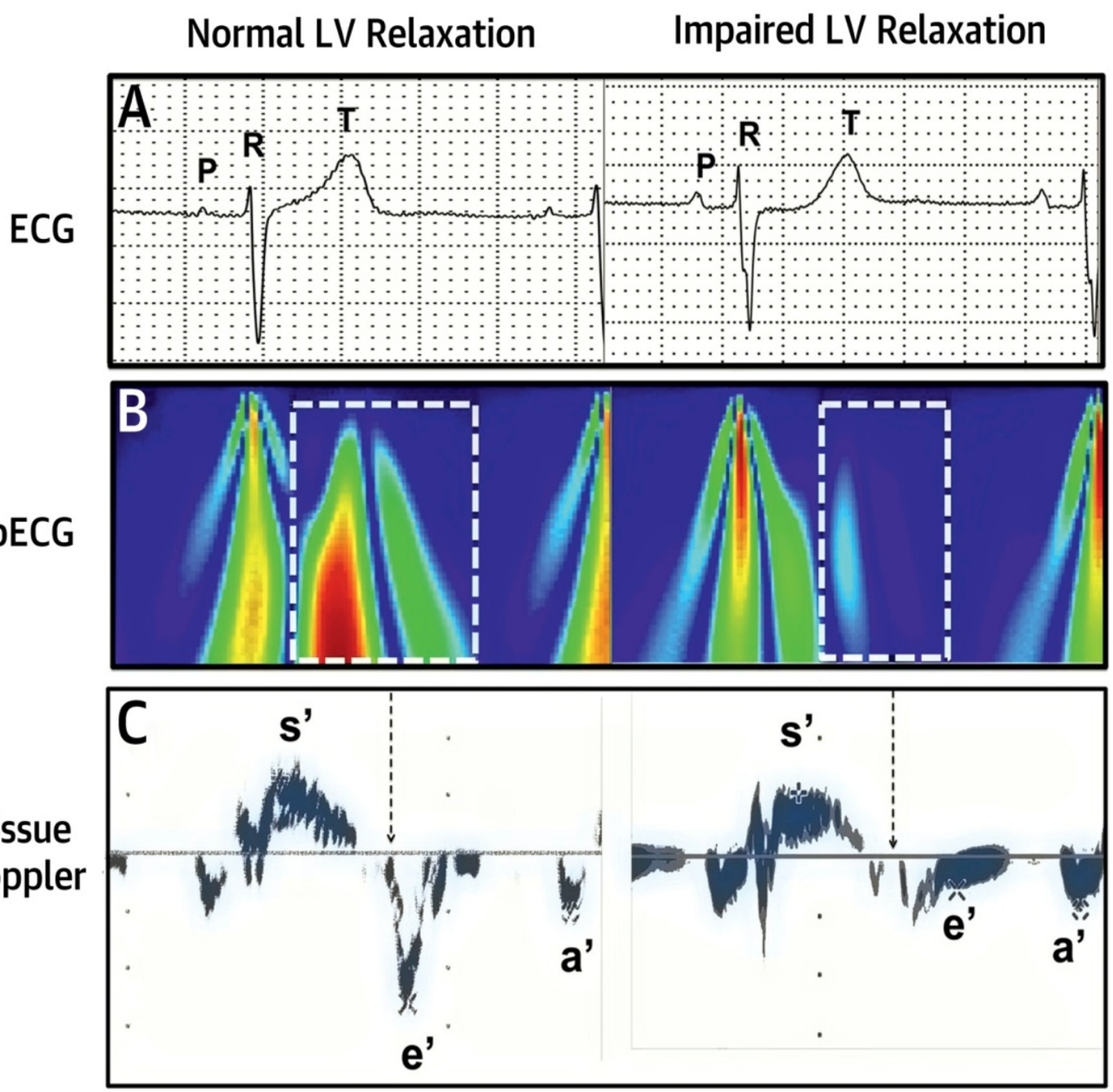
Innovative AI Algorithms Automate Both Clip Selection and Ejection Fraction Calculation

June 19, 2018 09:00 AM Eastern Daylight Time

SAN FRANCISCO--(BUSINESS WIRE)--Bay Labs, a medical technology company at the forefront of applying artificial intelligence (AI) to cardiovascular imaging, today announced its EchoMD AutoEF software product received 510(k) clearance from the U.S. Food and Drug Administration (FDA) for the fully automated clip selection and calculation of left ventricular ejection fraction (EF). EF is the single most widely used metric of cardiac function and used as the basis for many clinical decisions**.** The EchoMD AutoEF algorithms eliminate the need to manually select views, choose the best clips, and manipulate them for quantification, an often time-consuming and highly variable process.

BAYLABS

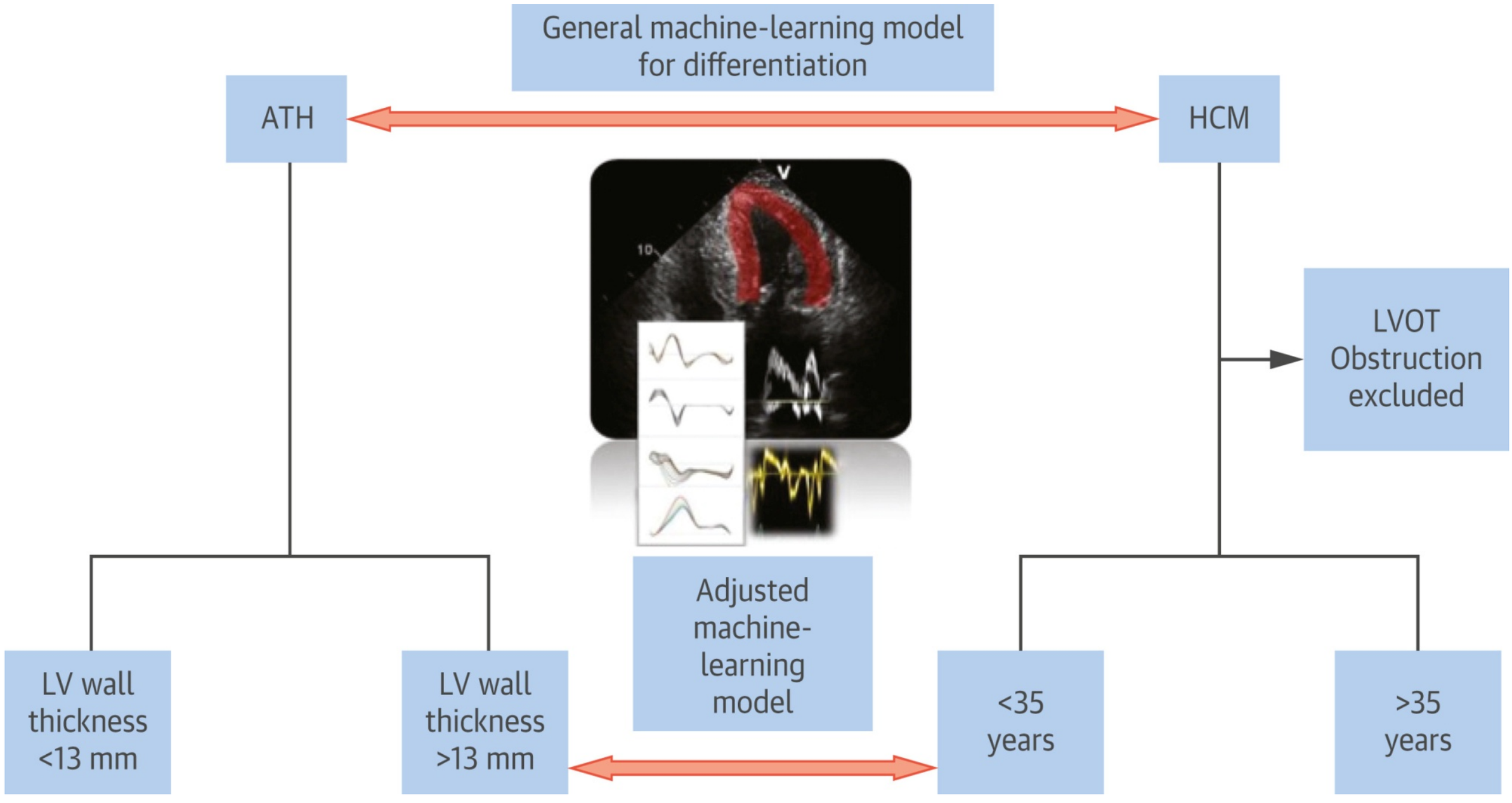
Continuous wavelet-based time-frequency analysis of ECG for predicting LV mechanical relaxation



- N=188, CTA, ECG and echo
- ML based on 370 features of signal processed ECG identified abnormal e' (sens 80% and spec 84%)
- Greater accuracy in those older, obese and hypertensive
- Identified 23 of 28 with CAD

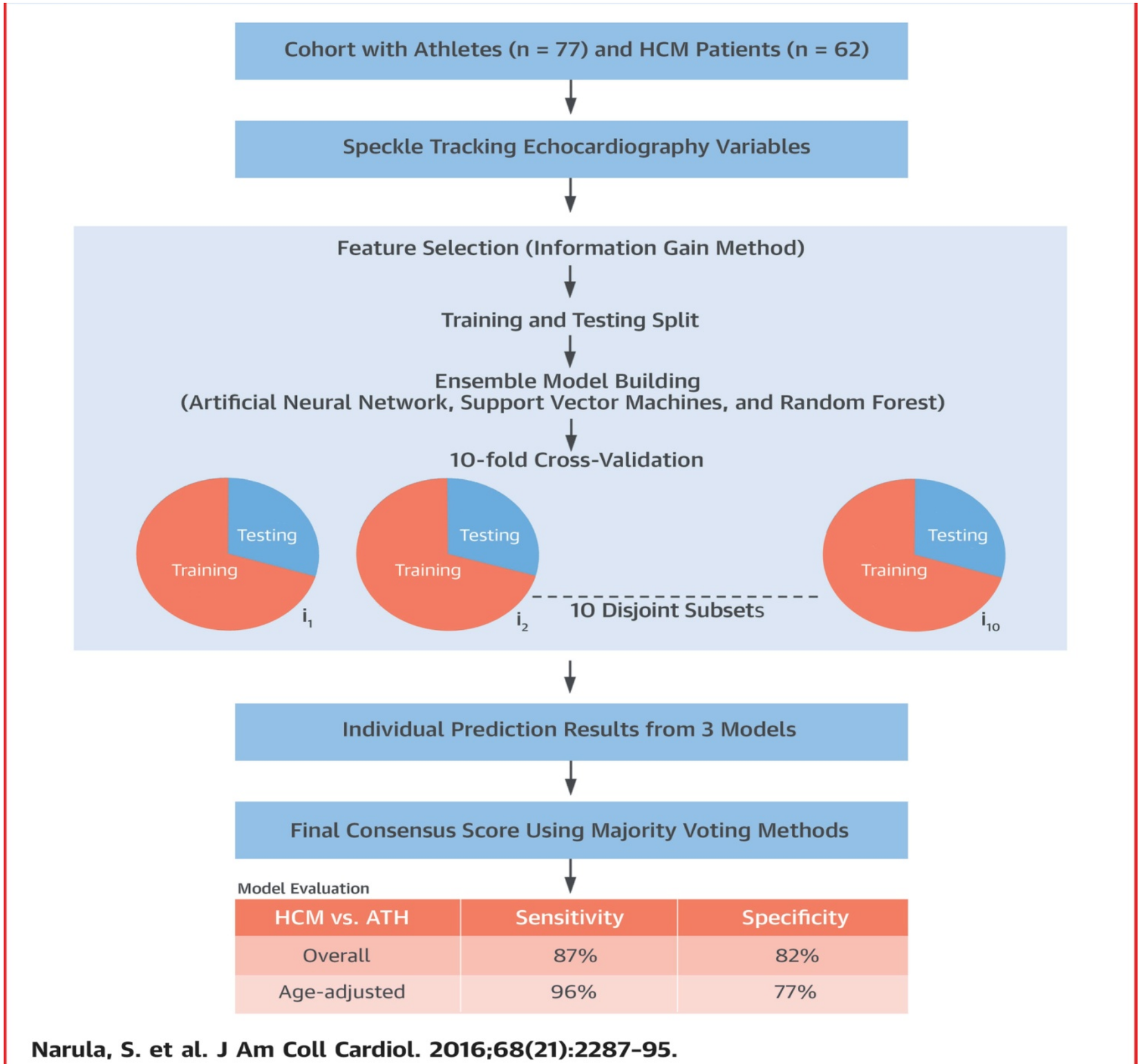
Sengupta PP et al, JACC 2018

Machine learning algorithms: HCM vs Athlete heart



Narula S et al, JACC 2016

Machine learning: HCM vs ATH



Model Evaluation

HCM vs. ATH	Sensitivity	Specificity
Overall	87%	82%
Age-adjusted	96%	77%

Narula, S. et al. J Am Coll Cardiol. 2016;68(21):2287–95.

Echo GPS

Toronto Echo Masters

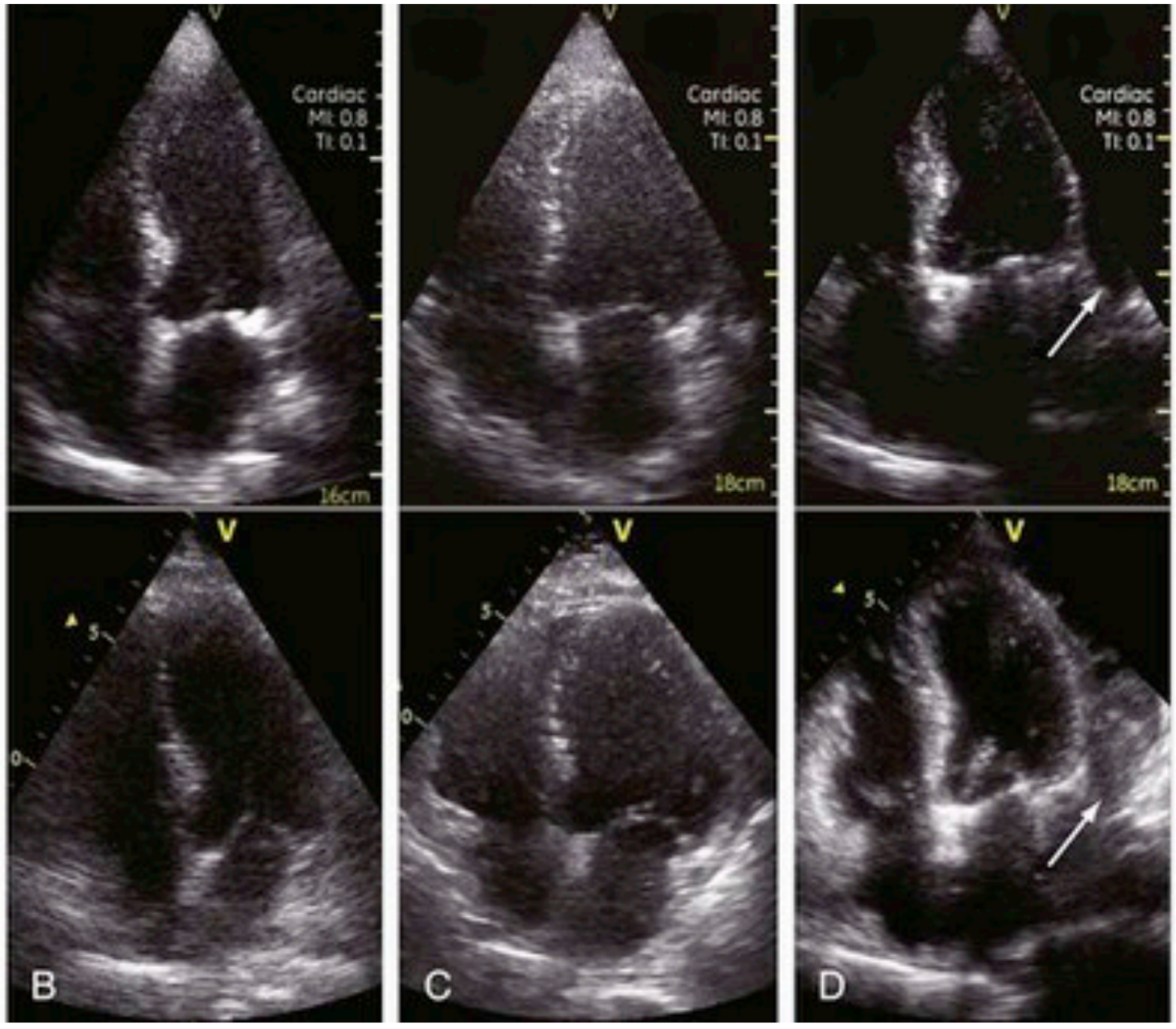
ASE Echovation

Nashille USA

June 2018


Quick ID
END EXAM
100%
22:23
MI
0.6
TIS
0.1
Frame Rate
30 Hz
Gain
57
Depth
18.0 cm
Transducer
S4-1
Preset
FAST
Power
-0.3 dB
Fast Flow
MMode
Depth
Gain
Slow Flow
Save Loop

PHILIPS
Lumify



Suboptimal

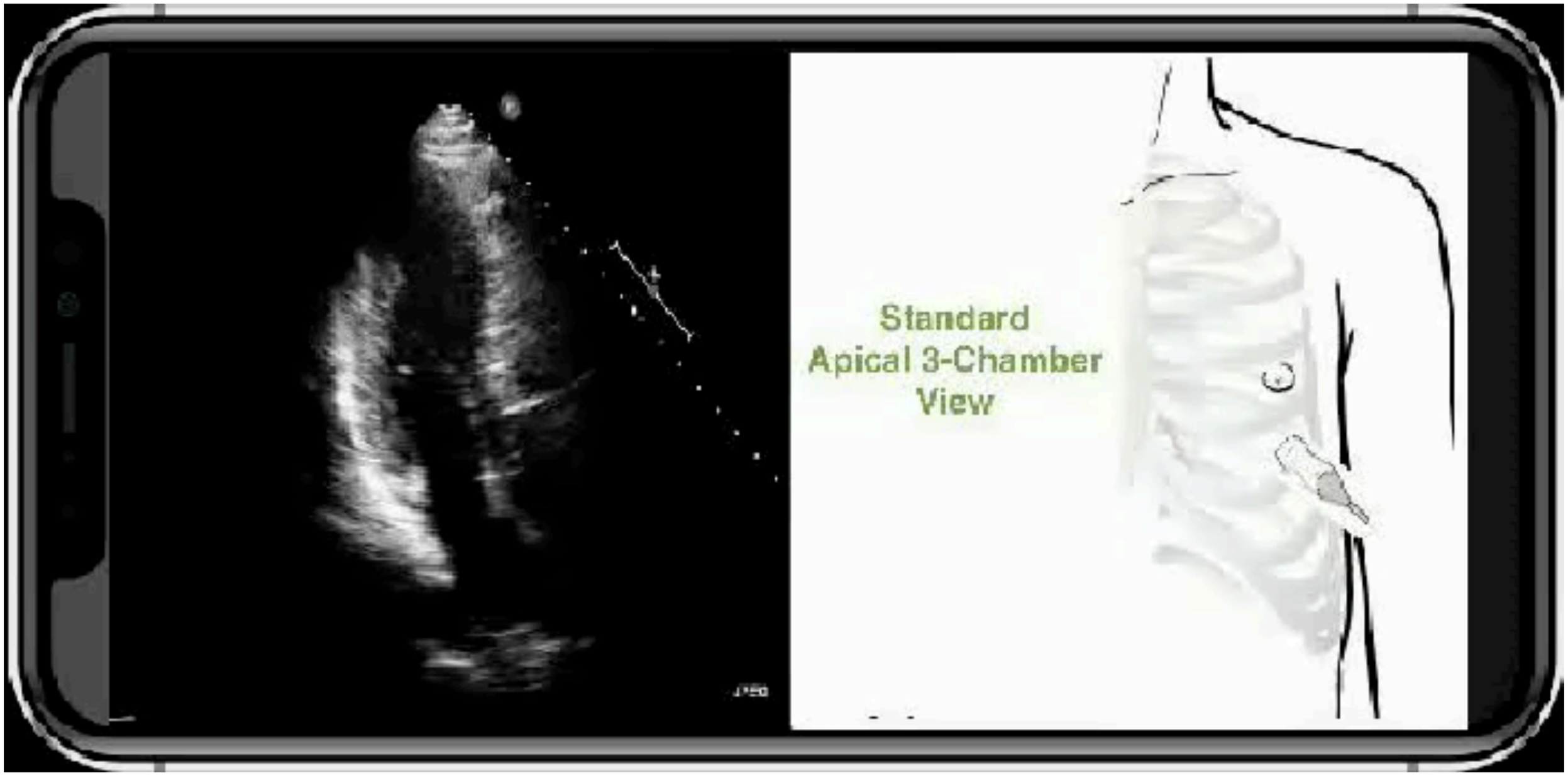
Quality

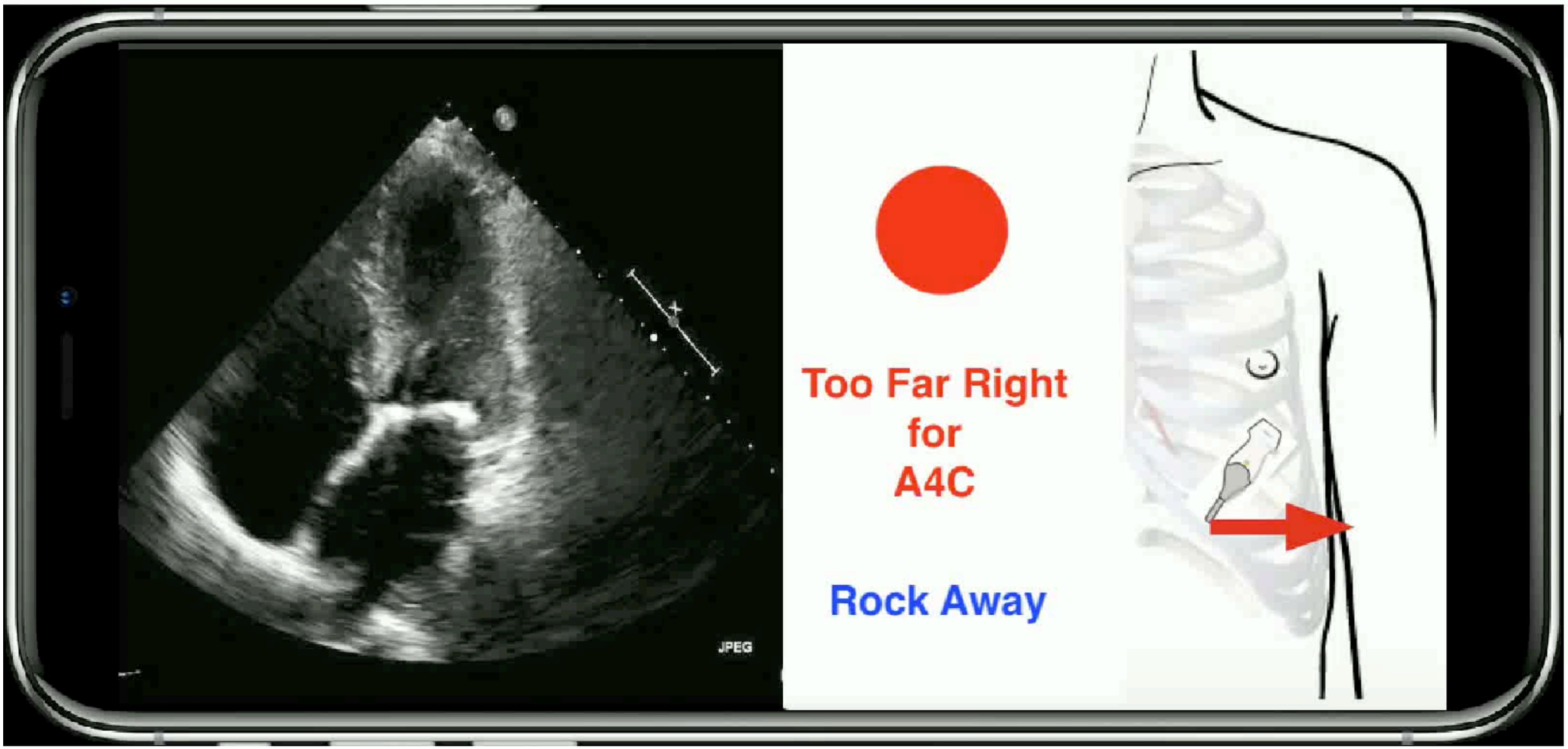
Novice

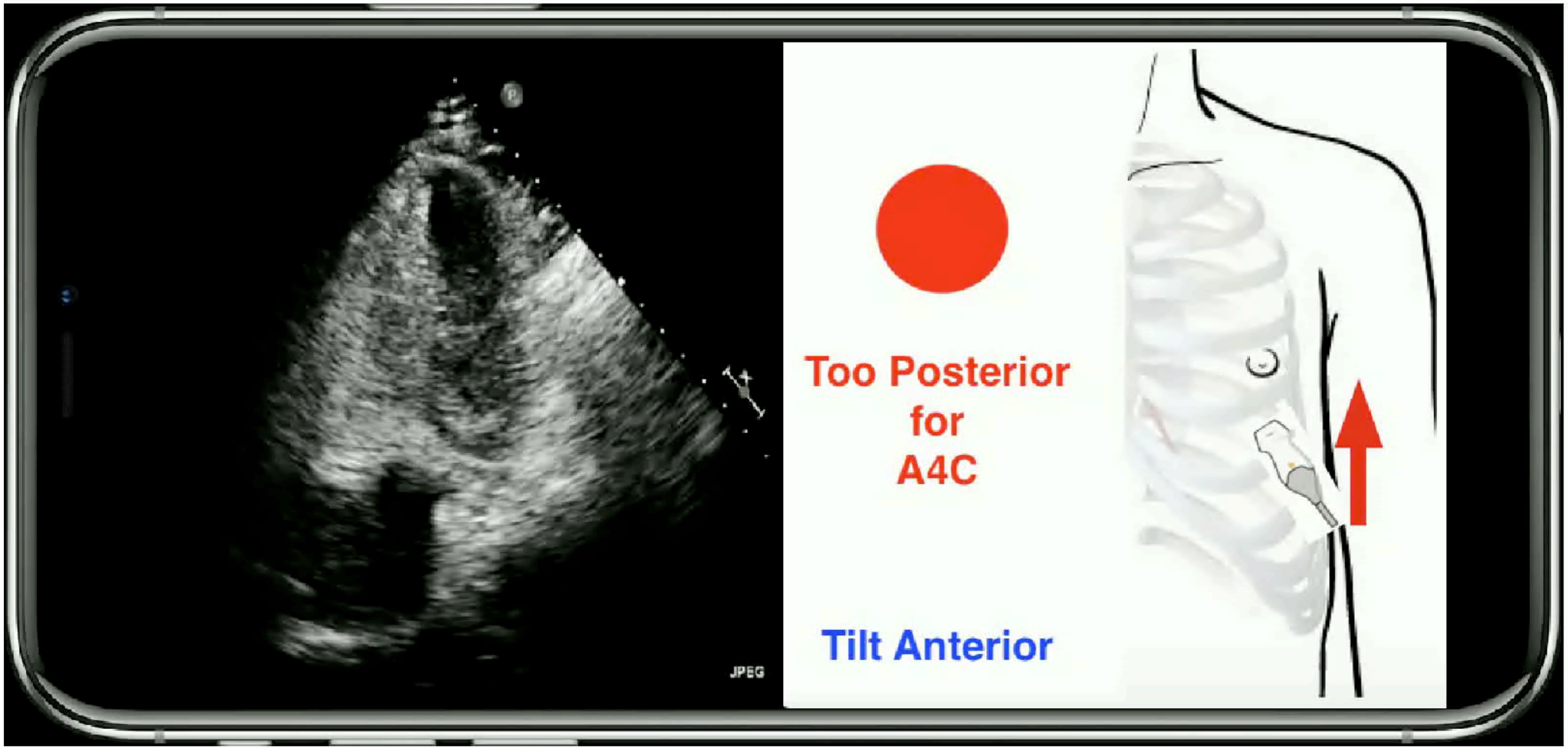
Time Hours

Image

Months


Standard
Apical 3-Chamber
View


JPEG
Too Far Right
for
A4C
Rock Away


JPEG
Too Posterior
for
A4C
Tilt Anterior

Results - Accuracy

4-chamber view - 95%

2 & 3-chamber views - 96%

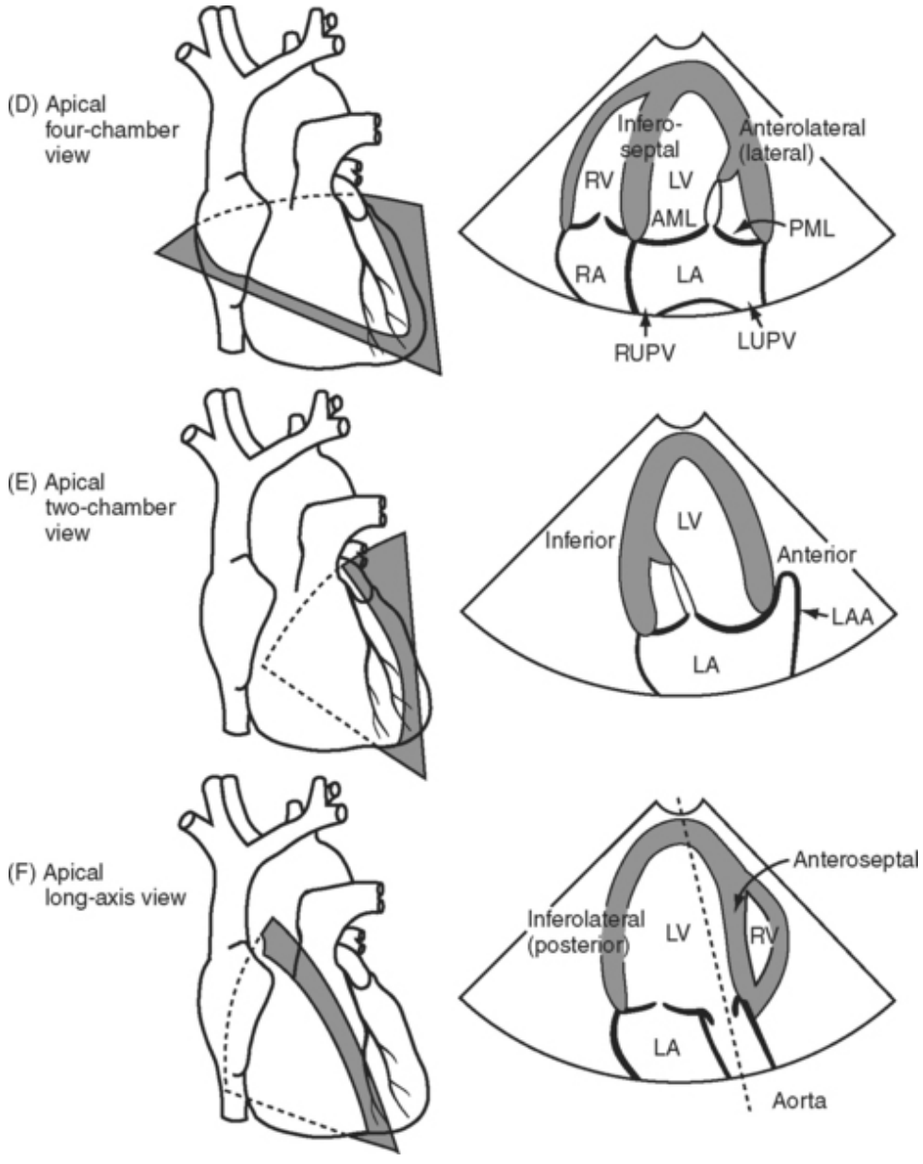
Apical foreshortening - 87%

This proof-of-concept pilot solution

Prospective Study

50 normal volunteers
(mean 55 y.o. Range 22-80 y.o., M:F 1:1)

35 training & 15 accuracy



The world is not perfect !

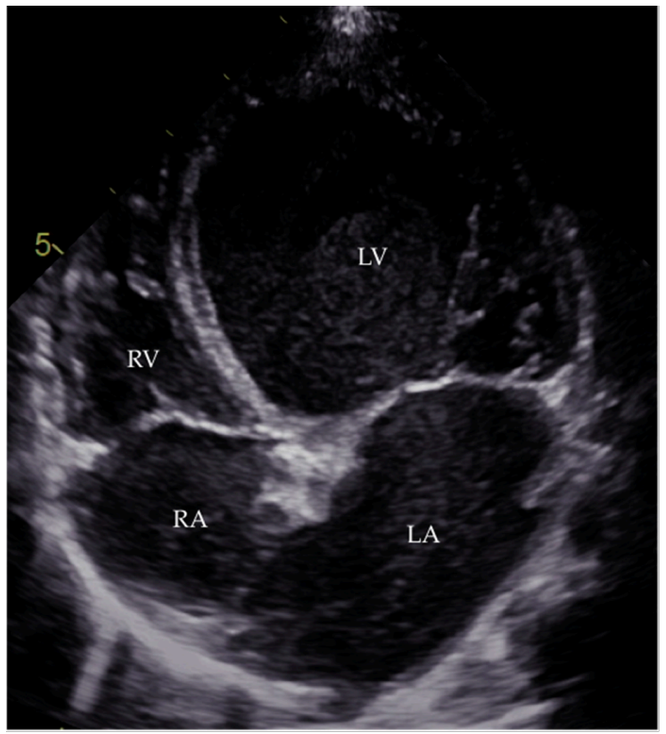
Technically difficult

Suboptimal images

Real time analysis

Pathologies e.g. cardiomyopathy

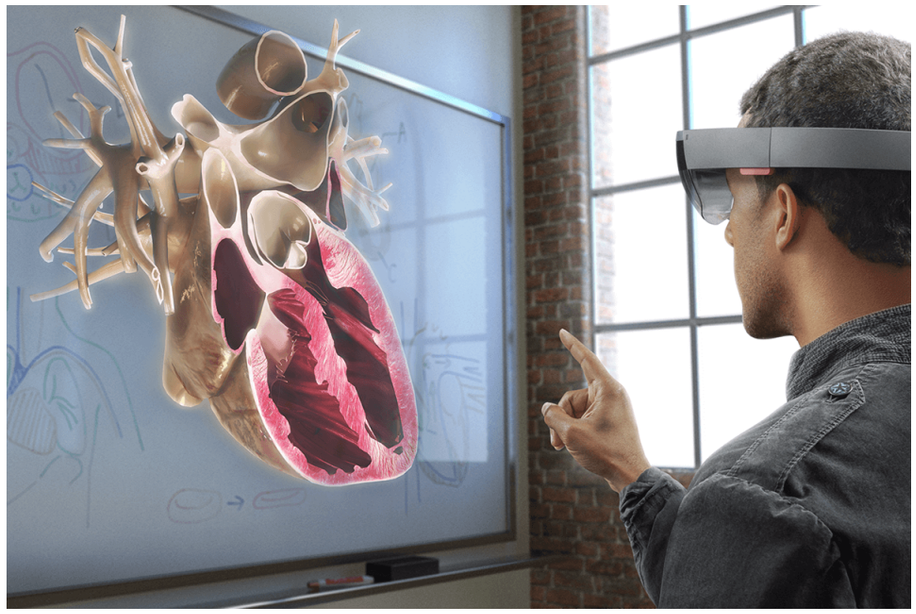
Competition



Impact

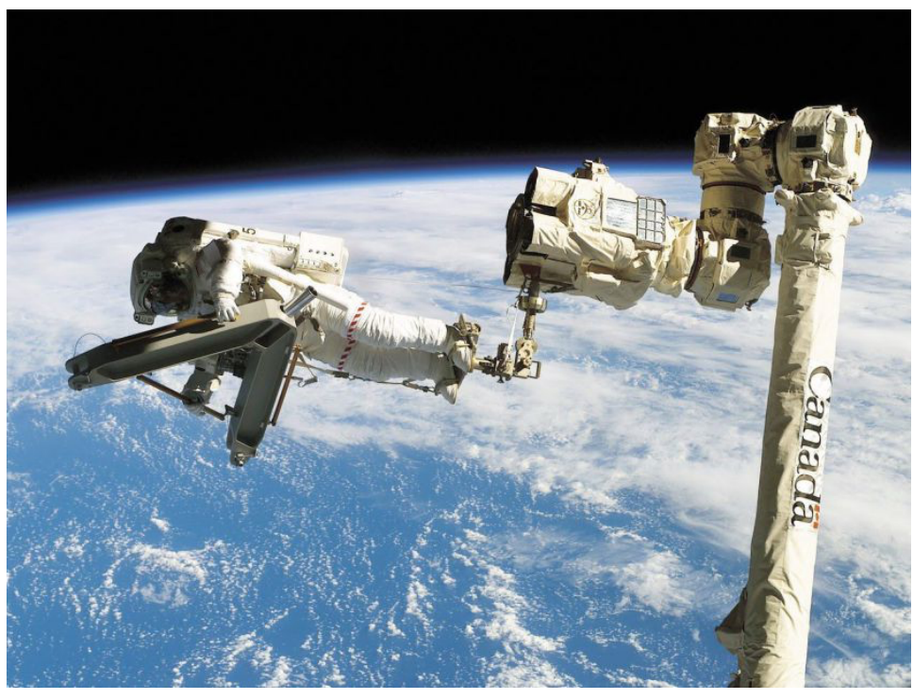
Save 400,000 hrs/yr

Deploy in remote areas



Upgrade existing machines

Multi-platforms (mobile devices/ headsets)



GI GO

IN

=

OUT

Cardiac Diagnostic Tests

- Improve diagnostic accuracy
- Improve quality of echo acquisition and reporting.
- Extract information **not** apparent to the naked eye e.g. stress and strain
- Reduce observer fatigue
- Improve timeliness of reports
- Reduced cost

Brave new world

“Radiology” Is Going Away . . . and That’s Okay: Titles Change, A Profession Evolves

Armin Moehrle
MEDKEN, Marshall, Texas

JACR Home
JACR | Journal of the American College of Radiology
Health Services Research & Policy ▪ Clinical Practice Management ▪ Data Science ▪ Training & Education ▪ Leadership

The **bad news** is that the robots are coming to do your job.

The **good news** is that robots are coming for the most mind-numbing, spirit-crushing, stultifying and isolating aspects of your job.

JACR March 2018Volume 15, Issue 3, Part B, Pages 499–500

Some of the practical tools …

Chamber Quantification Normal Ranges and Partition Values

Left Ventricle

Right Ventricle

Echocardiography

Aortic Root Index
AVA (Continuity Equation VMax)
AVA (Continuity Equation VTI)
Aortic Valve Velocity Ratio
dP/dt (LV Contractility)
dP/dt (RV Contractility)
Left Atrial Pressure (MR)
LA Volume (Biplane Method)
LV EF (Dumesnil Method)
LV EF (Modified Quinones Equation)
LV EF (Simplified Quinones Equation)
LV Fractional Shortening
LV Mass and LV Mass Index
LV Diastolic Function Diag. (Normal LVEF)
LV Filling Pressures Est. (Depressed LVEF or N LVEF with Diastolic Dysf.)
Modified Bernoulli Equation
Myocardial Performance Index (LV)
Myocardial Performance Index (RV)
Mitral Valve Area (PHT)
Mitral Valvuloplasty Score (MGH)
Prosthetic AV (DVI)
Prosthetic AV (EOA)
PCWP by E/e' (Nagueh Formula)
PISA (Mitral Regurgitation)
PISA (Mitral Stenosis)
Prosthetic MV (DVI)
Prosthetic MV (EOA)
Qp/Qs
RVSP (TR)
Stroke Volume, Cardiac Output
Sinus of Valsalva Dimensions

Exercise Stress Testing

Max. Predicted Heart Rate Achieved
Maximum Predicted Heart Rate by Age
Mets & VO2 (Treadmill)
Rate Pressure Product

General

Body Mass Index (BMI)
Body Surface Area (BSA)

LV Mass and LV Mass Index

MDMath

Inputs

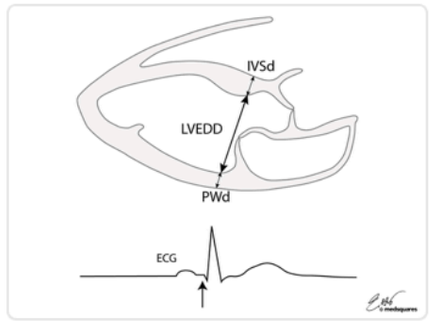
LVEDD		mm
IVSd		mm
PWd		mm
Height		cm
Weight		kg
Gender	Male	

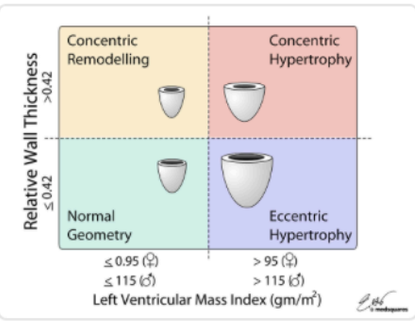
Clear Calculate

Results

LV Mass		g
LV Mass Index		g/m²
Severity by LVMI		
RWT		
Geometry by RWT		

Illustrations





Information

Left ventricular mass and left ventricular mass indexed to body surface area estimated by LV cavity dimension and wall thickness at end-diastole.

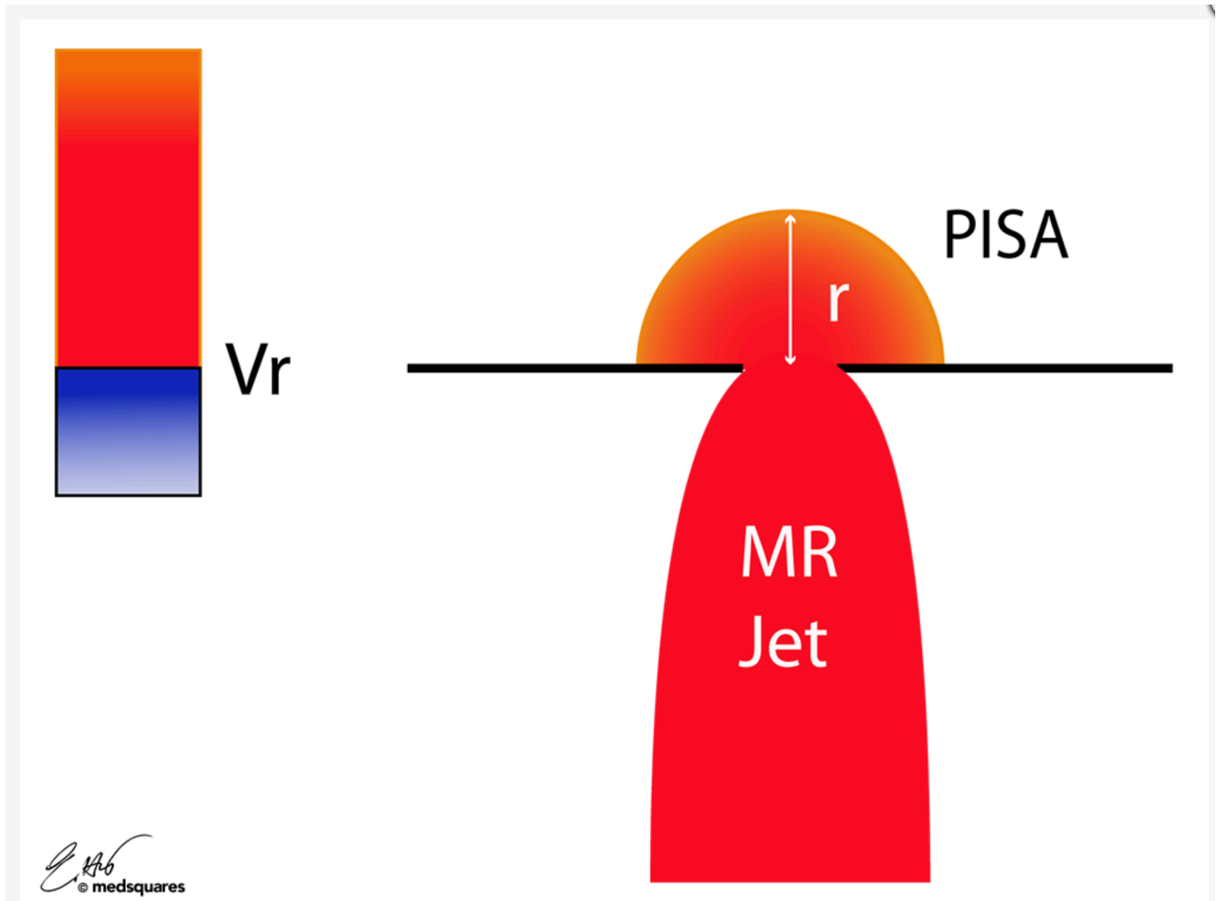
Relative wall thickness (RWT) allows further classification of LV mass increase as either concentric hypertrophy (RWT >0.42) or eccentric hypertrophy (RWT ≤0.42).

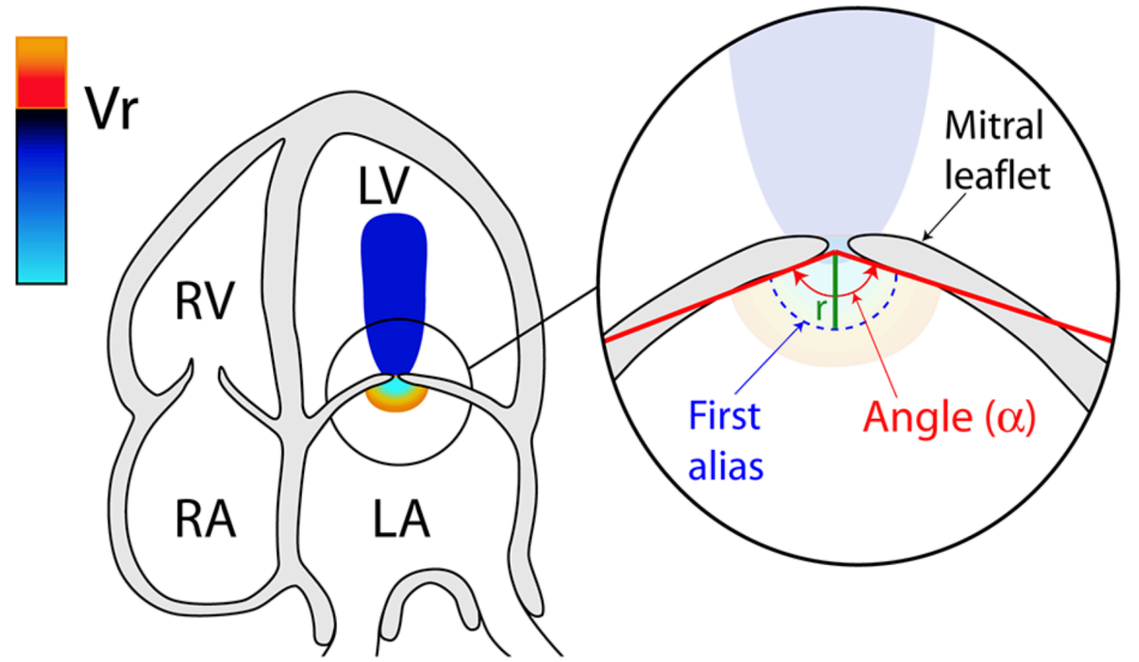
$$\text{LV Mass} = 0.8(1.04((LVEDD + IVSd + PWd)^3 - LVEDD^3)) + 0.6$$

$$RWT = \frac{2 \cdot PWd}{LVEDD}$$

Definitions

LVEDD	LV end-diastolic dimension (mm)
IVSd	Interventricular septal thickness at end-diastole (mm)





Originally drawn in 2005

May You Live In Interesting Times

"*Like it or not we live in interesting times.*

They are times of danger and uncertainty; but they are also more open to the creative energy of men than any other time in history."

Robert Kennedy
June 6, 1966
University of Cape Town

The best way to predict the future is to invent it.

(Alan Kay)

Thank You

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