

COME L'INTELLIGENZA ARTIFICIALE STA CAMBIANDO, E CAMBIERÀ GLI ALGORITMI DEI DISPOSITIVI CARDIACI IMPIANTABILI



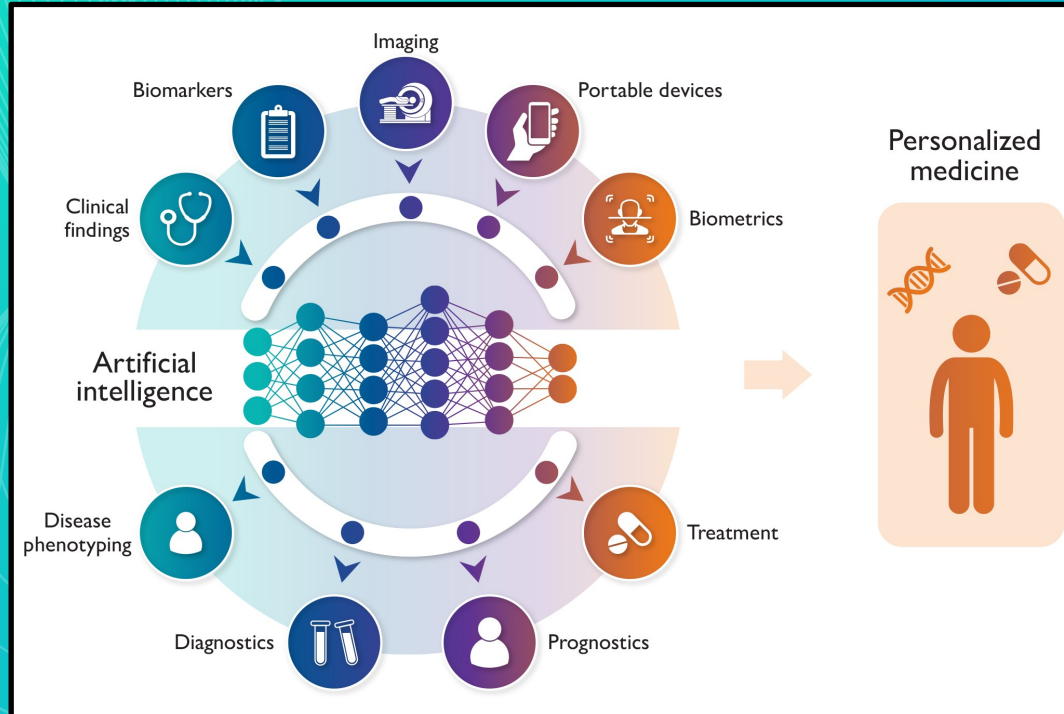
**Analisi automatica degli ECG ed EGM:
dalle applicazioni attuali alla clinica predittiva.
AI nella lettura ECG e negli ICM**

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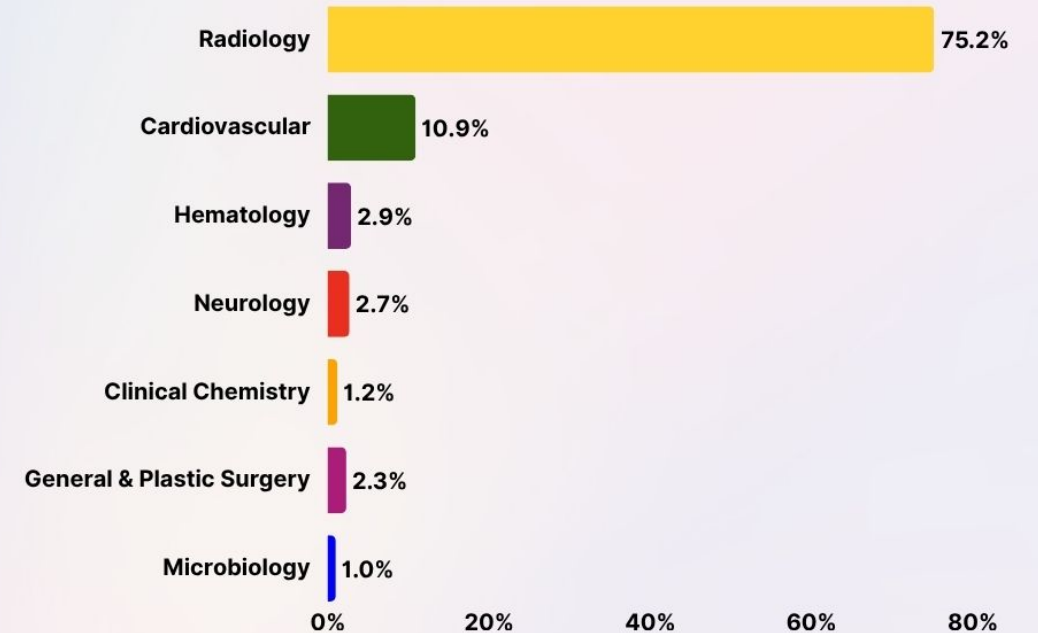


AI in Cardiology



Lusher et al, Eur Heart J 2024

AI-ENABLED DEVICES IN MEDICAL FIELDS



Source: SQ Magazine

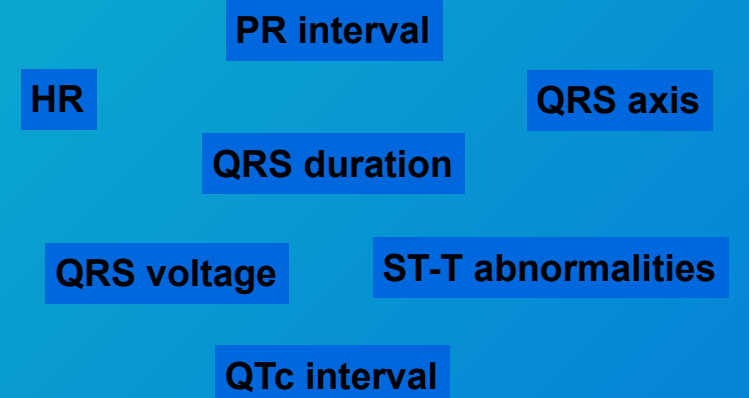
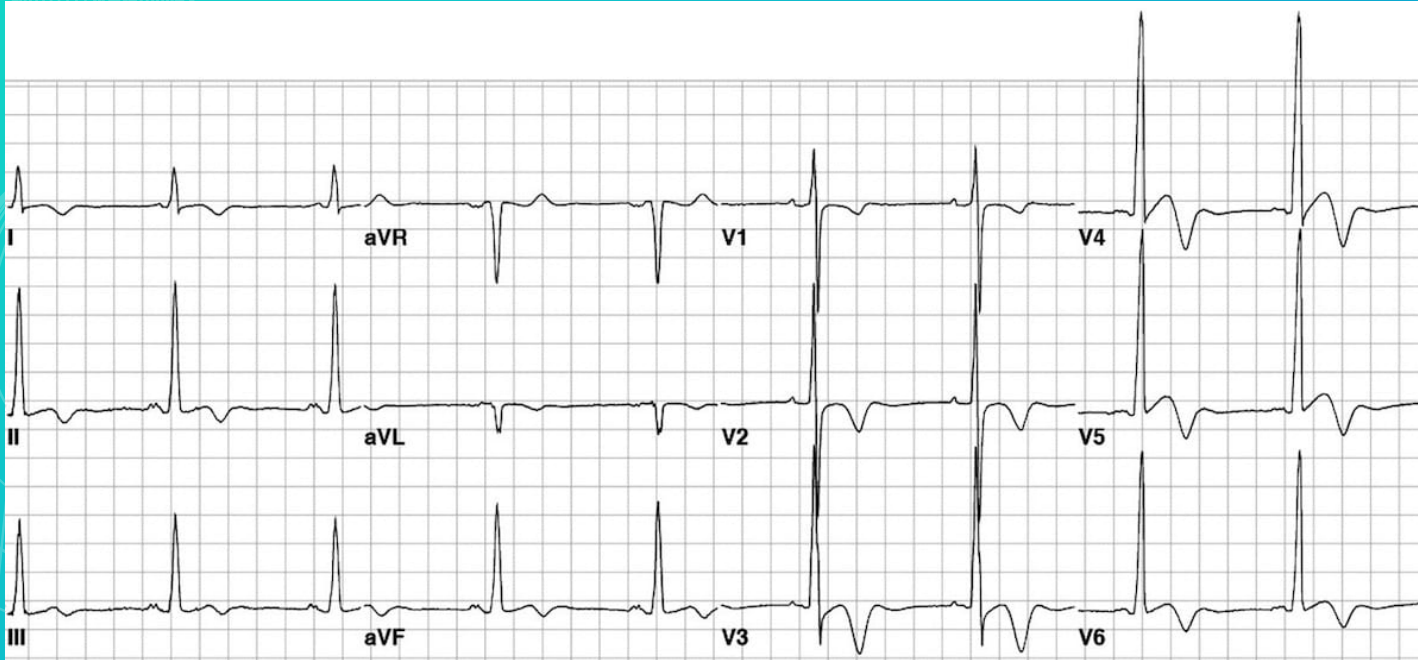
AI applied to 12-lead ECG and ICM

12-lead ECG

ICM



“Classic” human-based ECG analysis



*Human-based integration
of the above features*

Diagnosis

HCM

Limitation of the “Classic” approach

1

Limited number of features contemporarily integrated

2

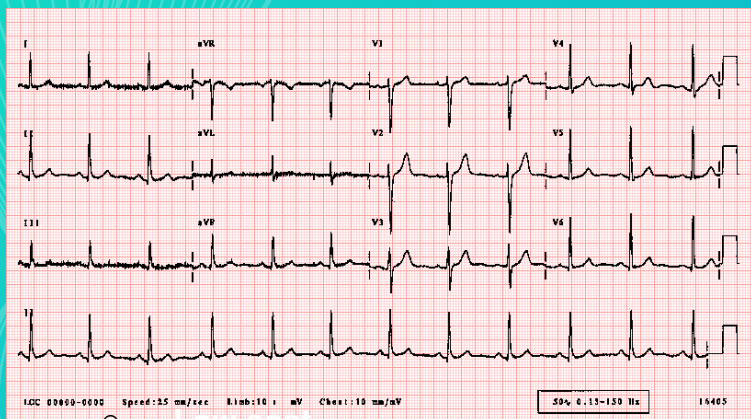
Only “known” (already described) features can be used for analysis

3

Limited capture of complex non-linear interaction between the features

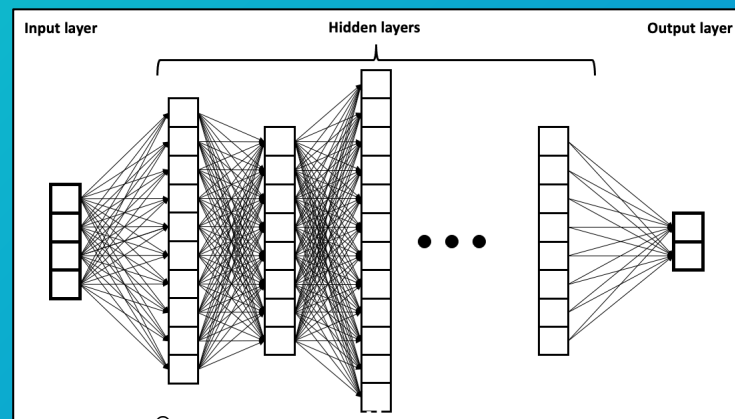
AI-powered electrocardiography

ECG



- Low cost
- Wide availability
- Non invasive

AI



- Computational power
- Automatic feature extraction (deep neural networks - DNN) → known + unknown features

AI-enabled ECG



- Streamlining **human** capability
- First pass interpretation
 - Triage work flow
 - Scalability

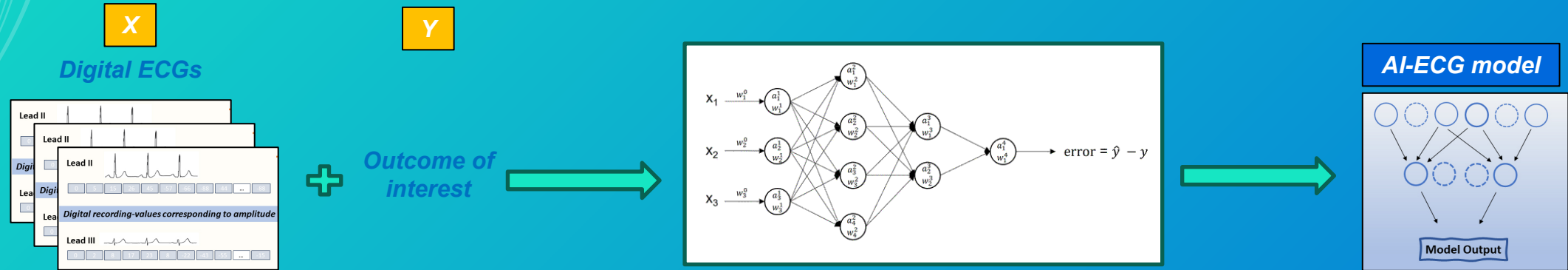


- Beyond **human** capability
- Seeing what a clinician cannot
 - 'Value-added' ECG read
 - Moving beyond normal/abnormal

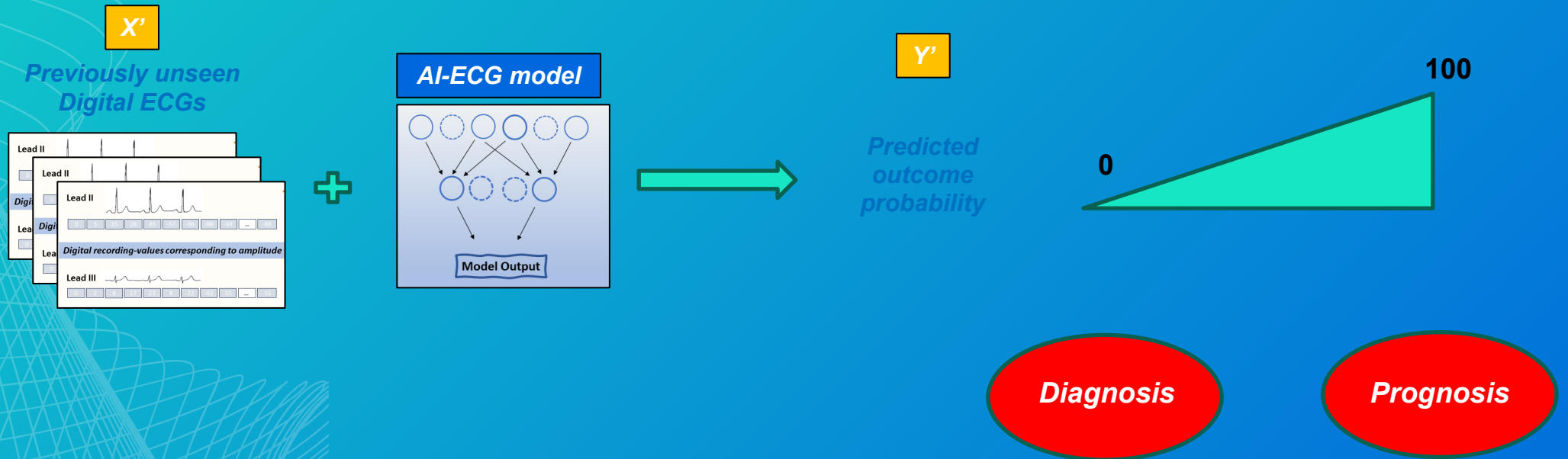


AI-ECG model training and testing

TRAINING



TESTING



Diagnosis

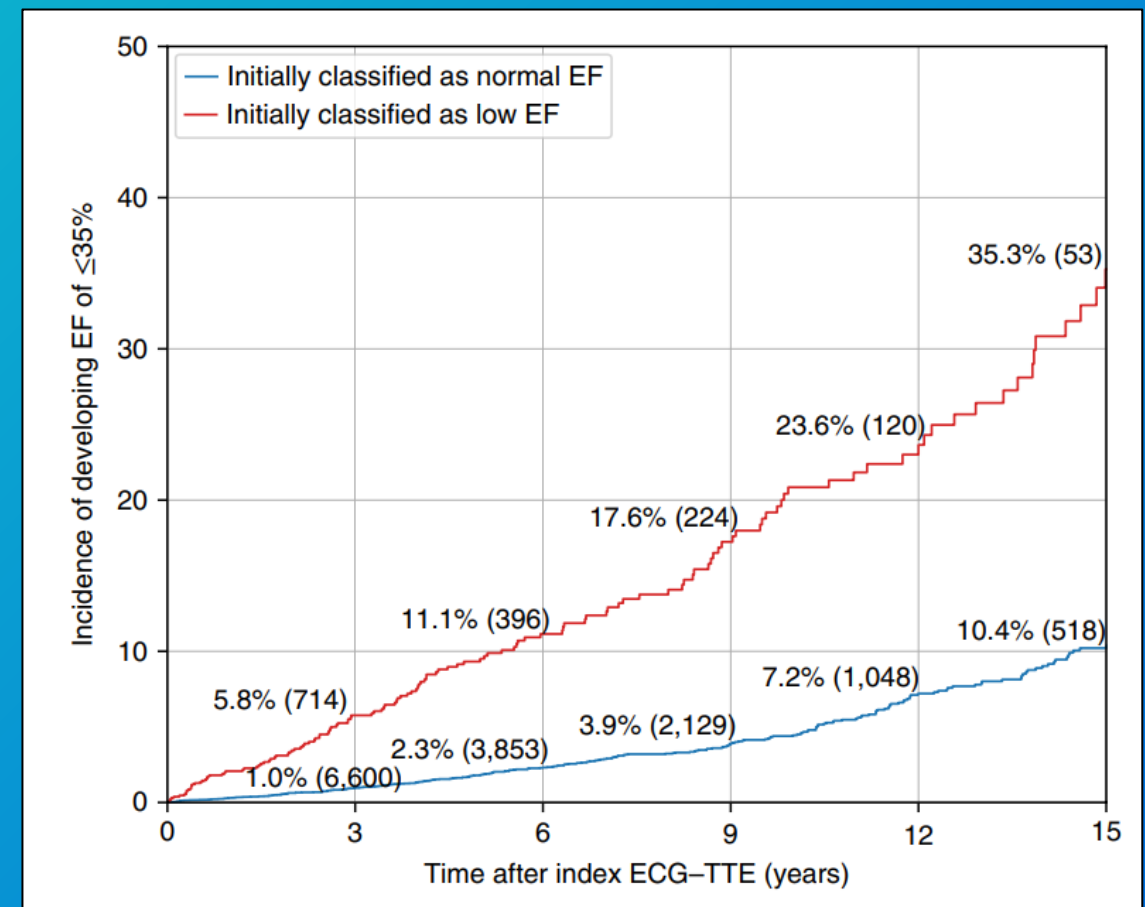
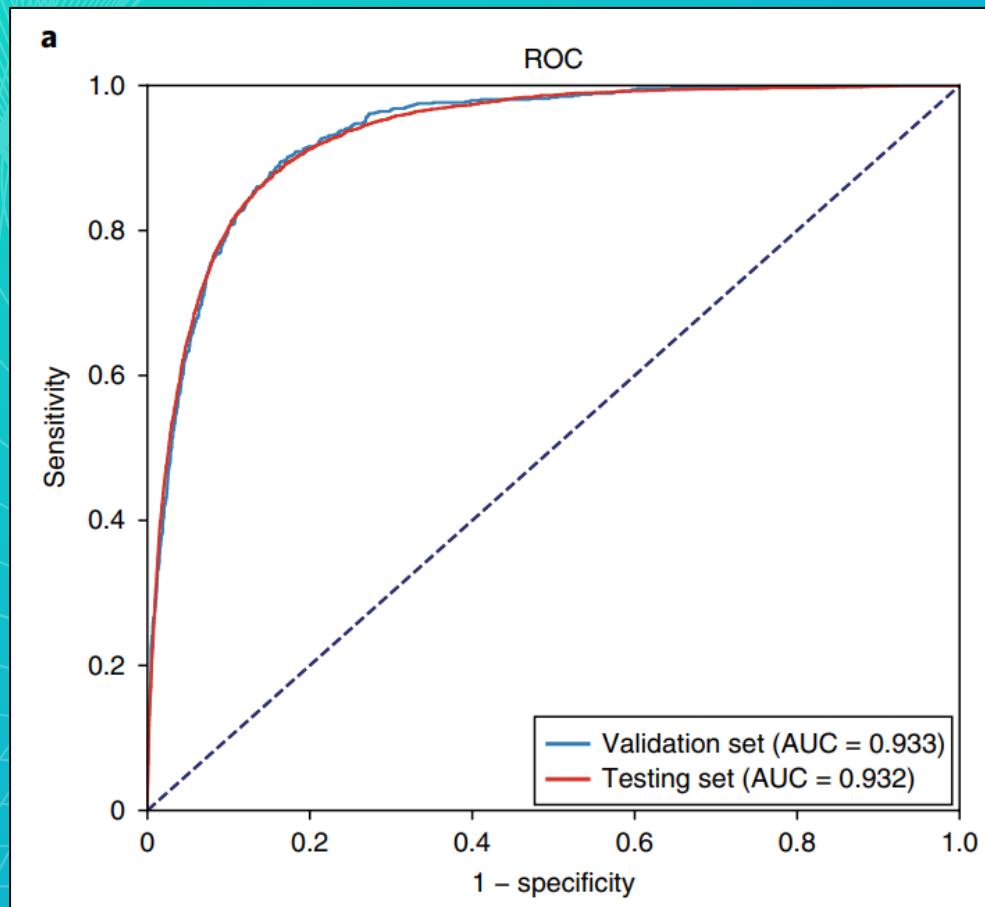
Prognosis

AI-ECG: *low LVEF detection*

LVEF < 35%



Mayo Clinic,
Rochester,
USA



AI-ECG: *diagnostic* framework

«Occult» AFib
from sinus rhythm ECG

Attia et al, Lancet 2019

Low LVEF

Attia et al, Nat Med 2019

Hyperkalemia

Galloway et al, JAMA Cardiol 2019

HCM

Ko et al, JACC 2020



Mayo Clinic, Rochester, USA

Cardiac amyloidosis

Grogan et al, Mayo Clin Proc 2021

Aortic stenosis

Cohen-Shelly et al, EHJ 2021

DCM

Shrivastava et al, Am J Cardiol 2021

ARVC

Haq et al, EHJ Digit Health 2023

LQTS

Bost et al, JAMA Cardiol 2021

Pulmonary hypertension

Du Brock et al, Eur Resp J 2024

AI-ECG: *prognostic* framework

AI-ECG risk estimator platform (AIRE)

Sau et al, Lancet Digital Health 2024 (in press)



Imperial College
London,

12 lead ECG



BIDMC - 190K

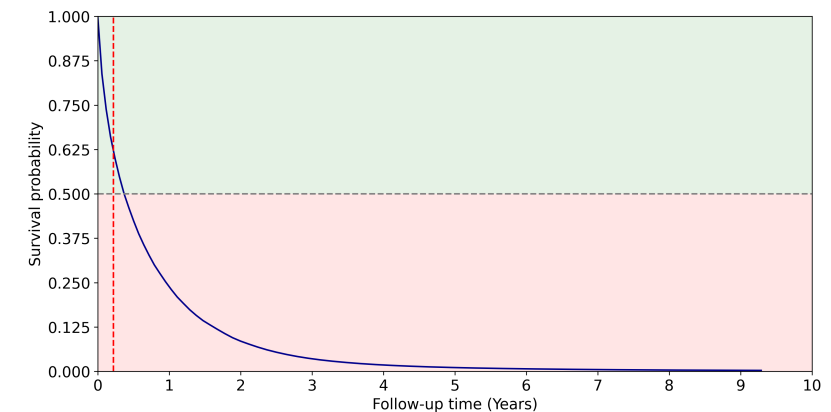
1.2 million ECGs

Random split (by patient)

60% for training/validation

40% hold-out test set

Convolutional neural network



*Patient-specific survival curve
for a given outcome*

AI-ECG: *prognostic* framework

AI-ECG risk estimator platform (AIRE)

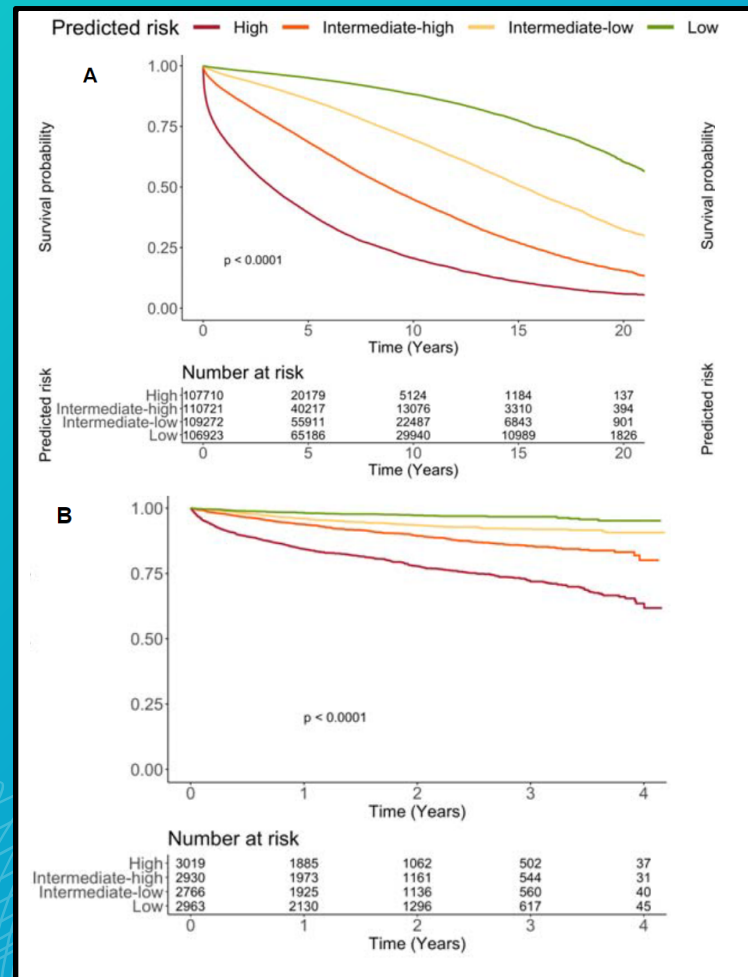
Sau et al, Lancet Digital Health 2024



Imperial College
London,
UK

All-cause death

CV death



Low risk

Reference

Intermediate-low risk

2.04 (2.00-2.09)

Intermediate-high risk

3.95 (3.87-4.04)

High risk

8.73 (8.54-8.91)

Low risk

Reference

Intermediate-low risk

2.21 (1.71-2.87)

Intermediate-high risk

3.60 (2.82-4.59)

High risk

8.04 (6.37-10.16)

AI-ECG: *prognostic* framework

Death

Sau et al, Lancet Digit Health 2024

Atherosclerotic CV disease

Sau et al, Lancet Digit Health 2024

Ventricular arrhythmias

Sau et al, Lancet Digit Health 2024

Incident HTN

Sau et al, JAMA Cardiol 2025

Incident AF

Sau et al, Heart Rhythm 2025



Cardiac Electrophysiology
& AI Research Group



*Imperial College
London,
UK*

Regurgitant VHD

Sau et al, JAMA Cardiol 2025

CV death

Sau et al, Lancet Digit Health 2024

Heart failure

Sau et al, Lancet Digit Health 2024

Incident T2DM

Pastika et al, abstract AHA 2024

Complete heart block

Sau et al, JAMA Cardiol 2025

AI-ECG: *occlusive myocardial infarction* detection

OMI vs non-OMI



European Heart Journal - Digital Health (2024) 5, 123–133
<https://doi.org/10.1093/ehjdh/zta074>

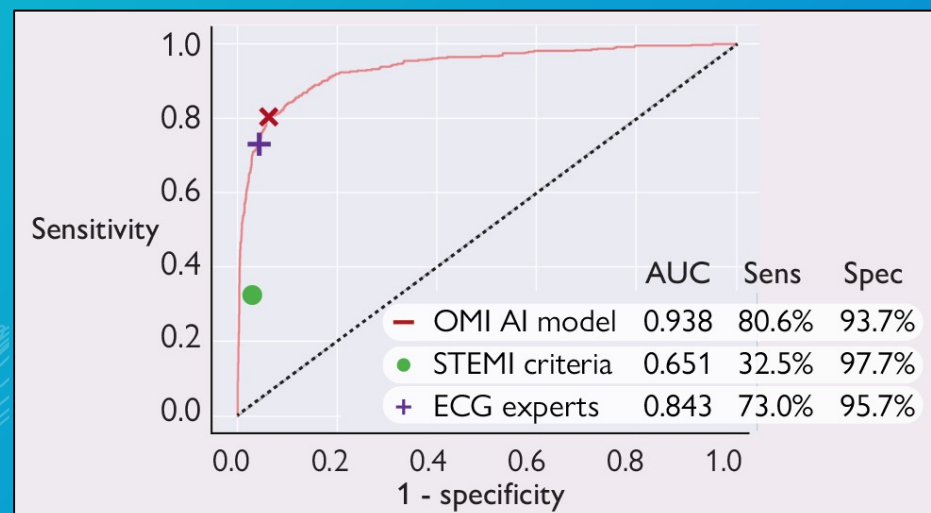
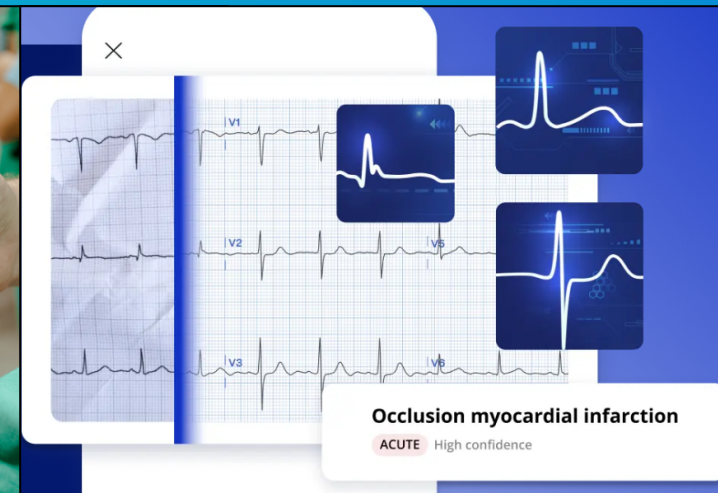
ORIGINAL ARTICLE

International evaluation of an artificial intelligence-powered electrocardiogram model detecting acute coronary occlusion myocardial infarction

Robert Herman^{1,2,3,*}, Harvey Pendell Meyers⁴, Stephen W. Smith^{5,6}, Dario T. Bertolone^{1,2}, Attilio Leone^{1,2}, Konstantinos Bermpeis^{1,2}, Michele M. Viscusi^{1,2}, Marta Belmonte^{1,2}, Anthony Demolder³, Vladimir Boza^{3,7}, Boris Vavrik³, Viera Kresnakova^{3,8}, Andrej Iring³, Michal Martonak³, Jakub Bahyl³, Timea Kisova^{3,9}, Dan Schelfaut², Marc Vanderheyden², Leor Perl¹⁰, Emre K. Aslanger¹¹, Robert Hatala¹², Wojtek Wojakowski¹³, Jozef Bartunek², and Emanuele Barbato¹⁴



Queen of Hearts
AI-ECG model



AI-ECG derived biomarkers

AI-ECG estimated age



Delta age

↑ AI-ECG predicted age higher than chronological age

Increasing positive δ age associated with:

- All-cause and CVD mortality
- Markers of accelerated aging
- CAC score >0



↓ AI-ECG predicted age lower than chronological age

Negative δ age associated with:

- Low CAC scores

δ age influenced by:

- Exercise levels
- Better social connection status

AI-ECG-derived age may provide insights into patients' current and potential future disease status and risk factors

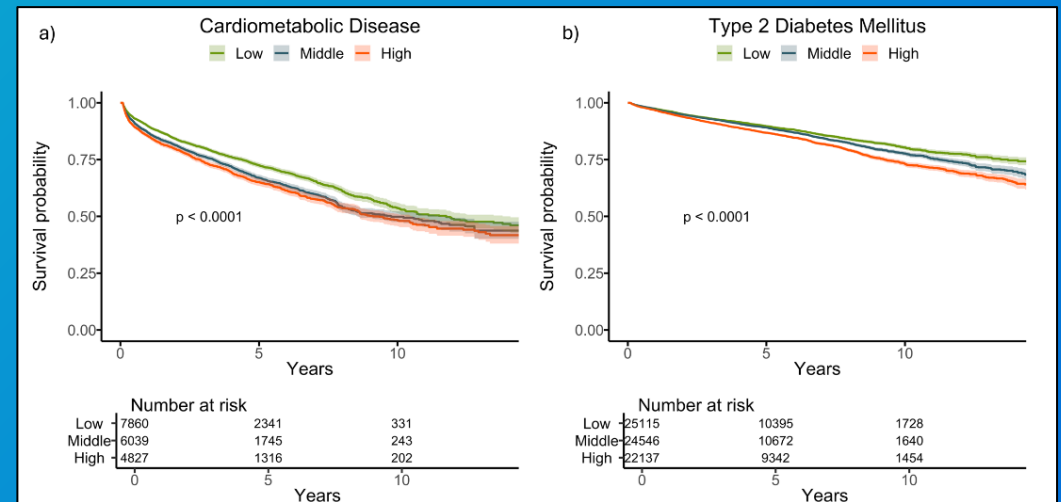
Lopez-Jimenez F et al, JACC EP 2024

AI-ECG estimated body mass index (BMI)



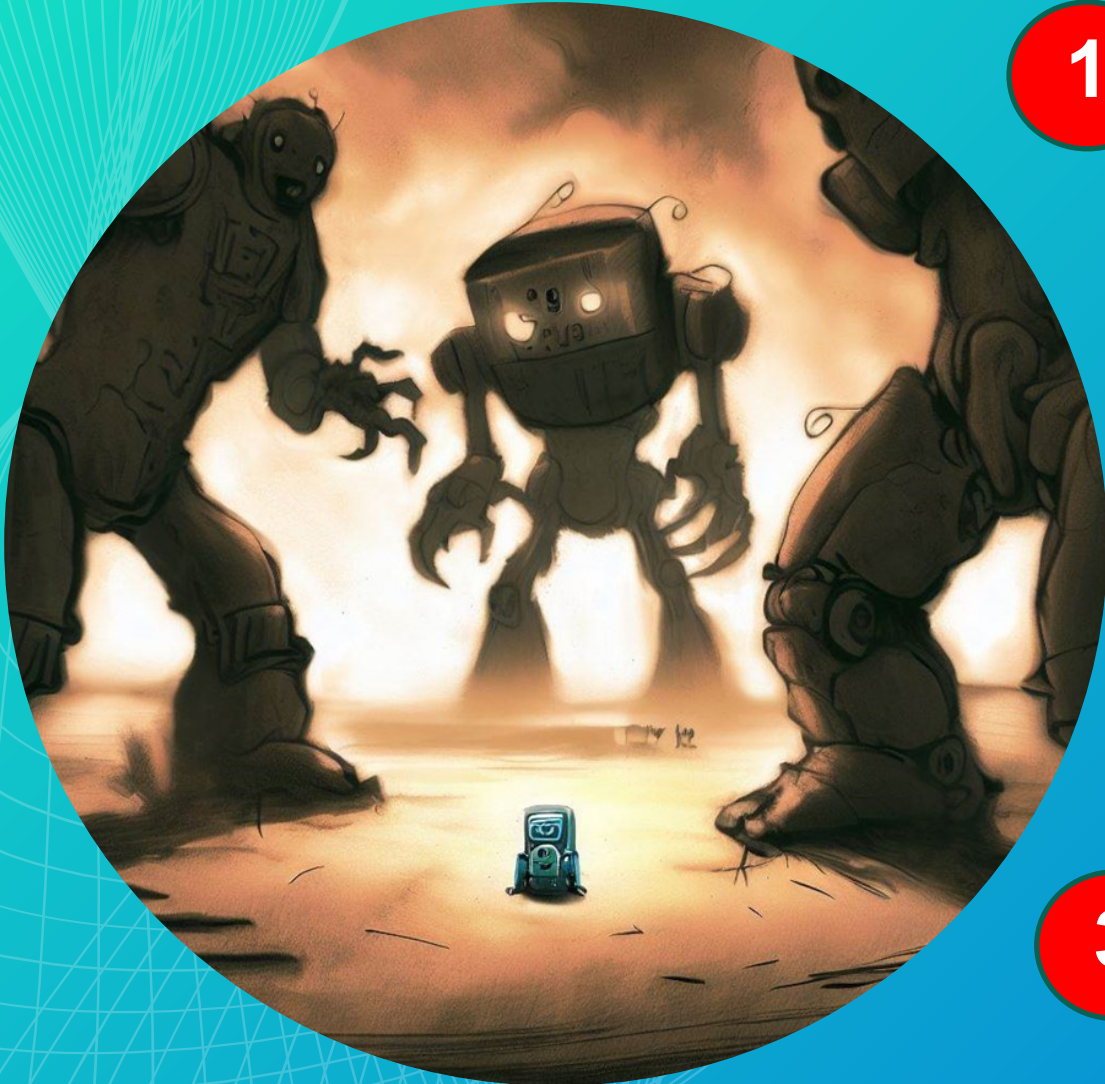
Delta BMI

Higher deltaBMI are associated with cardiometabolic disease



Pastrika et al, NPJ Digit Med 2024

Ongoing issues



1

Explainability

2

Validation and reproducibility in independent datasets

3

Integration into routine clinical workflow

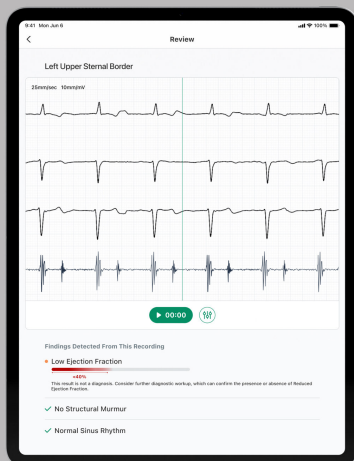
Achille's heel of AI systems: “real-world implementation”



Triple cardiovascular disease detection with an artificial intelligence-enabled stethoscope (TRICORDER) in the UK: a cluster-randomised controlled implementation trial



Mihir A Kelshiker*, Patrik Bächtiger*, Camille F Petri, Saloni Nakhare, Josephine Mansell, Karanjot Chhatwal, Abdullah Alrumayh, Jahed Zaman, Moulesh Shah, Holly Young, Helena Roy, Melanie T Almonte, Céire Costelloe, Yasmin Razak, Azeem Majeed, James P Howard, Carys Barton, Daniel B Kramer, Carla M Plymen, Nicholas S Peters



TRICORDER TRIAL

AI-Enabled Stethoscope for Cardiovascular Detection

Underdiagnosis of cardiovascular disease



Heart Failure



Atrial Fibrillation



Valvular Disease

AI-Enabled Stethoscope



- ECG + Heart Sounds
- AI Algorithms

Cluster RCT



205 Practices

1.55 Million Patients

Randomized Controlled Trial

Achille's heel of AI systems: “real-world implementation”

Population-Level Results

 **NO** Increase in Diagnoses

When Used

- ✓ Heart Failure Detection ↑ IRR 2.33
- ✓ Atrial Fibrillation Detection ↑ IRR 3.45
- ✓ Valvular Disease Detection ↑ IRR 1.92

Key Finding



LOW UPTAKE & INTEGRATION ISSUES

AI effective, but real-world adoption remains limited.

Key Implementation Finding

Main barrier =
low real-world uptake

- Only **12 725 examinations** across **972 clinicians**
- Workflow integration issues limited use.

AI applied to 12-lead ECG and ICM

12-lead ECG

ICM

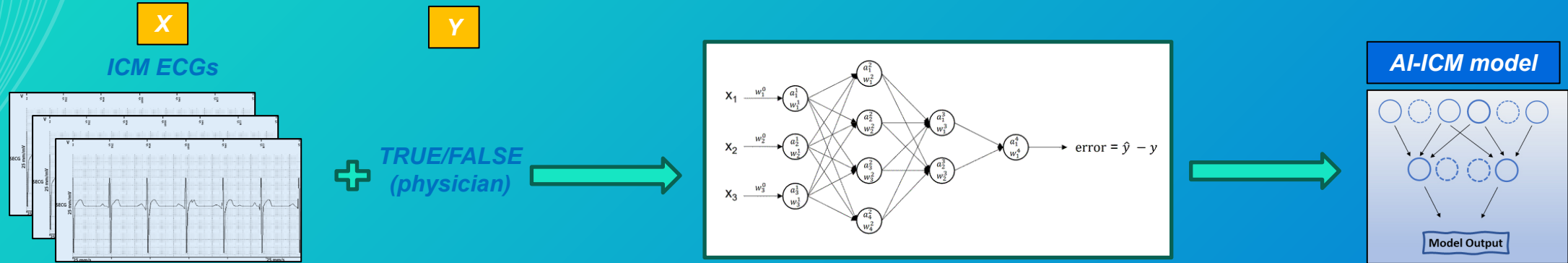


AI in ICM: why we desperately needed it

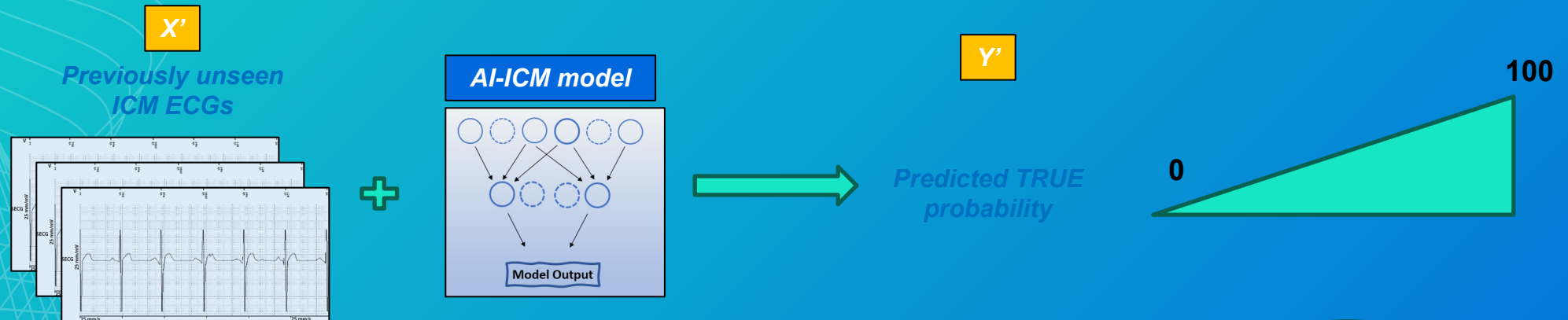
- ✖ ICMs have limitations in their accuracy, leading to a trade-off between sensitivity and specificity.
- ✖ Real-world registries of ICMs show that up to 80% of all detections are not true arrhythmias.

AI in the context of ICM ECGs

TRAINING



TESTING



Diagnosis

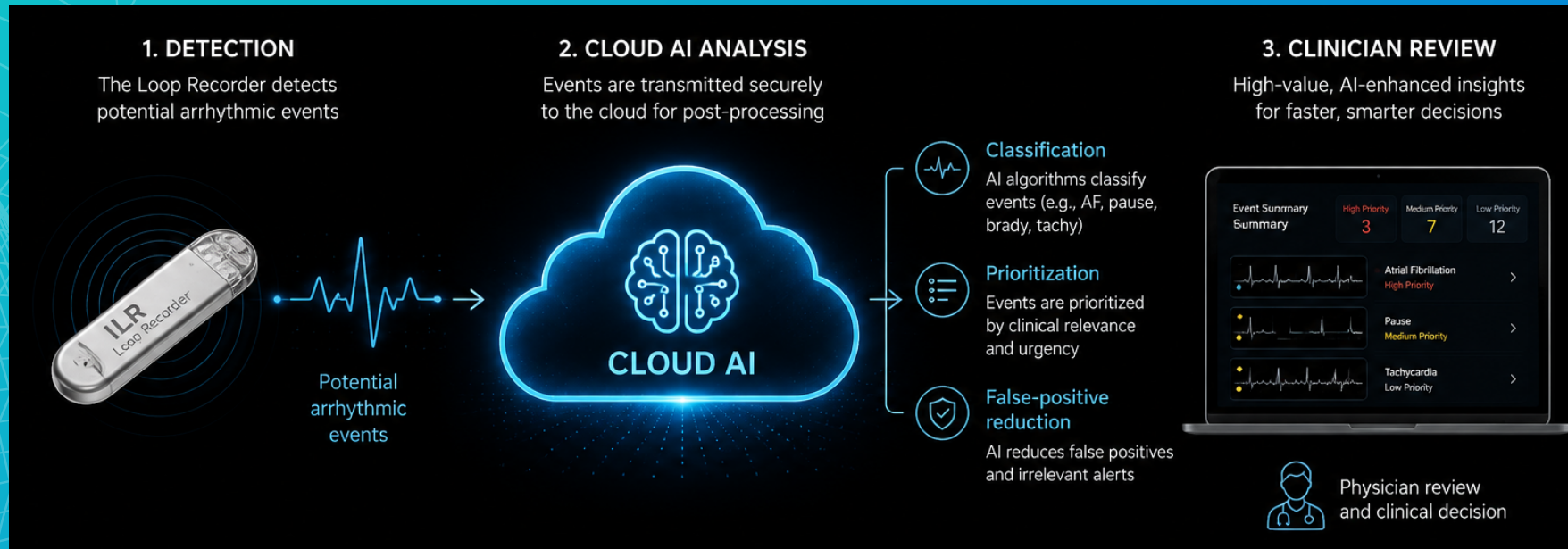
Why ICM is an “ideal” context for AI application?

1

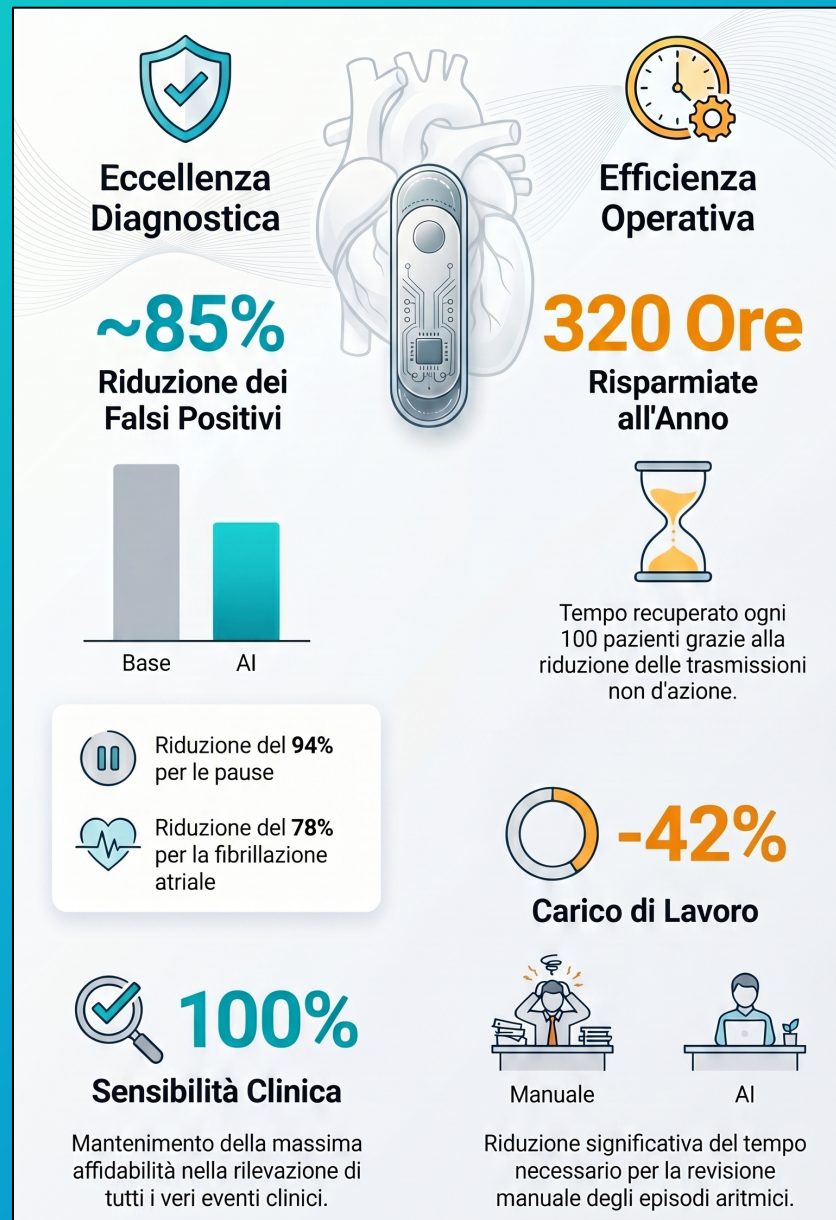
Extensive amount of raw digital data collected, with corresponding clinical adjudication

2

Fluid and complete integration into clinical workflow (“*a posteriori*” cloud-based analysis)



AI in ICM: a tangible impact



AI IN LOOP RECORDER ANALYSIS

BEFORE

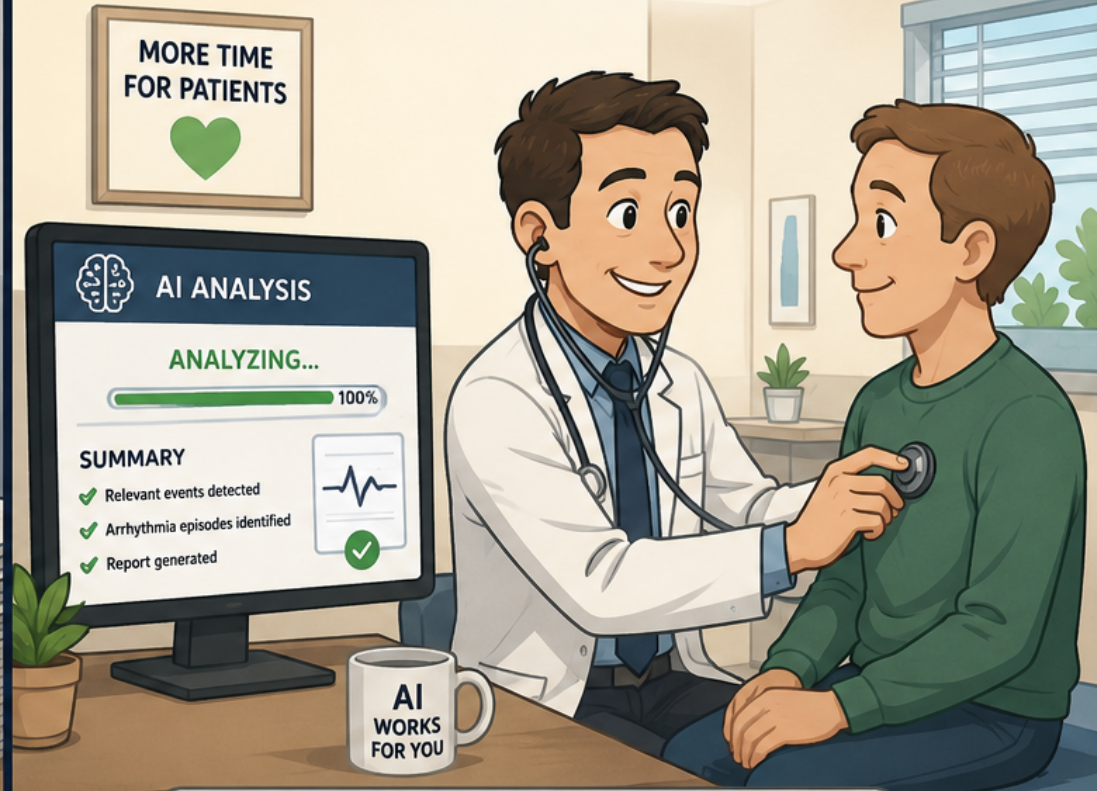
Manual review takes hours.
Too much data, too little time.



- Time-consuming
- High cognitive load
- Risk of missing events

AFTER

AI handles the data.
You focus on what matters most: your patients.



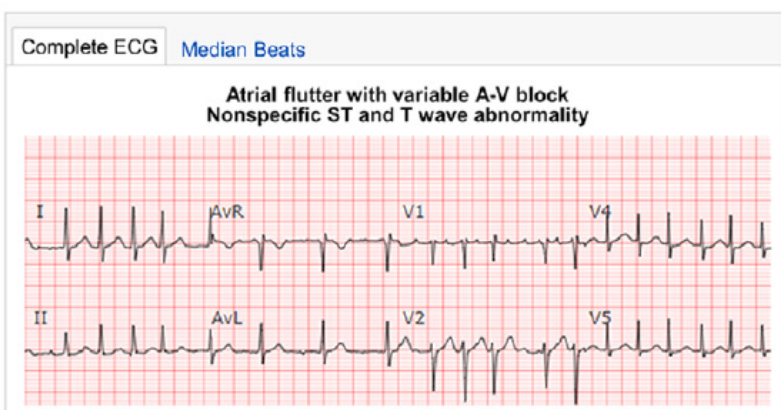
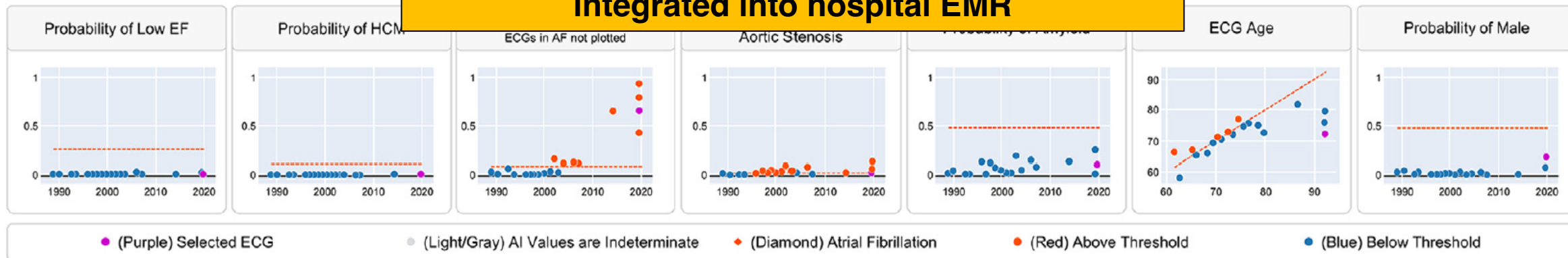
- Saves time
- Reduces cognitive load
- More time for patients
- Better care

Future perspectives



AI-ECG: Full integration into routine clinical workflow

AI-based prediction of different diagnosis/
outcomes
integrated into hospital EMR

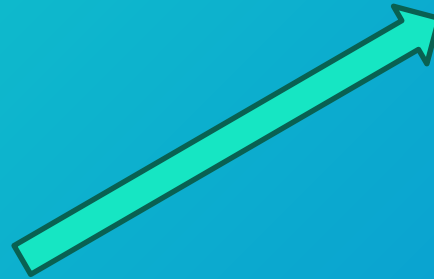
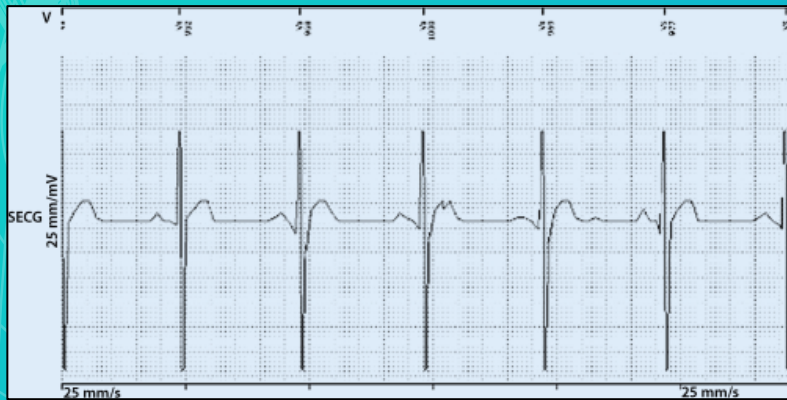


Results Compare ECGs									
ECG Date	Main Rhythm	Heart Rate	QT/QTc	PR/QRS	Real Age	ECG Age	P of Low EF (%)	P of AF (%)	P of HCM (%)
2019-Sep-19 05:38:56	Atrial flutter	116	326/453	null/84	92.21	72.04	0.60	65.63	0.01
2019-Sep-18 20:03:51	Sinus tachycardia	108	356/477	236/80	92.21	79.47	0.93	43.52	0.01



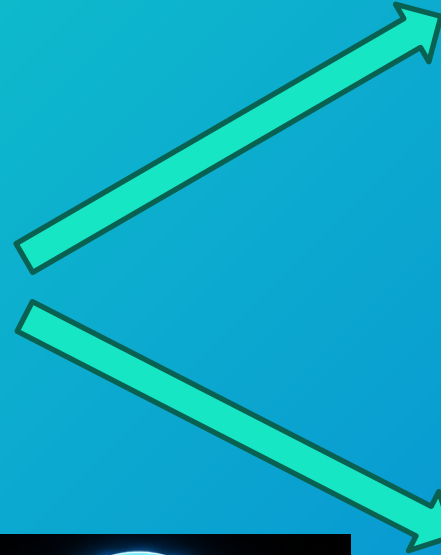
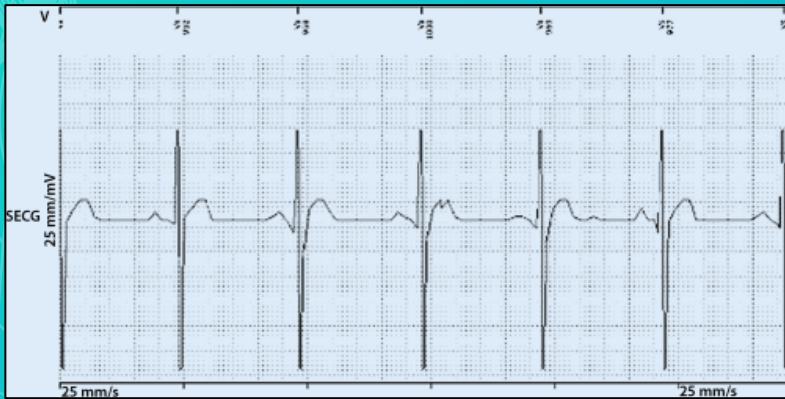
Explainability analysis

AI-ICM: From diagnostic...



Diagnosis
- Rhythm classification

AI-ICM: From diagnostic to multiparametric platforms



Diagnosis

- Rhythm classification
- Hidden structural heart disease detection

Prognosis

- Hard outcomes
- Incident comorbidities



Thank you for your attention!

Do you have any questions?

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