Towards Holistic & Comprehensive Cardiac Care

Use of Artificial Intelligence in Digital Health Technologies

Eleanor A. Lopez, MD, FPCC, FPSE, FAsFC, FACC

November 23, 2024

Towards Holistic &
Comprehensive Cardiac Care

"I think the biggest innovations of the 21st Century will be at the intersection of biology and technology."

Steve Jobs

Towards Holistic &
Comprehensive Cardiac Care

Disclosure

- No conflict of interest

Objectives

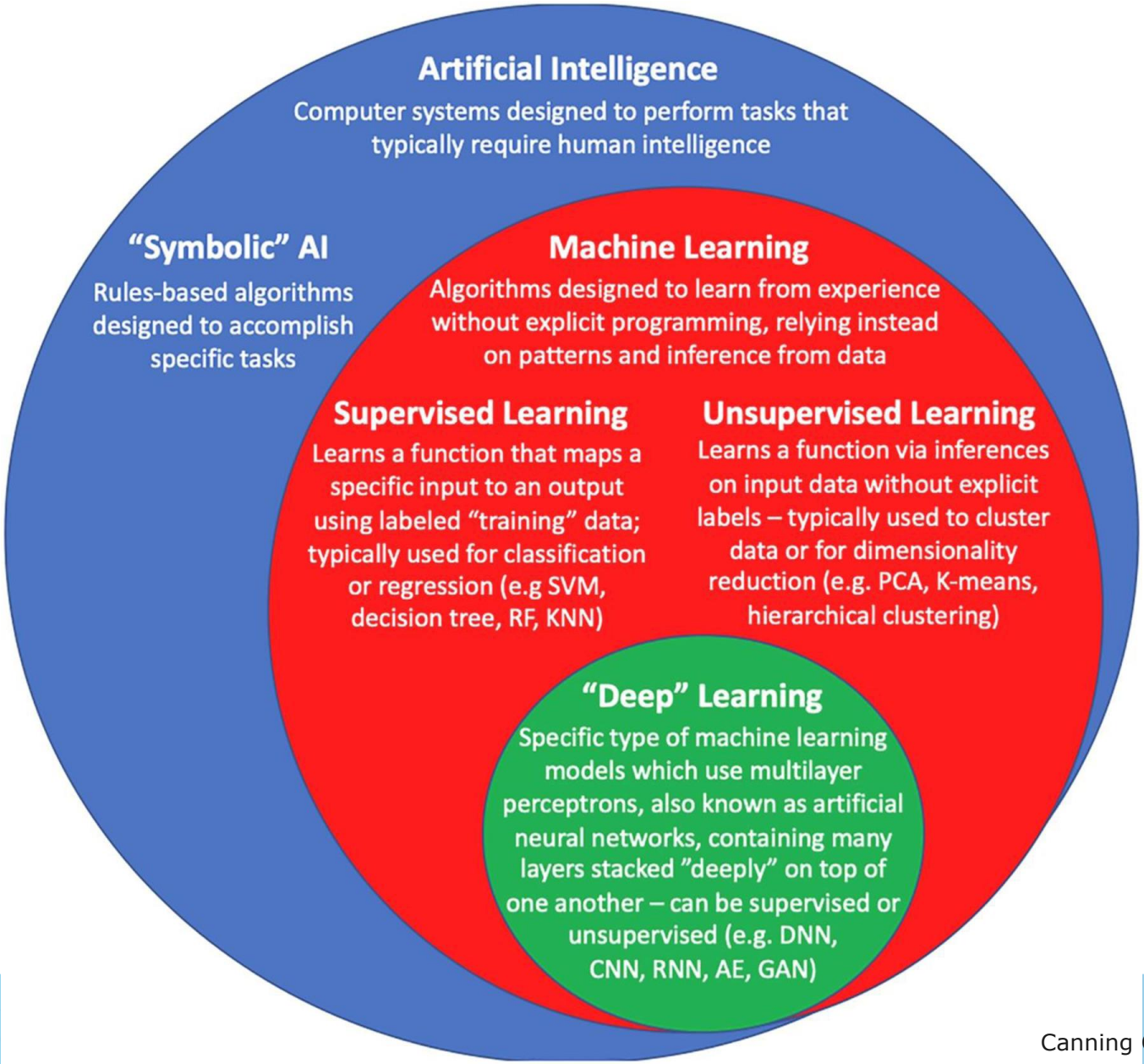
Towards Holistic & Comprehensive Cardiac Care

TO BRIEFLY DEFINE ARTIFICIAL INTELLIGENCE

TO DISCUSS DIGITAL HEALTH TECHNOLOGY AND ITS CLINICAL APPLICATIONS

TO CITE INNOVATIVE USE OF AI IN NON-INVASIVE CARDIOLOGY

What is artificial intelligence (AI)?



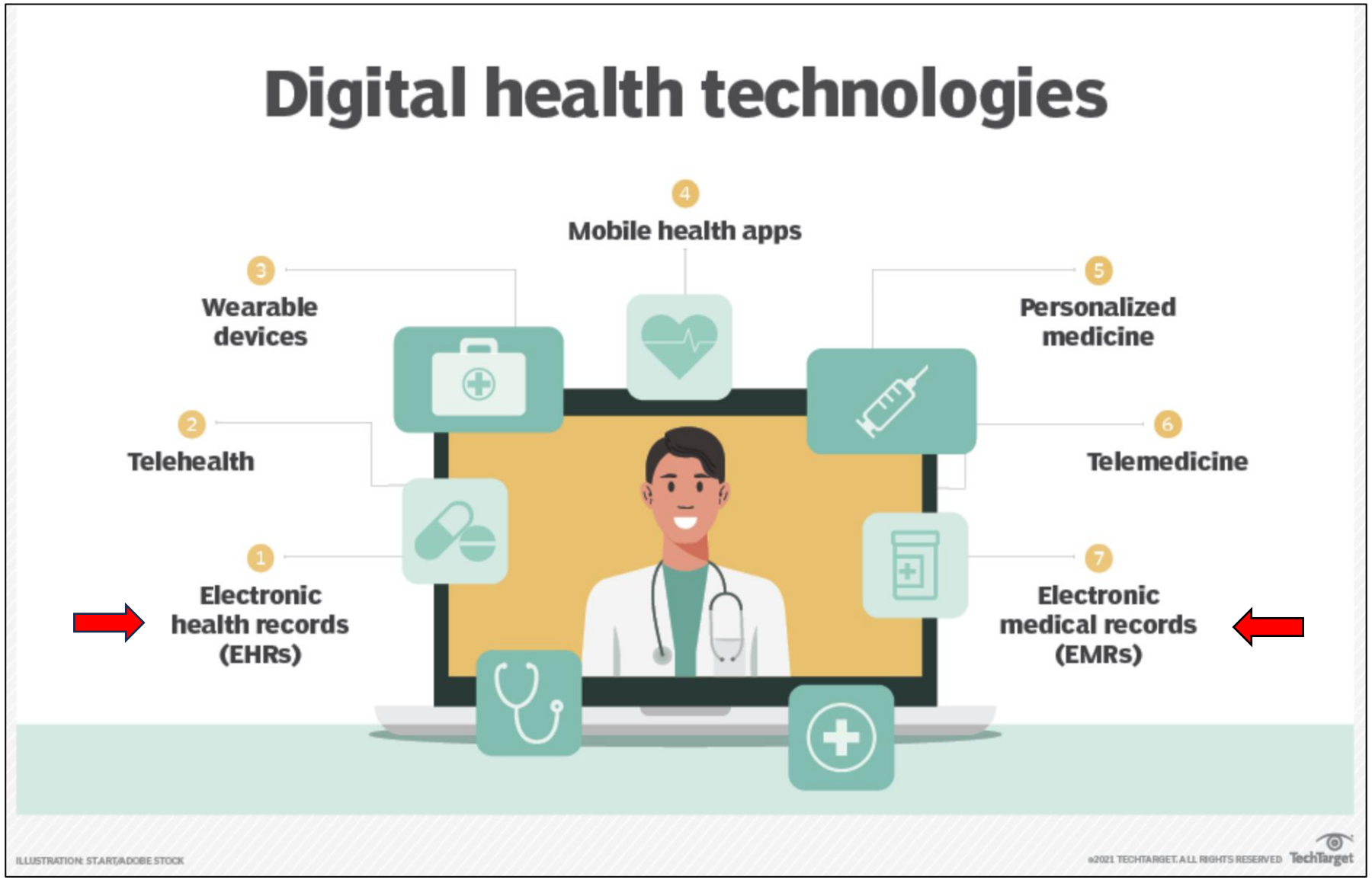
Towards Holistic & Comprehensive Cardiac Care

Canning C et al. Heart Fail Clin. 2023 Apr 7;19(3):391–405.

Towards Holistic &
Comprehensive Cardiac Care

What is digital health?

It is the application of information and communications technology to provide digital health interventions to prevent disease and improve quality of life.

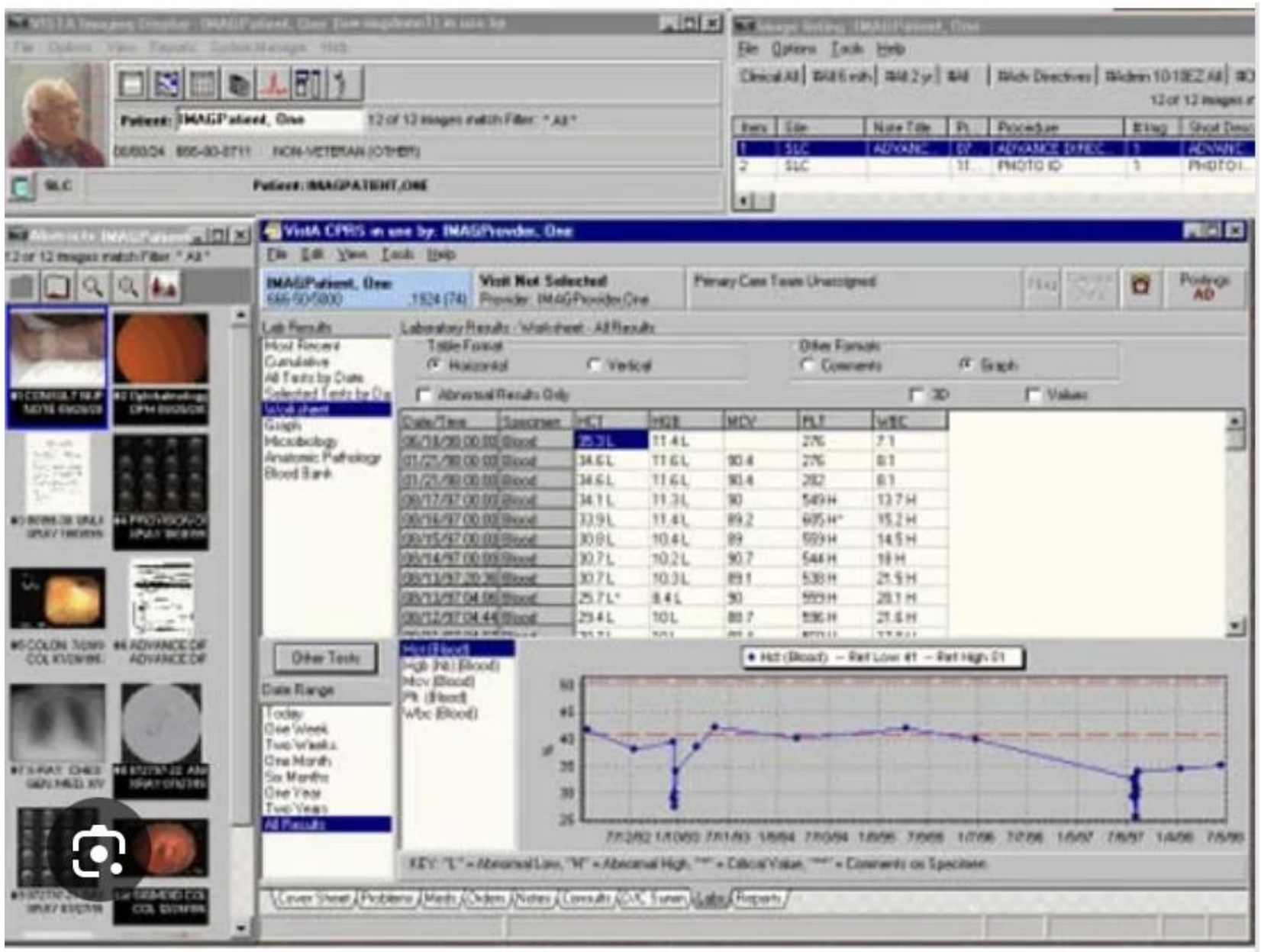

Digital health technologies
4
Mobile health apps
3
Wearable devices
5
Personalized medicine
2
Telehealth
6
Telemedicine
1
Electronic health records (EHRs)
7
Electronic medical records (EMRs)
ILLUSTRATION: ST.ART/ADOBE STOCK
©2021 TECHTARGET. ALL RIGHTS RESERVED
TechTarget

What is the difference between EHR vs EMR?

Electronic Health Record (EHR)

Towards Holistic & Comprehensive Cardiac Care

- An EHR is a digital version of a patient's paper chart. It includes a *more comprehensive* view of a patient's medical profile.
- Advantages of EHR
  - Improved patient care
  - Increase patient participation
  - Improved care coordination
  - Improved diagnostics and patient outcomes
  - Practice efficiencies and cost savings



Towards Holistic &
Comprehensive Cardiac Care

EHR enhances quality of care

- EHRs can reduce medication errors by up to 80%.[1]
- EHRs can improve patient care coordination.[2]
- EHRs can improve patient safety.[3]

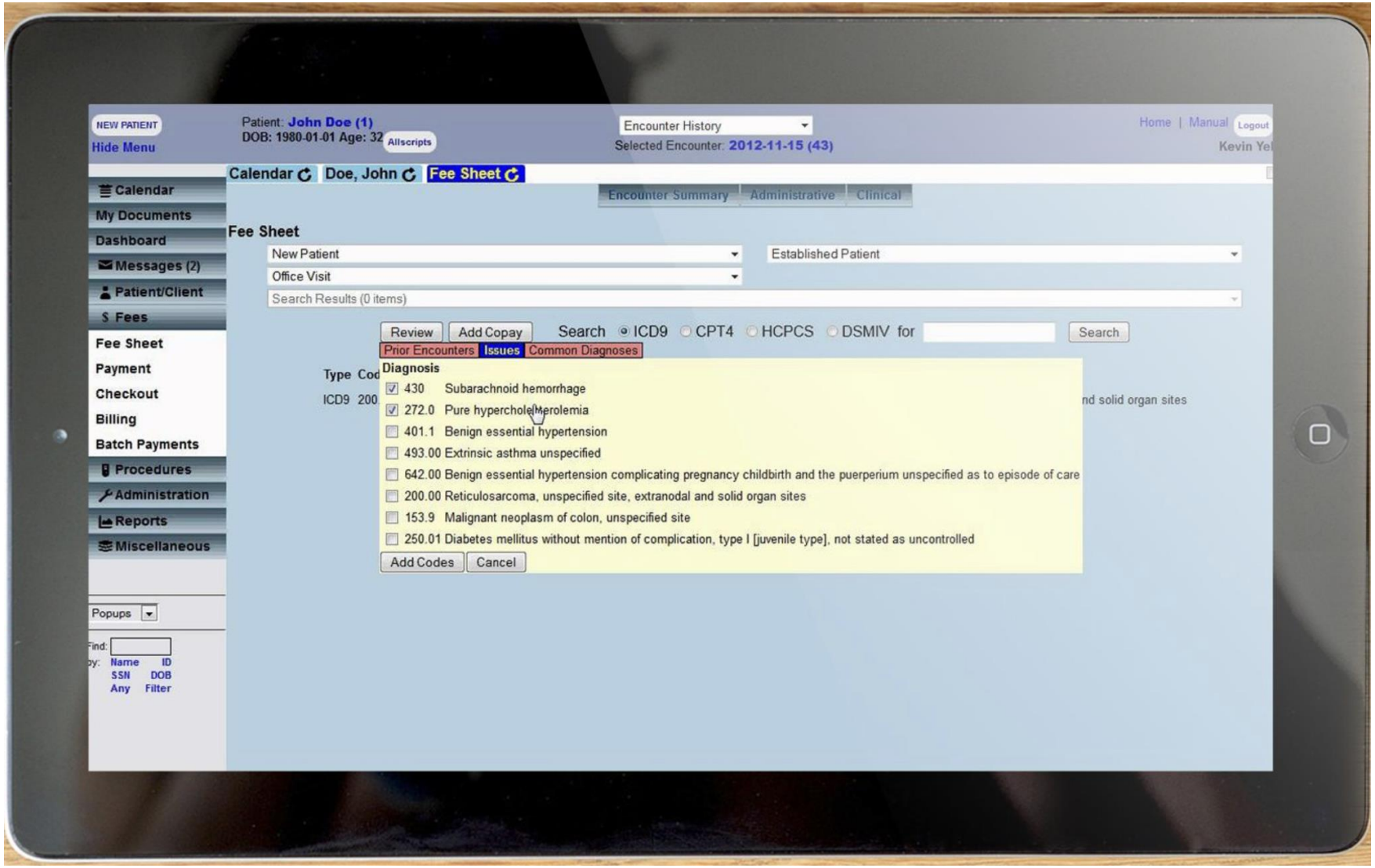
1. JAMA Internal Medicine, 2023
2. Health Affairs, 2023
3. The Lancet, 2023

Electronic Medical Record (EMR)

Towards Holistic & Comprehensive Cardiac Care

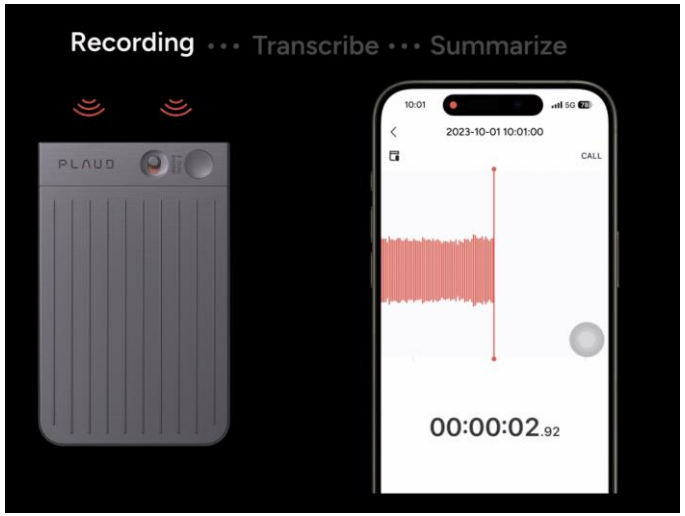
- An EMR is the digital version of the paper charts in a clinician's office. It contains the patient's medical and treatment in *one practice.*
- Advantages of EMR
  - Track data over time
  - Easily identify which patients are due for preventive screenings or checkups
  - Check how patients are doing on certain parameters, ex. BP readings or vaccinations
  - Monitor and improve overall quality of care within the practice

Towards Holistic &
Comprehensive Cardiac Care




EMR
personal record with basic health information for one practice
EHR
personal record with extensive health information that can be shared between practices

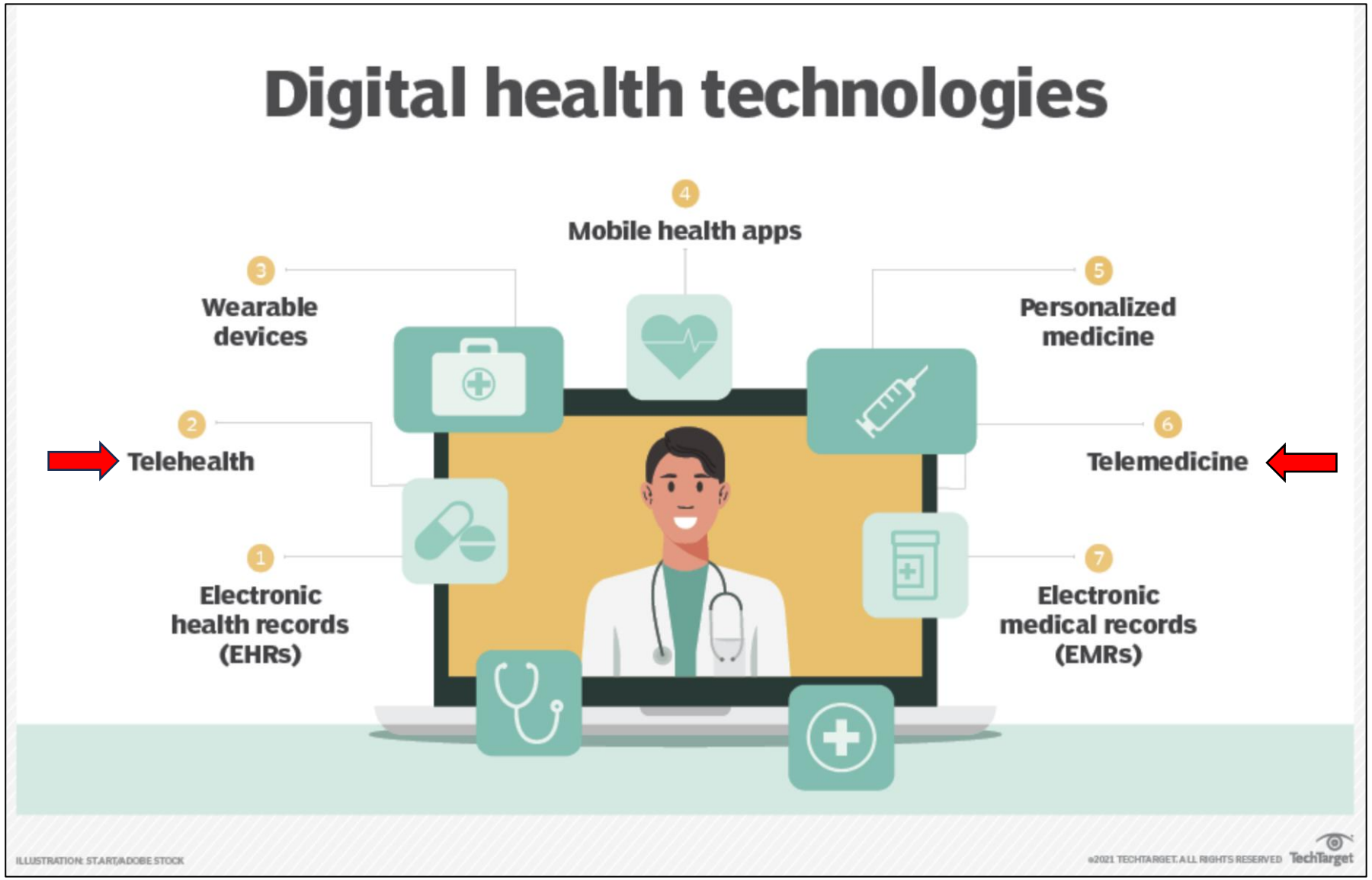
Electronic Medical Records



Towards Holistic & Comprehensive Cardiac Care

PLAUD

- AI voice recorder
- transcribes conversation into notes, then into EMR
- enables a physician to listen intently to a patient's concerns instead of jotting down notes
- powered by ChatGPT


Digital health technologies
4
Mobile health apps
3
Wearable devices
5
Personalized medicine
2
Telehealth
6
Telemedicine
1
Electronic health records (EHRs)
7
Electronic medical records (EMRs)
ILLUSTRATION: START/ADOBE STOCK
©2021 TECHTARGET. ALL RIGHTS RESERVED
TechTarget

Telehealth

Towards Holistic & Comprehensive Cardiac Care

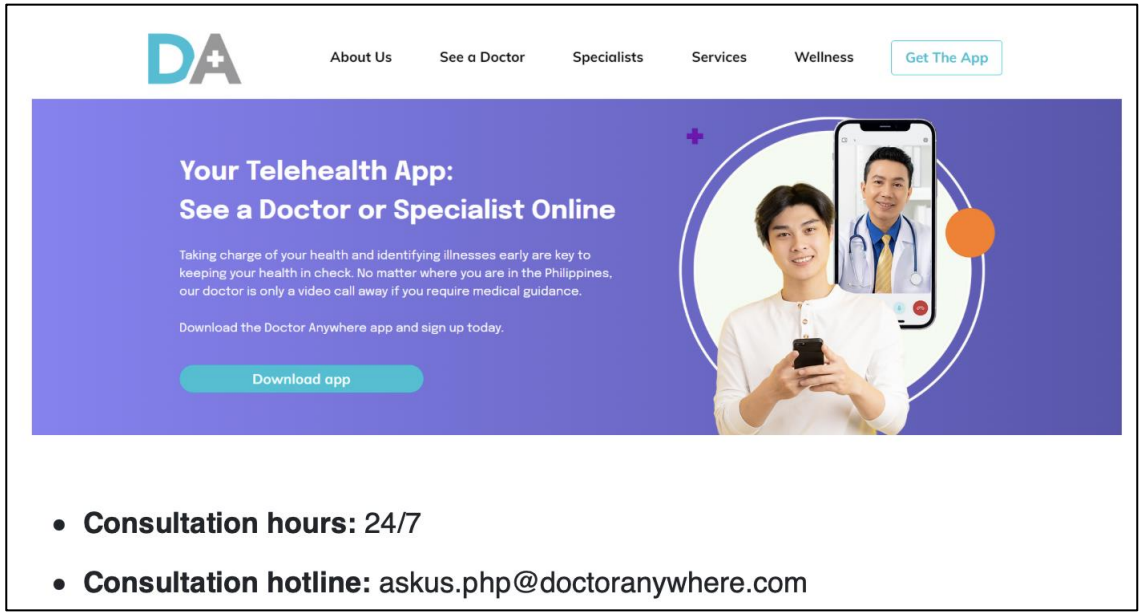
- Use of communications technologies to provide health care at a distance
  - remote monitoring of BP, HR, and other measurements obtained by a device worn by the patient and electronically sent to medical personnel

- Telehealth services may include telemedicine consultations and remote patient monitoring.

Telemedicine

Towards Holistic & Comprehensive Cardiac Care

- "Remote Healthcare"
- Teleconferencing provide patients with access to medical services, ex. consultations, diagnoses, prescriptions, and prescription fulfillment
- Also called
  - Telecare
  - e-health
  - Teleconsultation
  - Telehealth
  - Tele-radiology

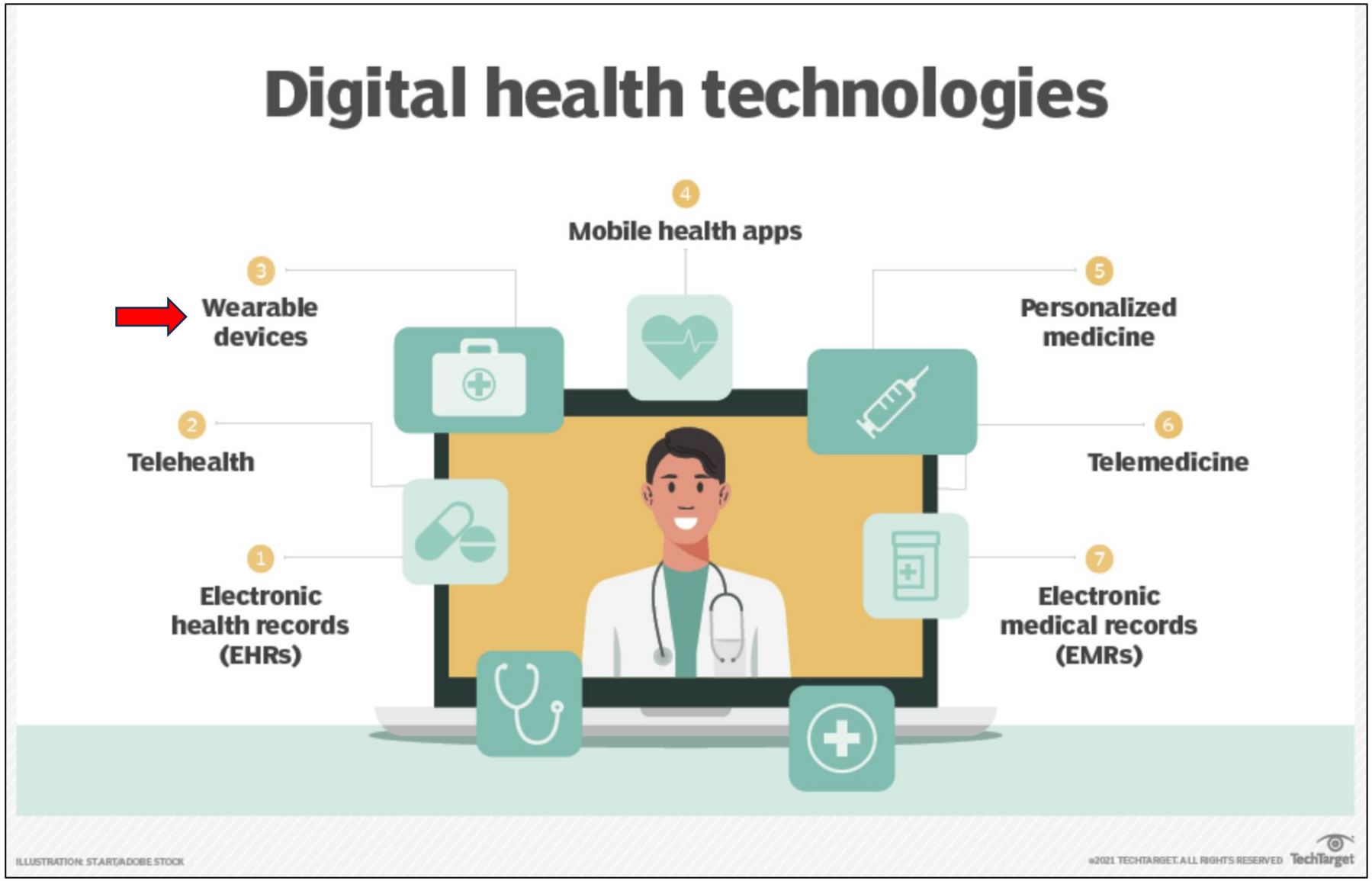


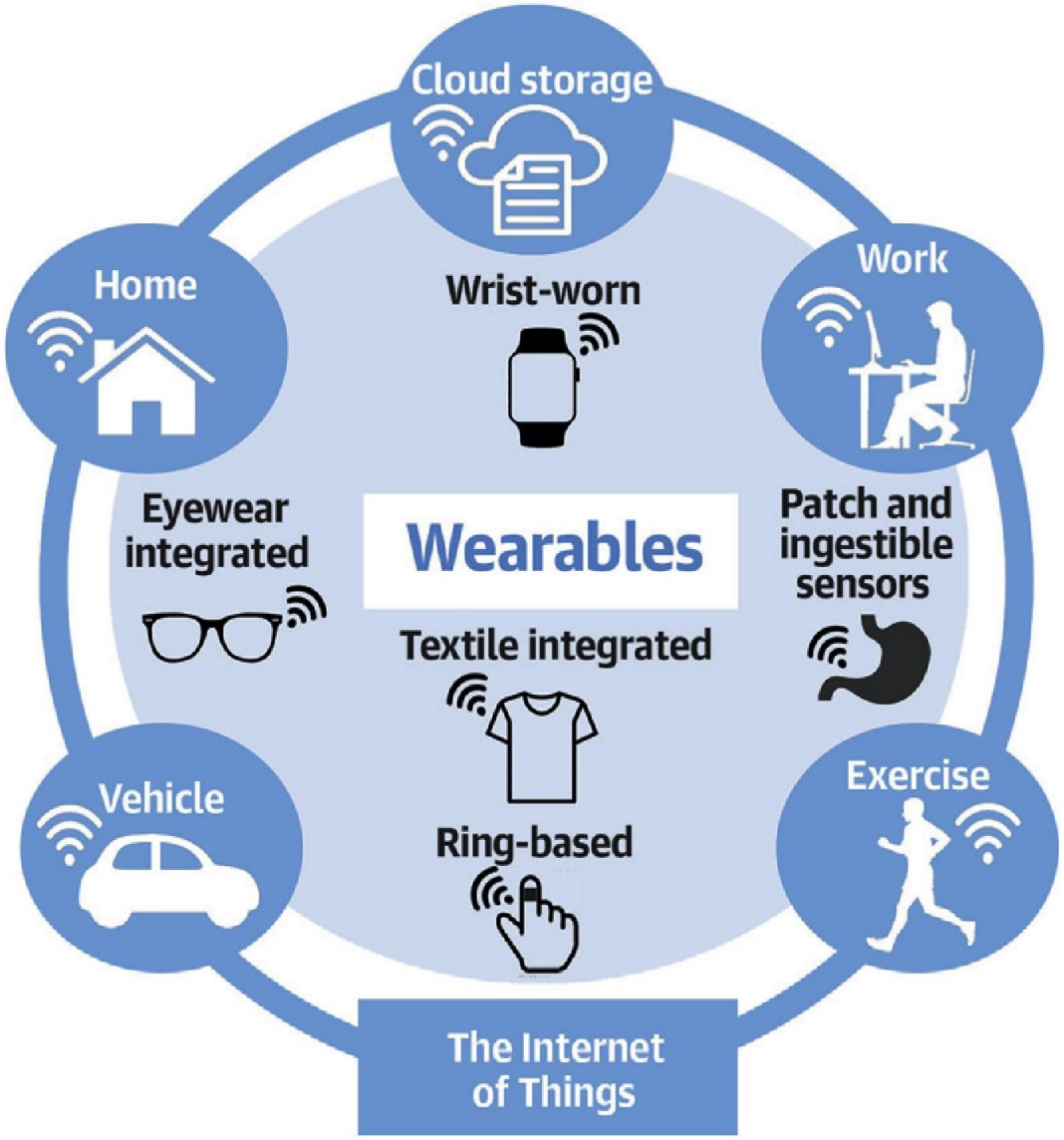
Challenges in telemedicine

Towards Holistic & Comprehensive Cardiac Care

- Limitations on physical examination and emphasizes the reliance on diagnostics
- Increased dependency on good internet and network service connections to ensure smooth teleconsultations
- Lack of respect for the physician's personal boundaries and work-life balance

Hilomen MS et al. Health Sciences Journal vol. 12 no.2(2023)


Digital health technologies
4
Mobile health apps
3
Wearable devices
5
Personalized medicine
2
Telehealth
6
Telemedicine
1
Electronic health records (EHRs)
7
Electronic medical records (EMRs)
ILLUSTRATION: START/ADOBE STOCK
©2021 TECHTARGET. ALL RIGHTS RESERVED
TechTarget



Varma N, et al. J Am Coll Cardiol. 2024;83(5):611-631

Wearable devices

Towards Holistic & Comprehensive Cardiac Care

- Smartphones- first wearable device
  - FitBit, Apple Watch, implanted devices
- Measure heart rate, blood glucose, sleep patterns, and other health indicators to provide medical professionals with data not available at a clinical visit.

Accuracy of wearable technology and smart watches

listic &
ardiac Care

KEY TAKEAWAYS:

- **44%** of people use wearable fitness devices to measure heart rate.
- **42%** of people use wearable fitness devices to measure caloric expenditure (calories burned).
- On average, wearable fitness devices have a slight tendency to **underestimate heart rate**.
- On average, there is a tendency for wearable fitness devices to **underestimate caloric expenditure**.
- Exercise intensity, motion of extremities during exercise, wrist position, interference between skin and sensors (sweat or dirt on the skin), and skin pigmentation have been shown to **decrease the accuracy** of wearable devices.
- **60%** of people use wearable fitness devices to track step count.
- On average, wearable fitness devices **underestimate step count by 9%.**

Korem E et al. Feb 2024

Error comparison

- ≤ 10 % error
- 10.1-25% error
- ≥ 25.1% error
- No Data Available

Towards Holistic & Comprehensive Cardiac Care

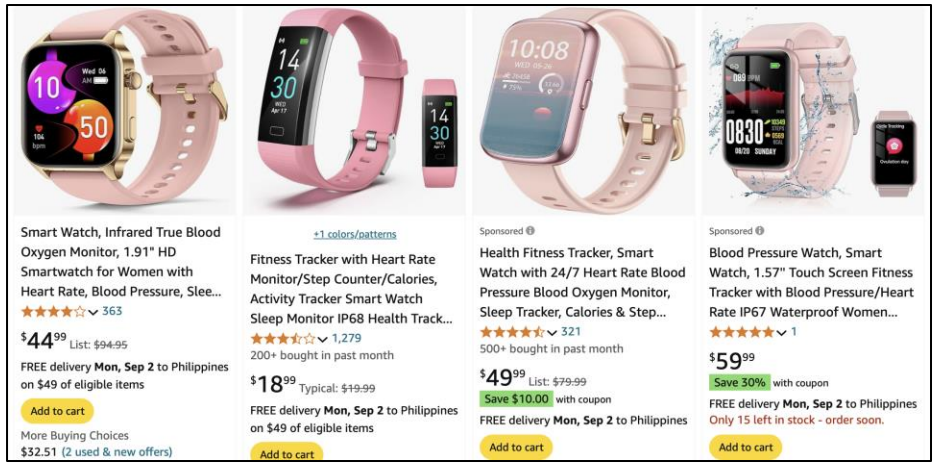
	Caloric Expenditure	Heart Rate	Steps	Sleep
Apple Watch	115%	.91%	3.4%	3%
Oura Ring	13%	3%	4.8%	6%
Whoop		0.3%		10%
Garmin	42.9%	1.39%	23.7%	2%
Fitbit	14.8%		21.9%	13%
Samsung	20.8%	1.1%	6.3%	
Polar	16.7%	2.2%		8%
Withings	98%	11%	58.3%	6%

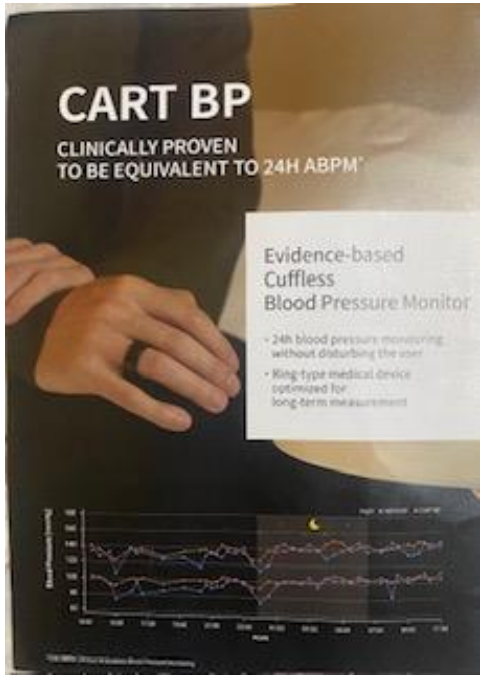
Korem E et al. Feb 2024

Cuffless BP measuring technologies

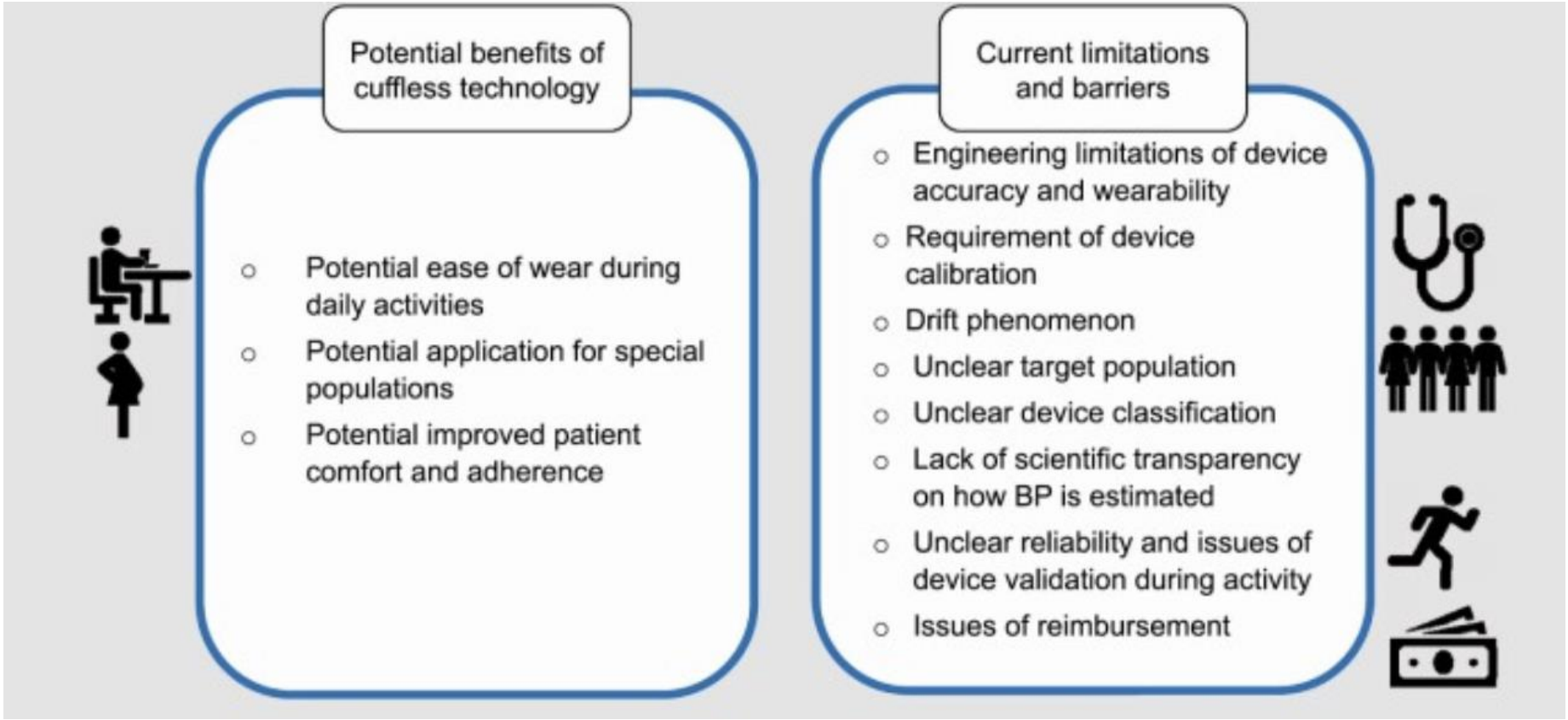
Towards Holistic & Comprehensive Cardiac Care

- No intrusive presence and function of the cuff
- Can obtain numerous BP readings in all settings and activities





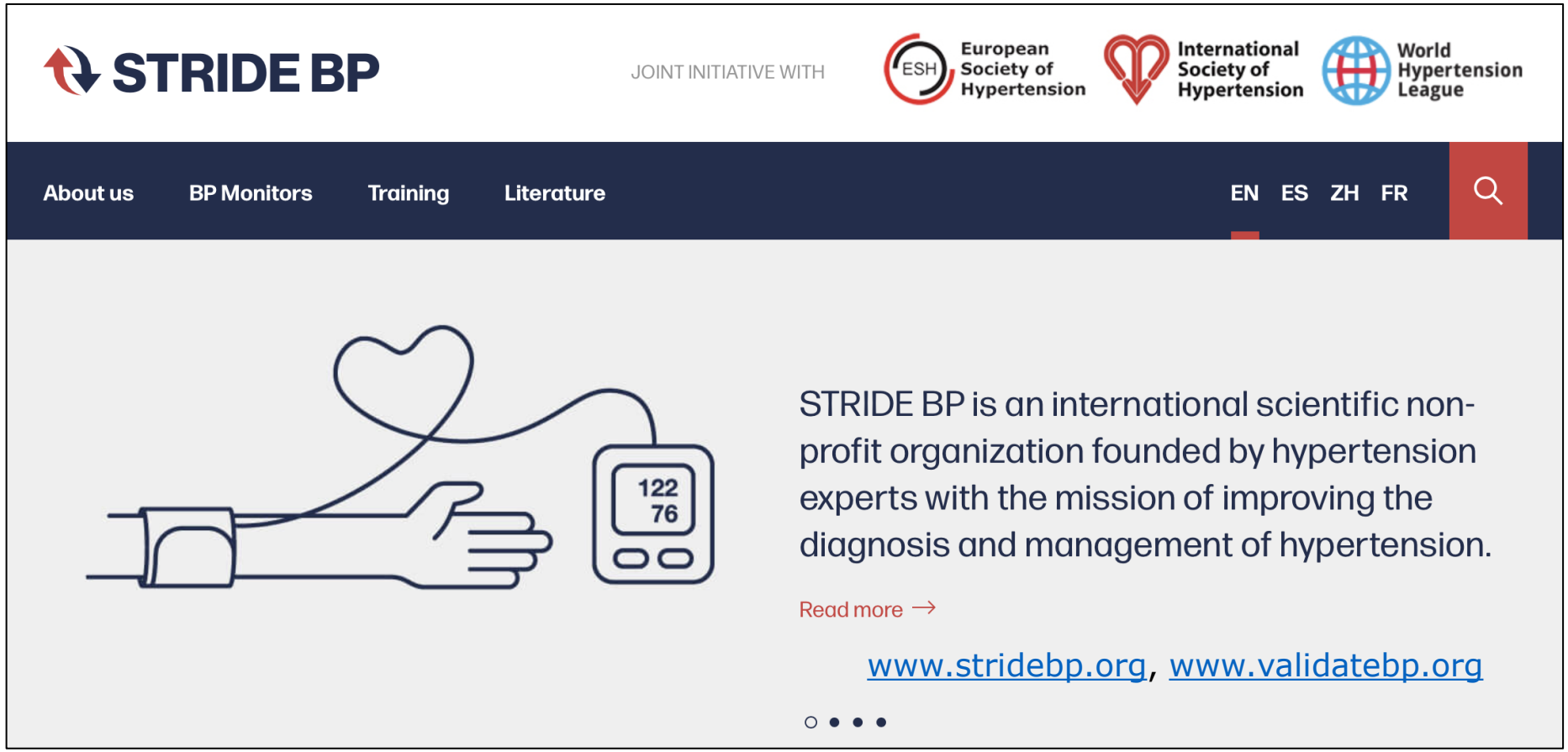
Cuffless BP devices



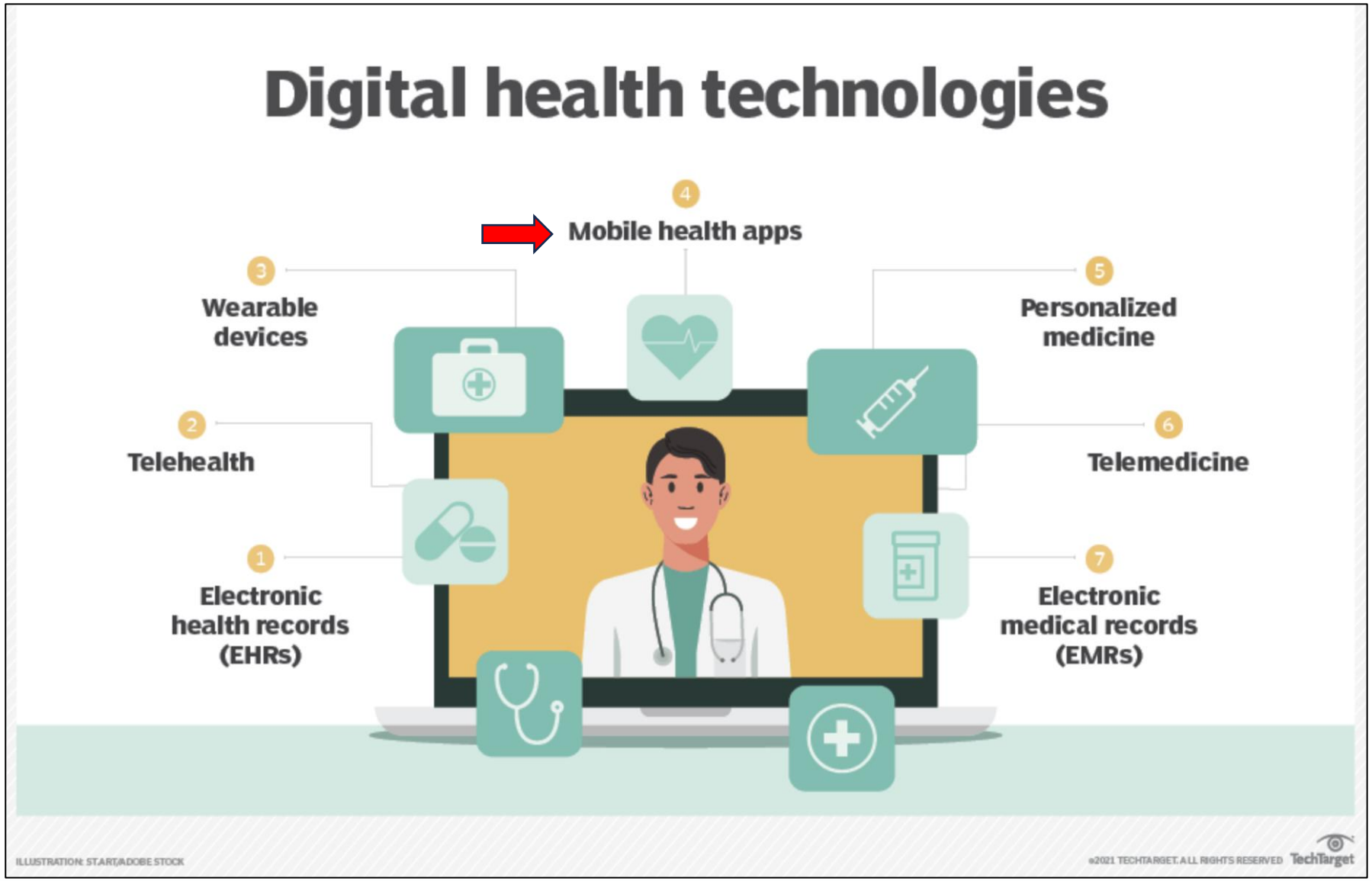
Bradley CK et al. Am J Hypertens.2022 May;35(5):380-387

"Of the commercially available oscillometric BP measurement devices, as few as 6% have been adequately tested."

Towards Holistic & Comprehensive Cardiac Care



McEvoy JW et al. 2024 ECG guideline on the Mx of elevated BP and hypertension


Digital health technologies
4
Mobile health apps
3
Wearable devices
5
Personalized medicine
2
Telehealth
6
Telemedicine
1
Electronic health records (EHRs)
7
Electronic medical records (EMRs)
ILLUSTRATION: START/ADOBE STOCK
©2021 TECHTARGET. ALL RIGHTS RESERVED
TechTarget

Mobile health applications for *patients*

Towards Holistic & Comprehensive Cardiac Care

dr+ on demand

Calm

oviahealth™

fitbit

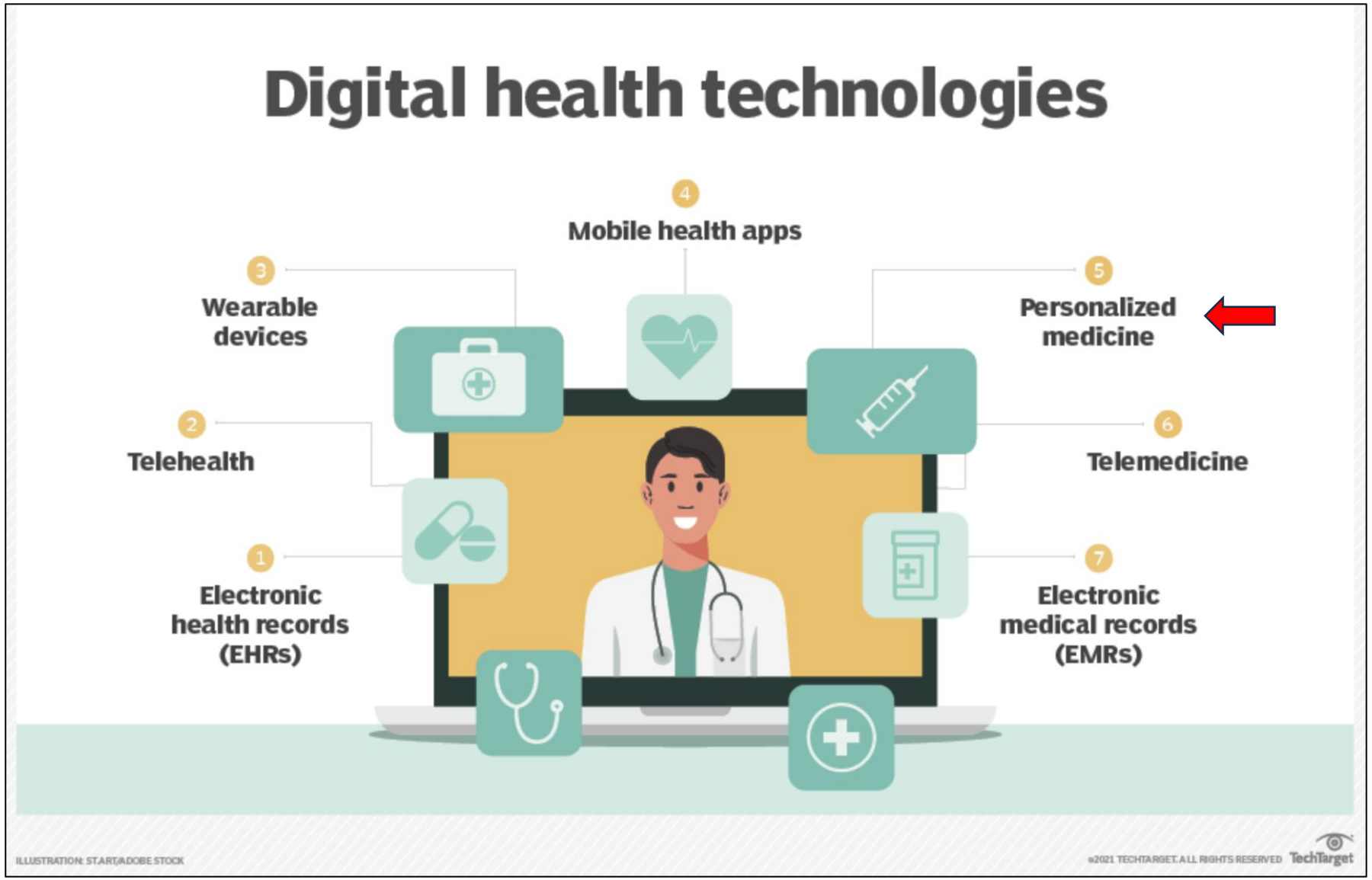
Mobile applications for *healthcare professionals*

Towards Holistic & Comprehensive Cardiac Care

Information Management	
Evernote	Note-taking and organization
Notability	Note-taking and organization
iAnnotate	PDF viewer
GoodReader	PDF viewer
Box	Cloud storage and file sharing
Dropbox	Cloud storage and file sharing
Google Drive	Cloud storage and file sharing
Communication and Consulting	
Doximity	Social networking site for MDs
Reference and Information Gathering	
Epocrates	Drug and medical reference
Dynamed	Drug and medical reference
Skyscape/Omnio	Drug and medical reference
Micromedex	Drug reference
Dynamed	Medical reference
UpToDate	Medical reference
Medscape	Medical reference

Patient Management and Monitoring	
Diagnosaurus	Differential diagnosis
Pocket Lab Values	Laboratory reference
Lab Pro Values	Laboratory reference
Archimedes	Medical calculator
MedCalc	Medical calculator
Mediquations	Medical calculator
Calculate	Medical calculator
AHRQ ePSS	Screening and prevention tool
Medical Education and Training	
MedPage Today	Continuing medical education
QuantiaMD	Continuing medical education

Towards Holistic &
Comprehensive Cardiac Care



Personalized Medicine

Towards Holistic & Comprehensive Cardiac Care

- Uses novel digital measurement and analytical techniques taking into account the deviation of one particular patient from the population
- Deviates from the *one-size-fits-all* paradigm
- Personalized medicine may tailor treatment approaches to each patient's genetic and molecular data, improving their efficacy and effectiveness.

Digital Health (DH) + *Artificial Intelligence* (AI) ➞ **Precision Medicine**

Patient Targeting

Towards Holistic & Comprehensive Cardiac Care

AI can identify patients who are least likely to churn and most likely to deliver high lifetime value.

From a clinical perspective

- target the patients who are most likely to respond well to the treatment over the long term

From a sales and marketing perspective

- focus the effort and funding of patient recruitment on those who are most likely to remain on the therapy for its intended duration

Kal Patel "The Power (And Peril) Of AI In Digital Health". Forbes Technology Council COUNCIL POST. Mar 8, 2024

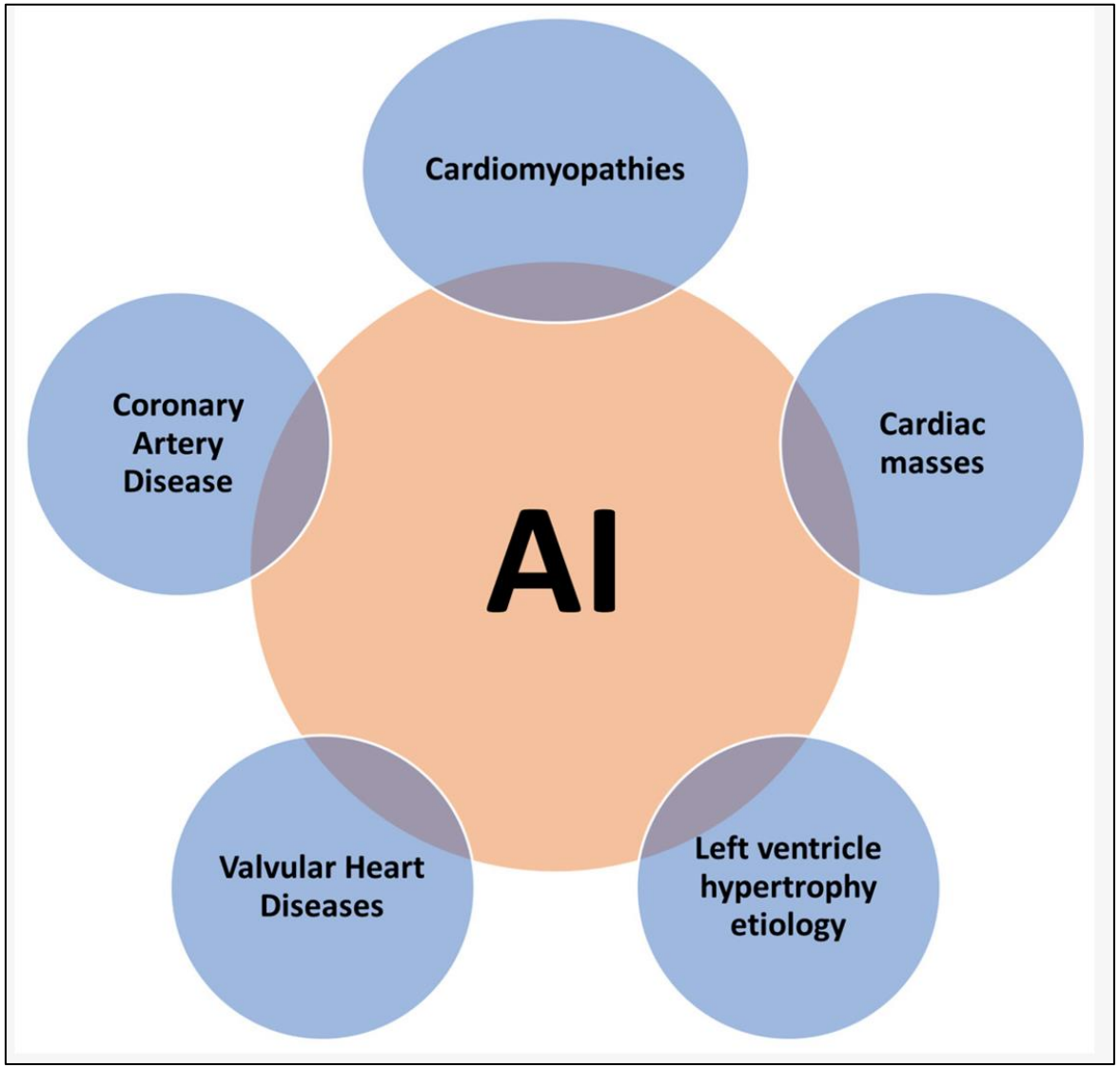
Digital Health: Imaging and diagnostics

Towards Holistic & Comprehensive Cardiac Care

- Technical solutions produce better medical imaging and better diagnostics.

Clinical applications of AI in **echocardiography**

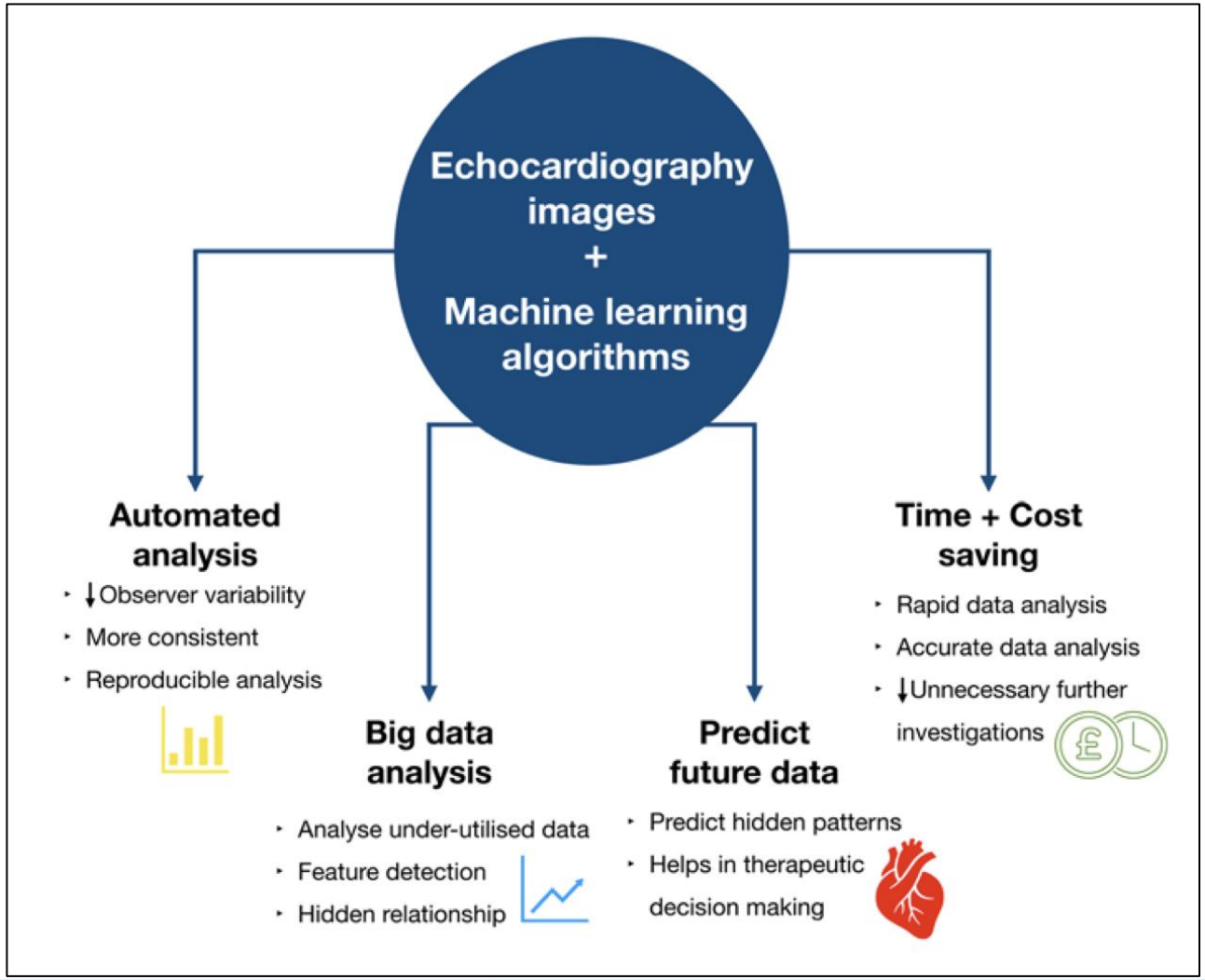
Towards Holistic & Comprehensive Cardiac Care



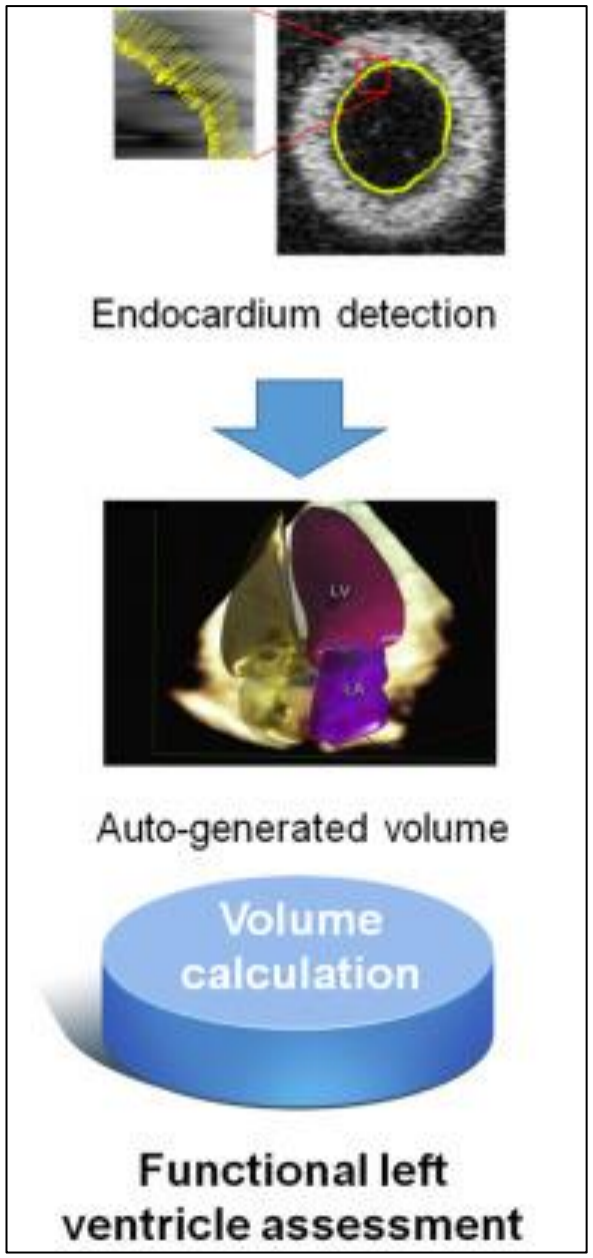
Barry T et al. J. Imaging 20 February 2023, 9(2), 50

Advantages of machine learning assisted echo interpretation

Towards Holistic & Comprehensive Cardiac Care



M Alsharqi et al. https://doi.org/10.1530/ERP-18-0056



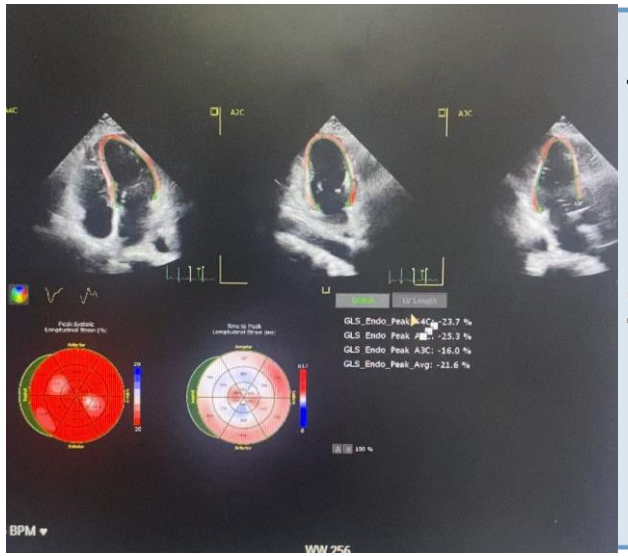
Functional LV assessment

Towards Holistic & Comprehensive Cardiac Care

- It is one of the most important and routine examination procedure in echocardiographic diagnosis.
- Indicators of the left ventricle systolic function
  - LV ejection fraction
  - LV volume
  - Wall motion and myocardial contractility
  - Global longitudinal strain (GLS)

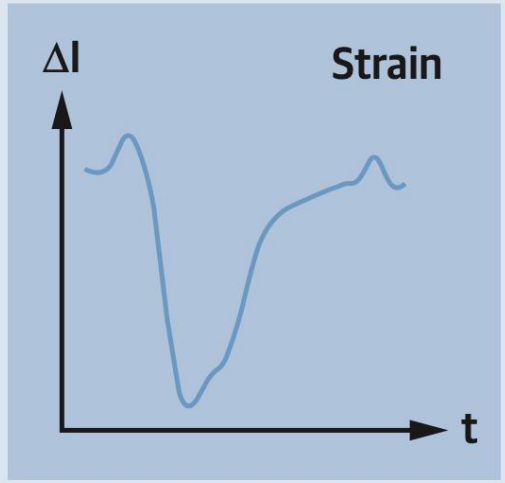
Jia Zhou et al. Cardiac Ultrasound. 2021 Aug 20;19(1):29.

AI for automatic measurement of LV Strain in Echo



1. Baseline myocardial length is extracted from the segmentation mask centerline at end diastole

2. The centerline is updated by the optical flow vector field for every frame in cycle



Care

P: n= 200; wide range of LV function, 61 ± 14 yrs, 72% males
I: Global longitudinal strain (GLS) using DL and AI
O: AI facilitated the clinical implementation of GLS
M: GLS by AI vs. a commercially available semiautomatic speckle-tracking software

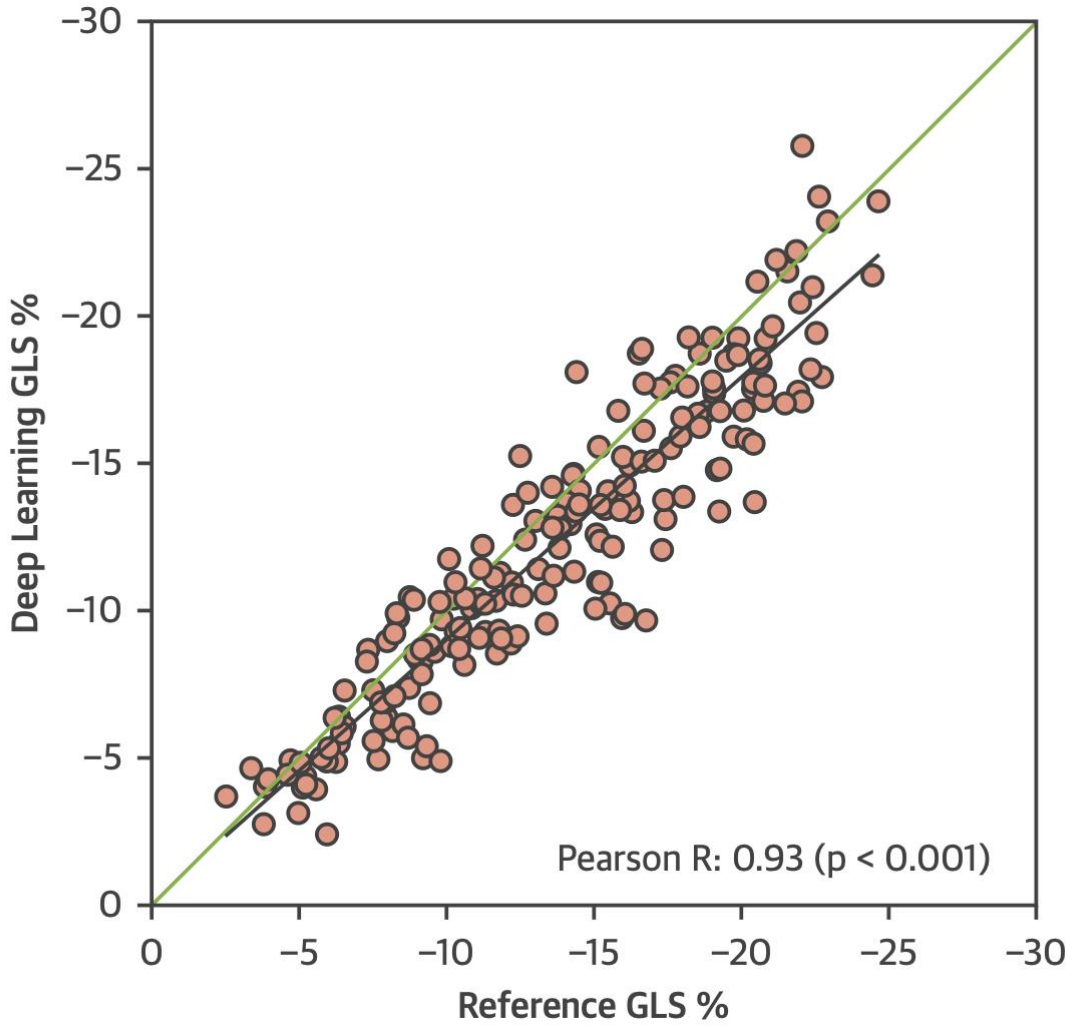
Salte, I.M. et al. J Am Coll Cardiol Img. 2021;14(10):1918–1928.

Fully automated measurements based on AI could facilitate the clinical implementation of GLS.

Mean GLS

AI	**12.1 ± 5.0%**
Conventional method	**13.5 ± 5.3%**

Median absolute deviation: 1.4%
Mean absolute difference: 1.8 ± 1.5%

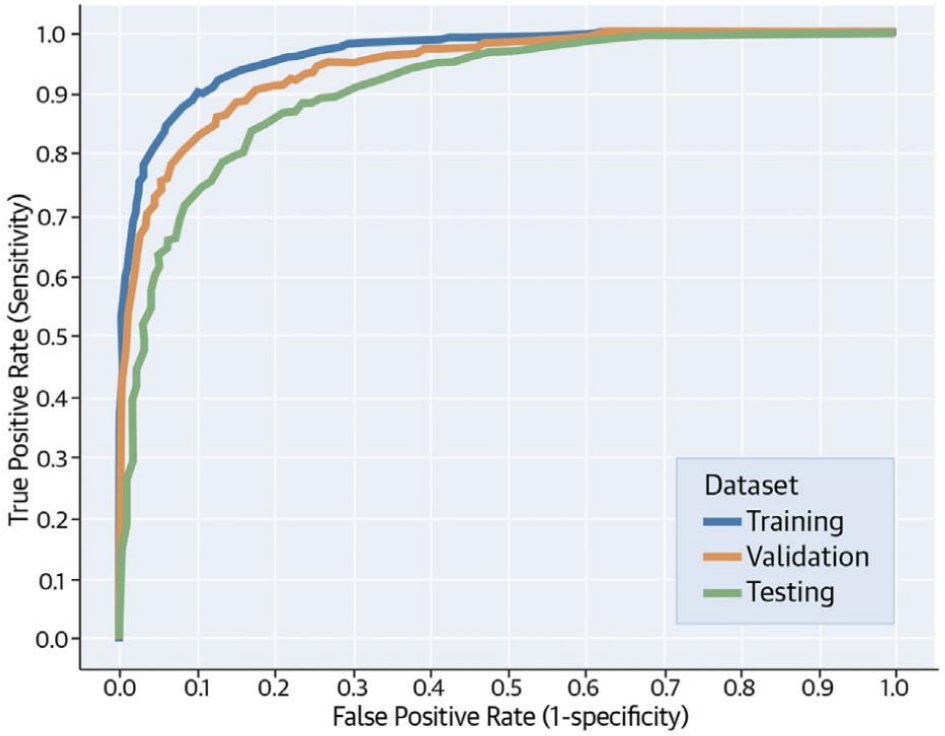


Salte, I.M. et al. J Am Coll Cardiol Img. 2021;14(10):1918–1928.

Automated echocardiographic detection of Heart Failure with Preserved Ejection Fraction (**HFpEF**) using AI

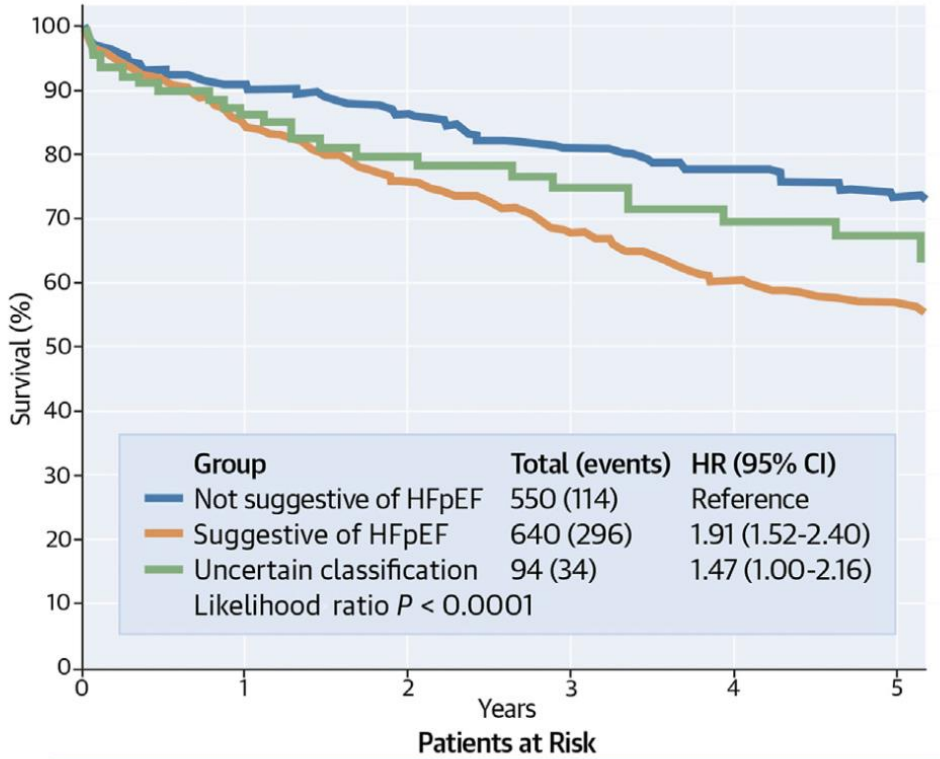
Towards Holistic & Comprehensive Cardiac Care

Classification Performance of AI Model



Training AUROC (95% CI): 0.97 (0.96-0.97)
Validation AUROC (95% CI): 0.95 (0.93-0.96)
Testing AUROC (95% CI): 0.91 (0.90-0.93)

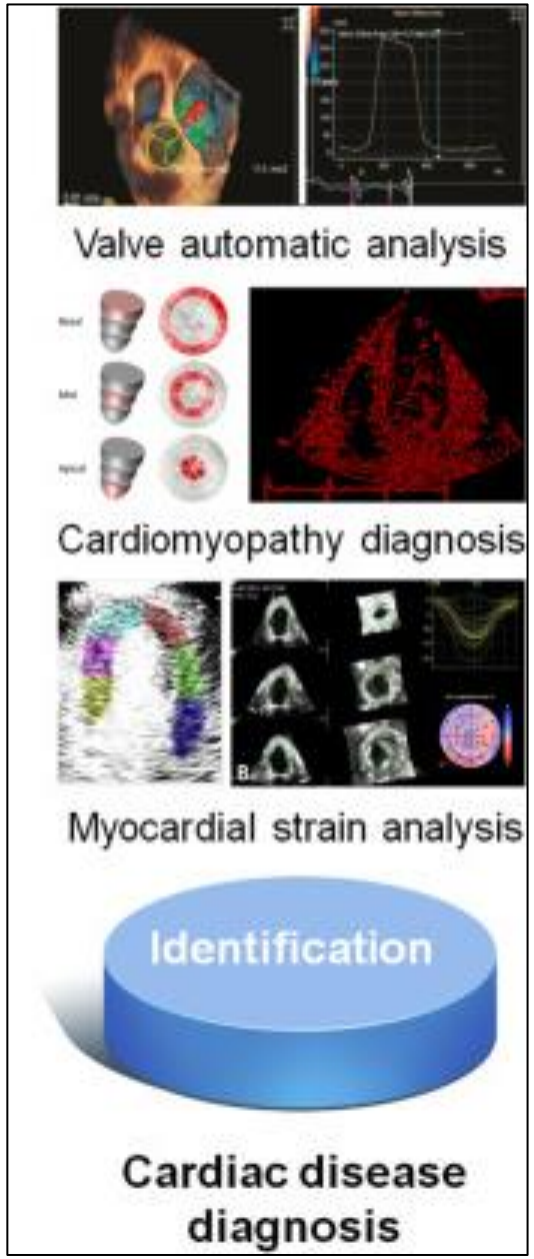
Age-Adjusted Mortality Risk According to AI Model



Patients at Risk

not suggestive of HFpEF	550	421	343	265	216	184
suggestive of HFpEF	640	434	308	229	167	145
uncertain	94	62	48	41	34	30

Ackerman AP et al. ACC Adv 2023;2(6):100452



Cardiac disease diagnosis

- Cardiac valve evaluation
  - Valve morphology
  - Valve regurgitation
- Cardiomyopathy

Jia Zhou et al. Cardiac Ultrasound. 2021 Aug 20;19(1):29.

Machine learning (ML) based phenotypes in patients with MR for transcatheter edge-to-edge repair (MV TEER)

Towards Holistic & Comprehensive Cardiac Care

P: 1426 patients

I: ML model: 609 patients (derivation cohort)

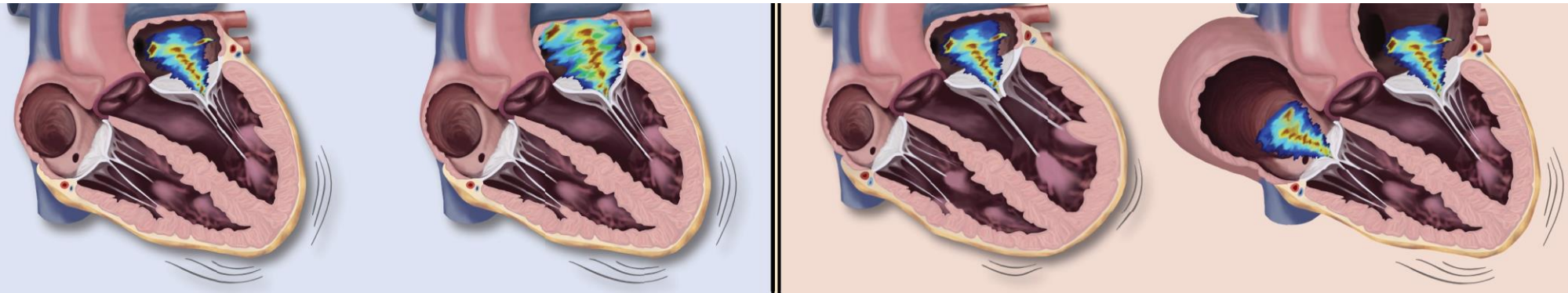
Validation: 817 patients from 2 external institutions

O: Cluster 3 or 4 remains significantly associated with 5-year all-cause mortality

M: Correlation of echo derived MR phenotypes with 5-year survival

Trenkwalder T et al. *Eur Heart J Cardiovasc Imaging*, Volume 24, Issue 5, May 2023, Pages 574–587,

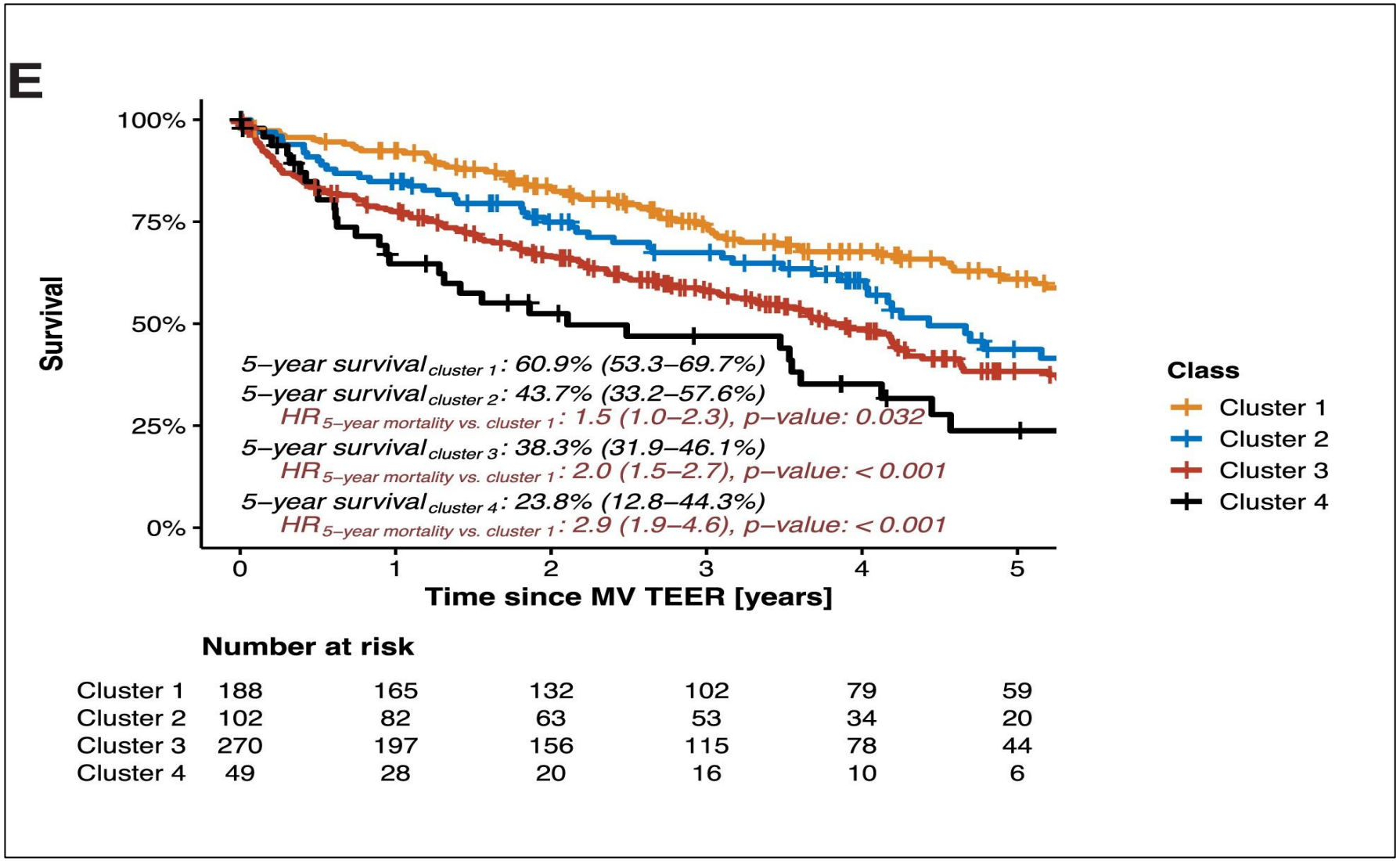
This novel phenotyping approach can refine risk stratification in patients undergoing MV TEER in the future.



Cluster 1: isolated mitral regurgitation	Cluster 2: secondary pulmonary hypertension	Cluster 3: failing left ventricle	Cluster 4: biatrial dilatation
LVEF: 56.5 ± 7.79%	LVEF: 55.7 ± 7.82%	**LVEF: 31.0 ± 10.4%**	LVEF: 51.5 ± 11.0%
LVESD: 35.2 ± 7.52 mm	LVESD: 34.9 ± 7.68 mm	**LVESD: 53.2 ± 10.9 mm**	LVESD: 41.0 ± 13.4 mm
MV EROA: 0.393 ± 0.153 cm^2	**MV EROA: 0.623 ± 0.360 cm^2**	MV EROA: 0.287 ± 0.123 cm^2	MV EROA: 0.438 ± 0.176 cm^2
LA volume: 117 ± 38.3 mL	LA volume: 149 ± 48.6 mL	LA volume: 142 ± 44.5 mL	**LA volume: 312 ± 113 mL**
sPAP: 42.0 ± 11.1 mmHg	**sPAP: 68.4 ± 16.2 mmHg**	sPAP: 48.8 ± 14.6 mmHg	sPAP: 48.9 ± 10.3 mmHg
TAPSE: 20.9 ± 4.20 mm	TAPSE: 17.0 ± 5.27 mm	TAPSE: 14.6 ± 4.11 mm	TAPSE: 17.1 ± 5.09 mm
RA area: 22.7 ± 5.84 cm^2	RA area: 28.0 ± 6.85 cm^2	RA area: 29.0 ± 10.3 cm^2	**RA area: 46.0 ± 8.83 cm^2**
5-year survival 60.9% (95% CI: 53.3–69.7%)	**5-year survival 43.7%** P=0.032 **(95% CI: 33.2–57.6%)**	**5-year survival 38.3%** P<0.001 **(95% CI: 31.9–46.1%)**	**5-year survival 23.8%** P<0.001 **(95% CI: 12.8–44.3%)**

Trenkwalder T et al. *Eur Heart J Cardiovasc Imaging*, Volume 24, Issue 5, May 2023, Pages 574–587.

Significant 5-year all-cause mortality in clusters 3 or 4



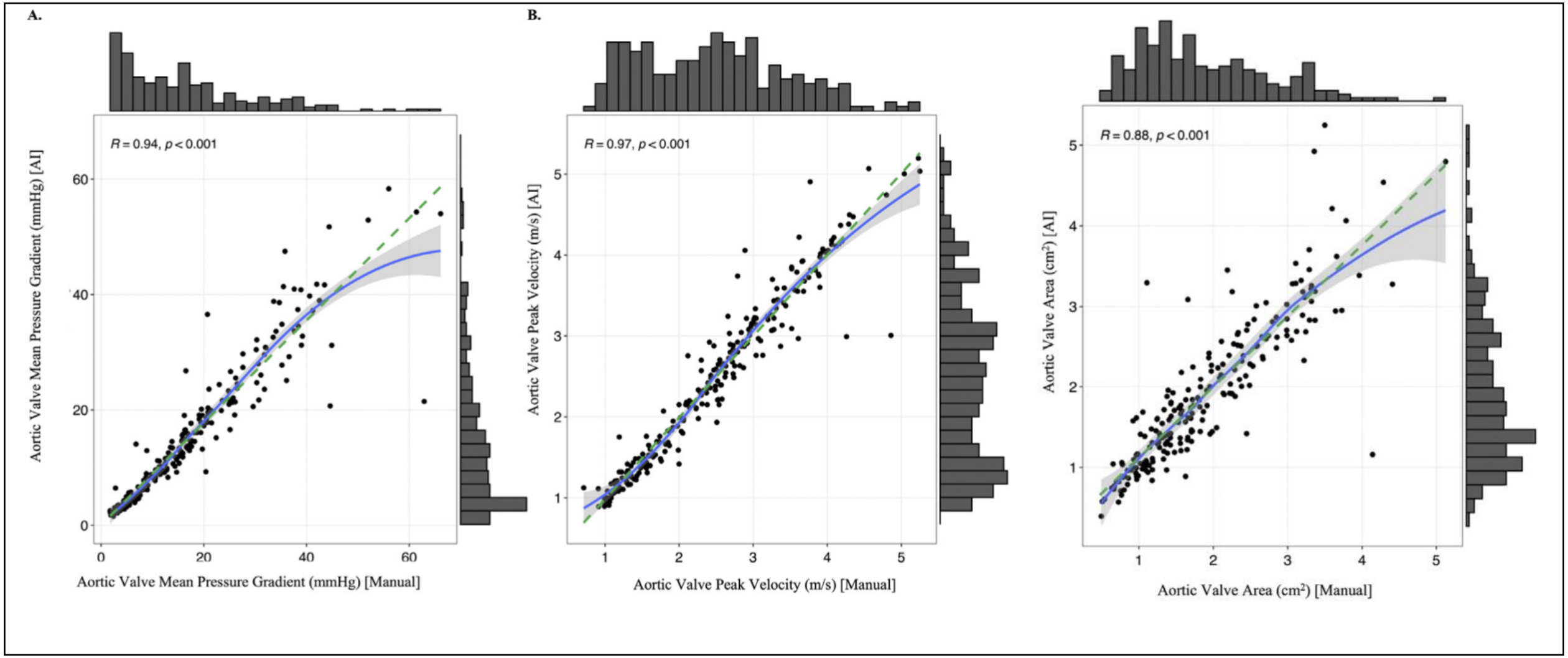
Towards Holistic & Comprehensive Cardiac Care

EACVI European Association of Cardiovascular Imaging
European Society of Cardiology

OXFORD UNIVERSITY PRESS

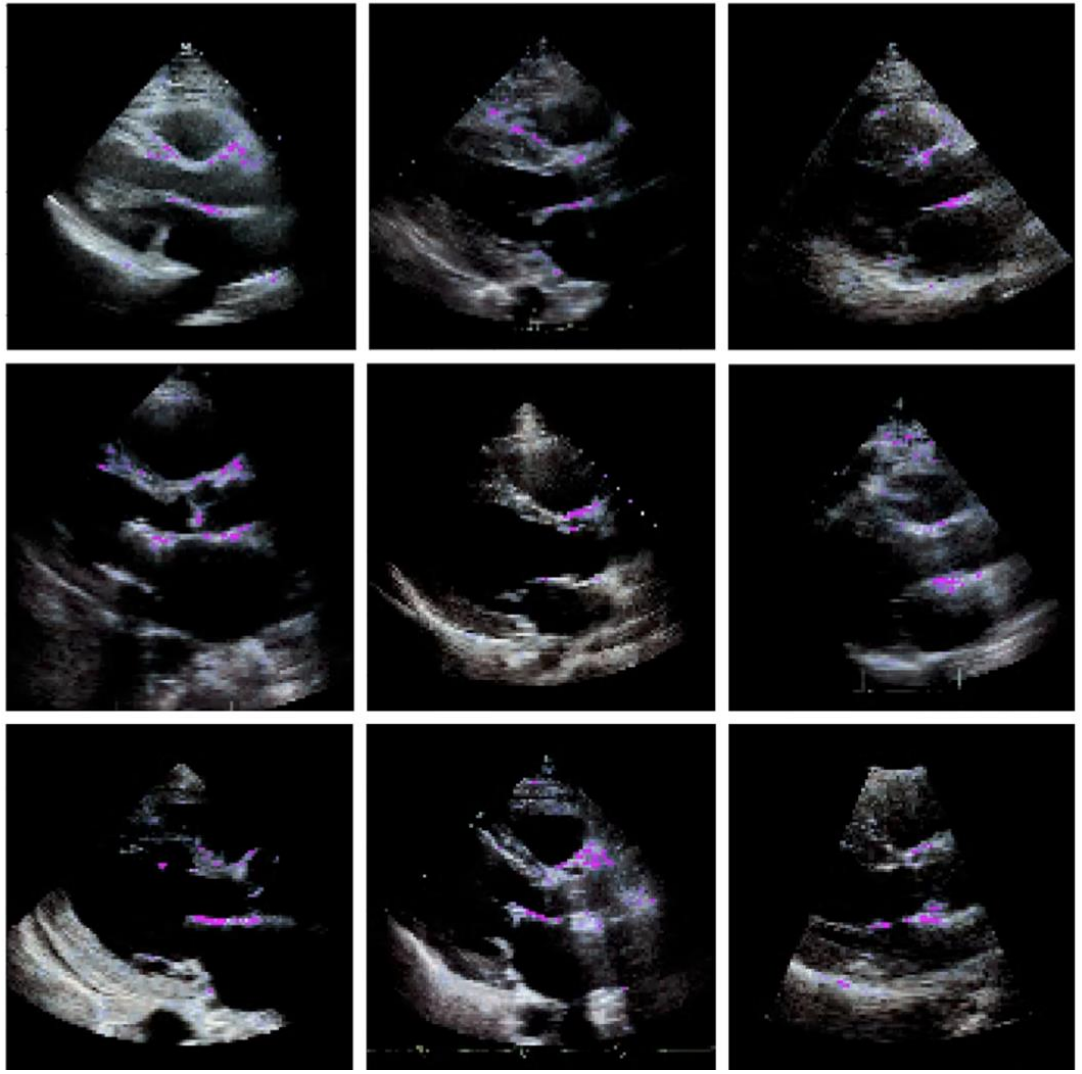
Eur Heart J Cardiovasc Imaging, Volume 24, Issue 5, May 2023, Pages 574–587, https://doi.org/10.1093/ehjci/jead013.

Aortic Stenosis: AI mimics human measurement of all relevant parameters in the adjudication of severity



Krishna H et al. J Am Soc Echocardiogr 2023;36:769-77.)

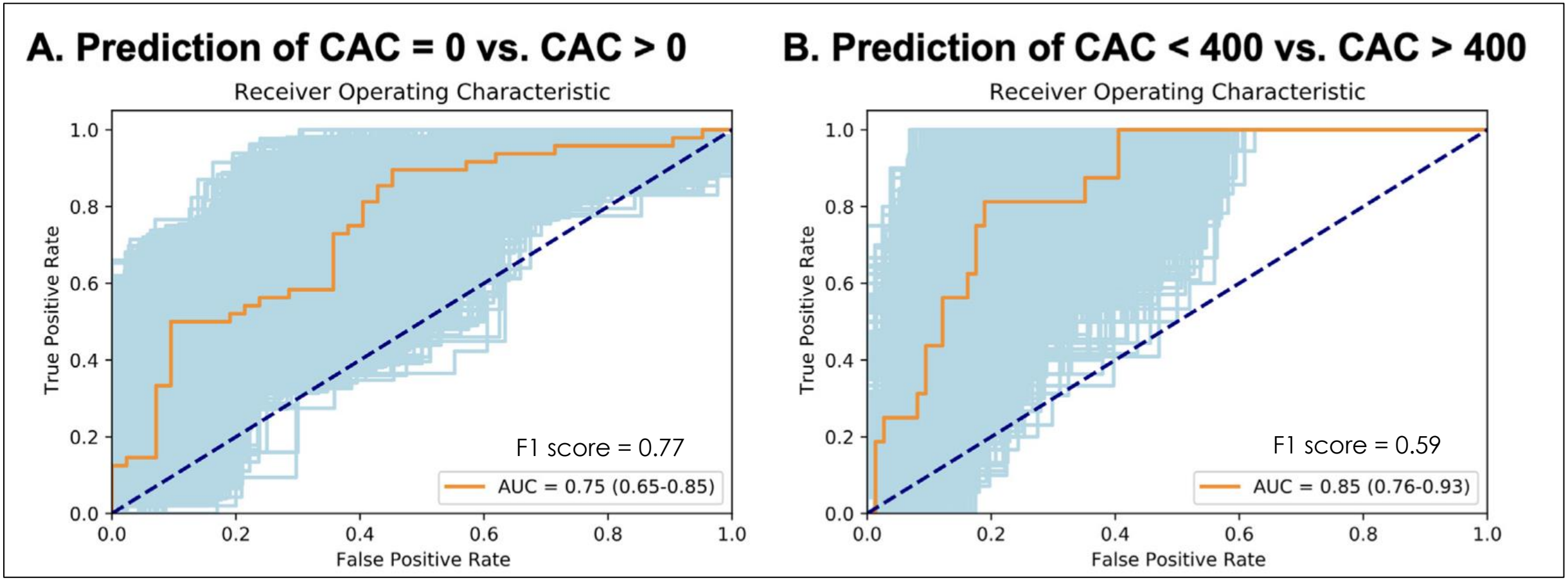
Deep learning (DL) prediction of coronary artery calcium score



- N = 1635 patients, mean age 72 yrs, 37.4% female and 31.4% nonwhite; CV comorbidities (25.4% HTN, 36.9% heart failure, 59.8% hyperlipidemia)
- Data set of 2881 TTE videos paired with coronary calcium computerized tomography (CT) scores
- A video-based AI convolutional neural network (CNN) was trained to predict CAC scores and prognosticate 1-year survival.

Yuan N et al. J Am Soc Echocardiogr 2023;36:474-81

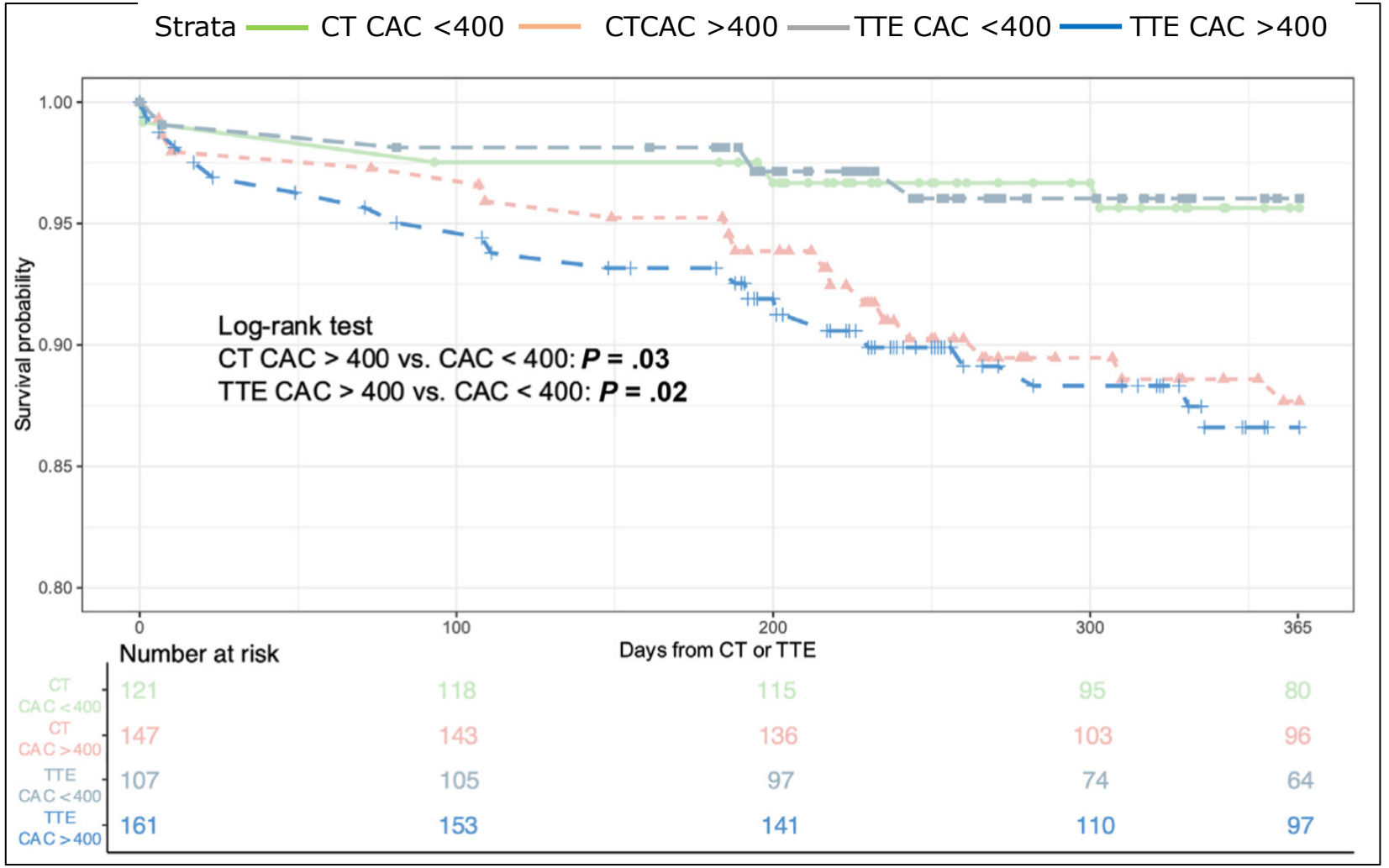
AI model was able to predict patients who had zero and high coronary calcium score.



Performance characteristics of a DL model for predicting CAC using PLAX TTE videos when applied to an external site test data set.

Yuan N et al. J Am Soc Echocardiogr 2023;36:474-81

TTE-predicted CAC >400 and CT CAC score >400 significantly predicted 1-year survival.



Kaplan-Meier survival curves for all-cause mortality over 1 year for patients in a held-out test data set stratified by CT CAC score < 400 versus >400 or by TTE-predicted CAC score < 400 versus >400.

Yuan N et al. J Am Soc Echocardiogr 2023;36:474-81

How does AI compare with the sonographers?

Blinded, randomized trial of sonographer versus AI cardiac function assessment

Bryan He, Alan C. Kwan, Jae Hyung Cho, Neal Yuan, Charles Pollick, Takahiro Shiota, Joseph Ebinger, Natalie A. Bello, Janet Wei, Kiranbir Josan, Grant Duffy, Melvin Jujjavarapu, Robert Siegel, Susan Cheng ✉, James Y. Zou ✉ & David Ouyang ✉

Nature **616**, 520–524 (2023) | Cite this article

- Blinded, randomized, non-inferiority trial
- June - August 2019 at Cedars-Sinai Medical Center

- Prospective evaluation by (mean years of practice):
  -25 cardiac sonographers (14.1 years)
  -10 cardiologists (12.7 years)

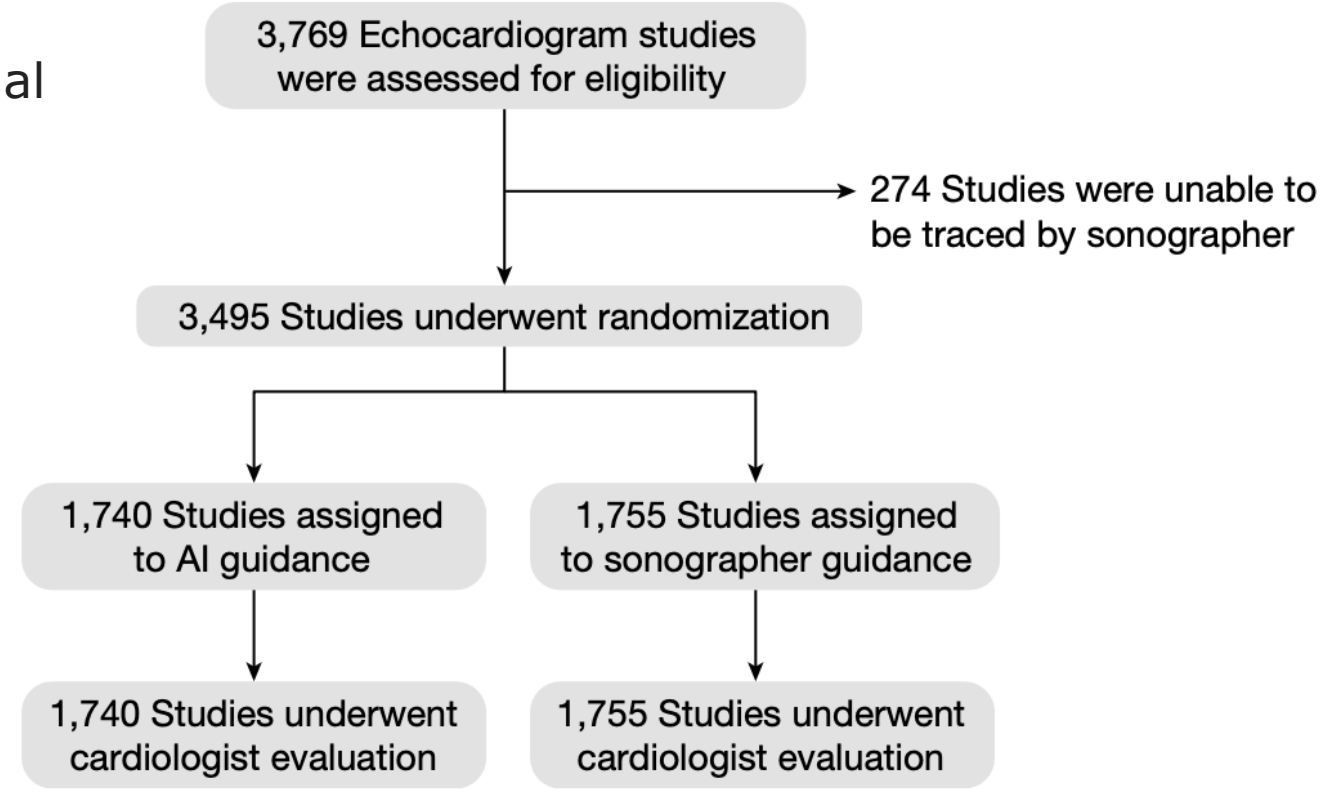
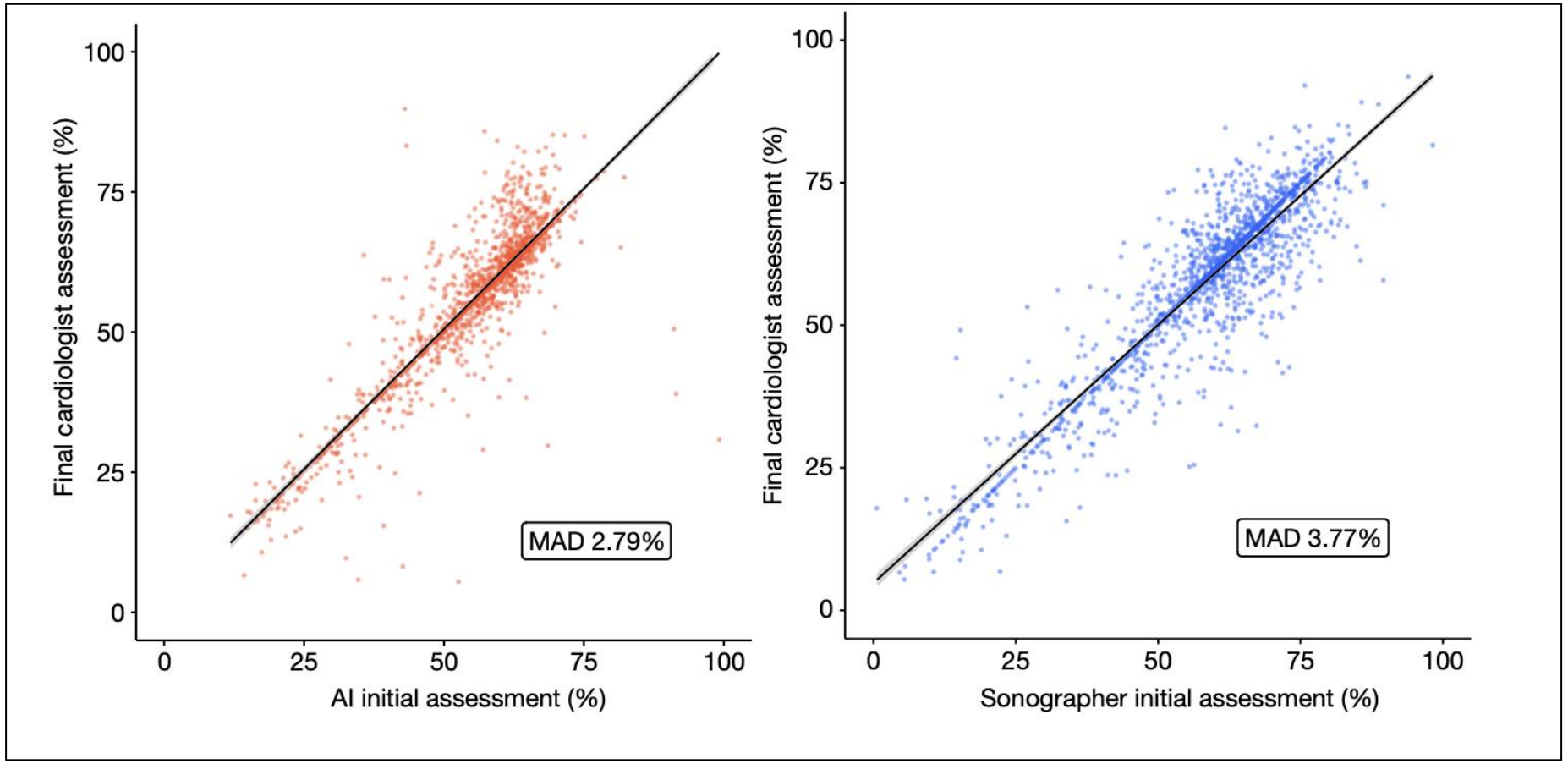


Fig. 1 | Consort diagram. Screening, randomization and follow-up.

AI-guided initial evaluation of LVEF was non-inferior and even superior to sonographer-guided initial evaluation.

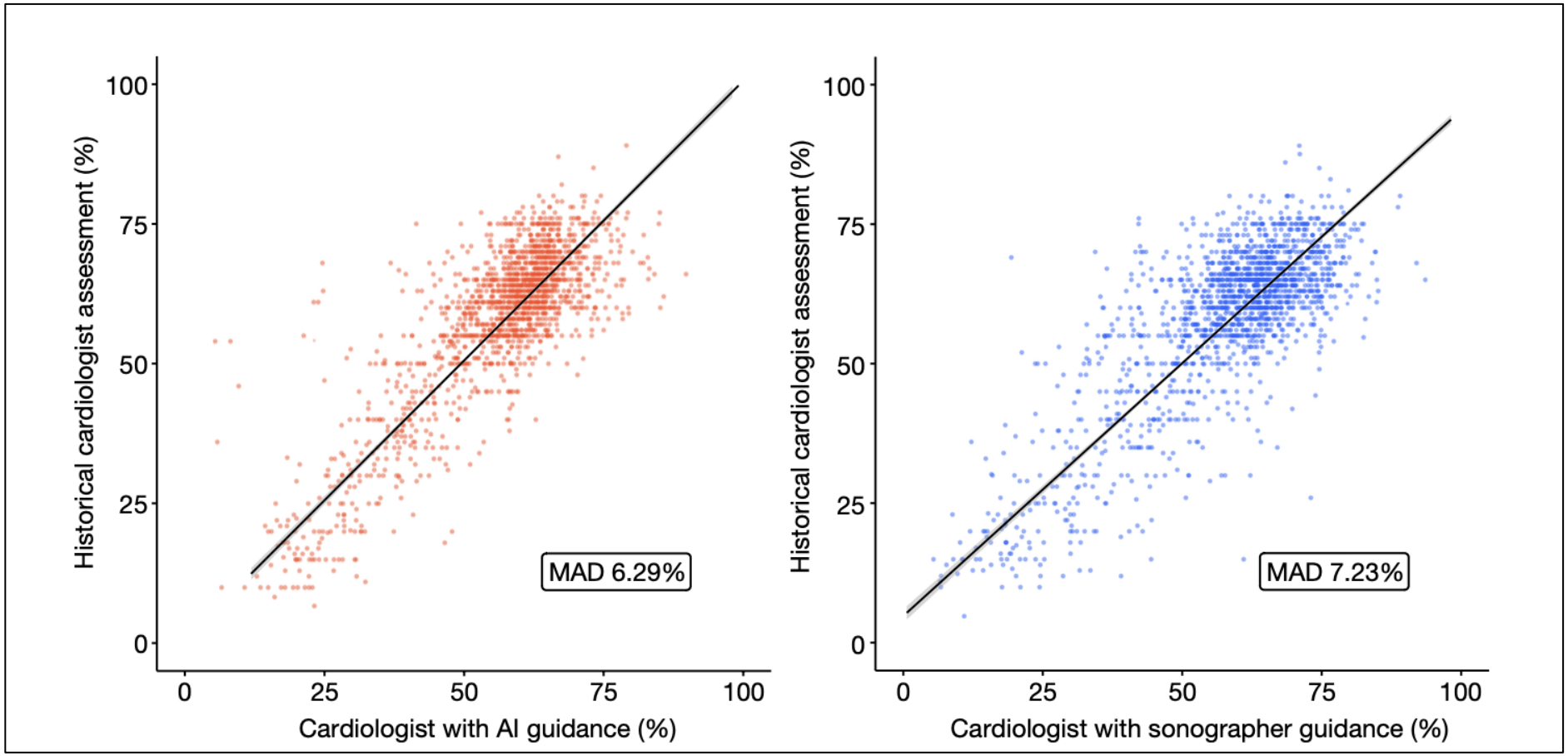


(Difference − 0.97%, 95% CI: −1.33% to −0.54%) P < 0.001 for superiority

MAD- Mean absolute difference

He B et al. *Nature*. 616, pages 520–524 Published online April 5, 2023

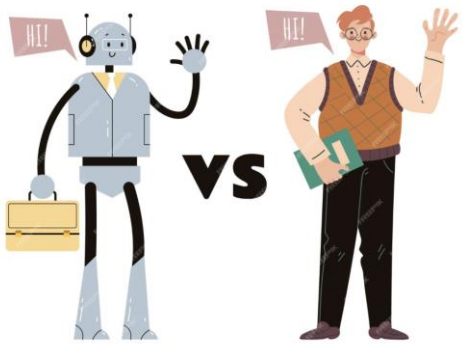
Cardiologists with initial AI guidance were less likely to substantially change the LVEF assessment for their final report.



(Difference −0.94%, 95% CI: −1.34% to −0.54%) $P < 0.001$ for superiority

MAD- Mean absolute difference

He B et al. *Nature*. 616, pages 520–524 Published online April 5, 2023



AI

- Efficiency of AI in data analysis
- Automation
- AI doesn’t get fatigued or biased
- Predictive healthcare and early intervention
- Reducing health care cost
- Staying at the forefront of knowledge

Human

- Human touch, empathy, and patient-doctor relationship
- Ethical implications and accountability challenges with AI
- The potential for AI to misdiagnose or be influenced by biases in the training data

ESC Congress 2023, Amsterdam

Privacy, security and other concerns with AI

Towards Holistic & Comprehensive Cardiac Care

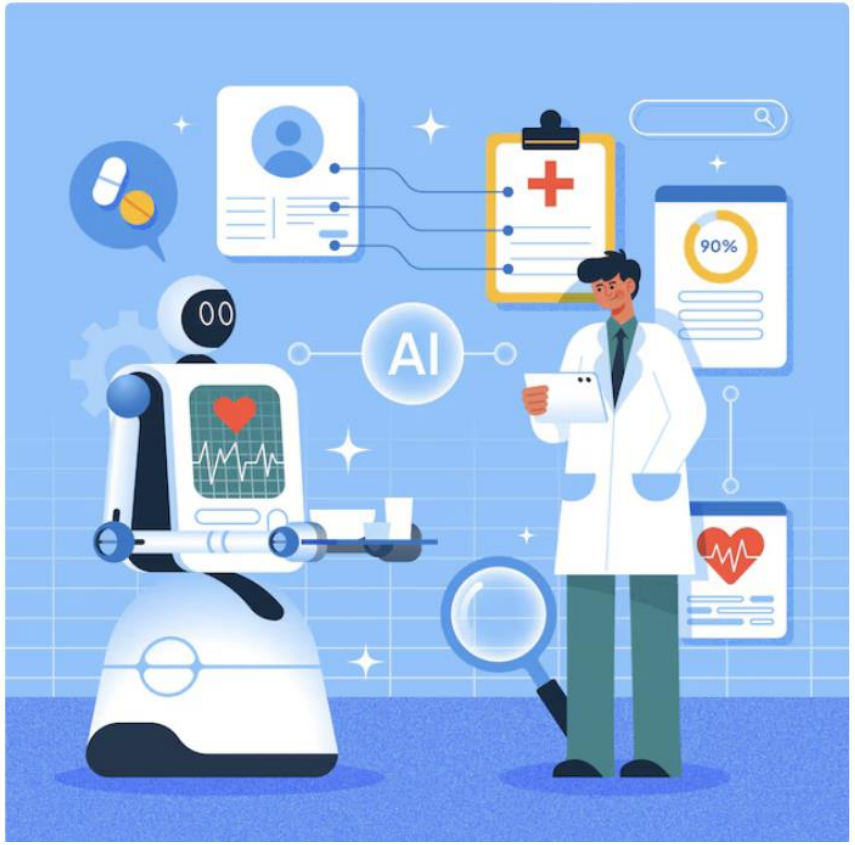
- Ensure that the data are safely and securely stored.
- Avoid bias. Ensure that the app's output is applicable to its intended patient population.
- Regulatory landscape
  - App developers need to keep abreast of regulatory developments and make sure their products guarantee compliance across multiple jurisdictions worldwide.

Towards Holistic & Comprehensive Cardiac Care

"Within the next few years, patients will go to their primary care facility for a medical problem.

They'll be greeted by a nonhuman who speaks in the language of their choice. Based upon the initial interview, which will be taken in note form, the patient will be diagnosed, and a prescription called into the pharmacy.

They'll pay the robot at a reception kiosk, and their meds will be delivered via driverless car."



Primary Care Meets Artificial Intelligence
Lambeth Hochwald, Medscape Cardiology, July 25, 2024

"AI is dramatically changing the field and

the role of the physician

BUT

it is not making the cardiologists superfluous".

2023 ESC Congress, Amsterdam

Towards Holistic &
Comprehensive Cardiac Care

Towards Holistic &
Comprehensive Cardiac Care