IA pour prédire la mort subite

Eloi MARIJON
Hôpital européen Georges Pompidou
Université Paris Cité

Conflits d’intérêts

Consultant pour Medtronic, Boston Scientific, Abbott, et Zoll

Classical Strategy for Reducing the SCD Burden

Decrease Occurrence

Prediction & Protection

Improve Survival

Classical Strategy for Reducing the SCD Burden

PREVENTION

Optimal but very challenging!!

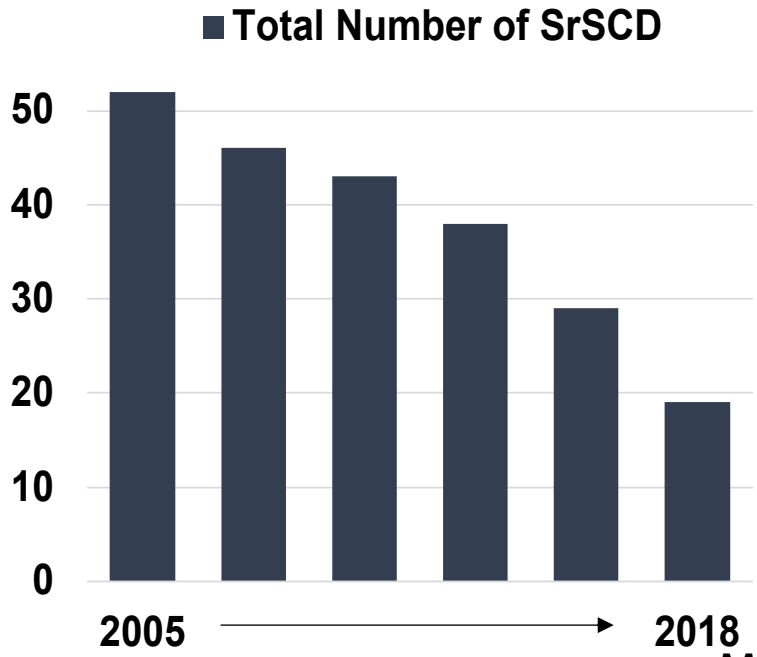
RESUSCITATION

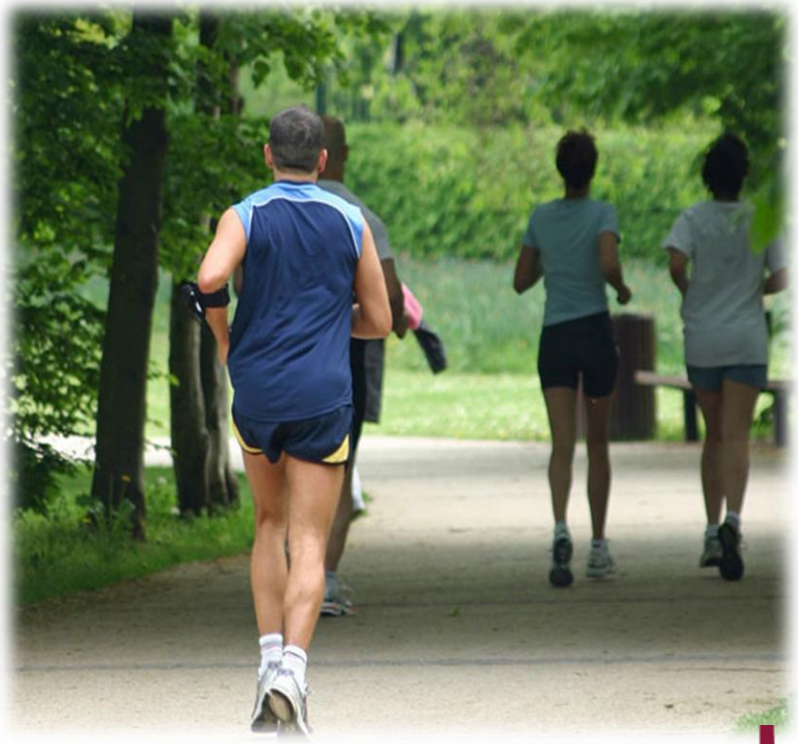
Maybe not optimal, but may be highly efficient!!

Reversible Death

Non-Reversible Death

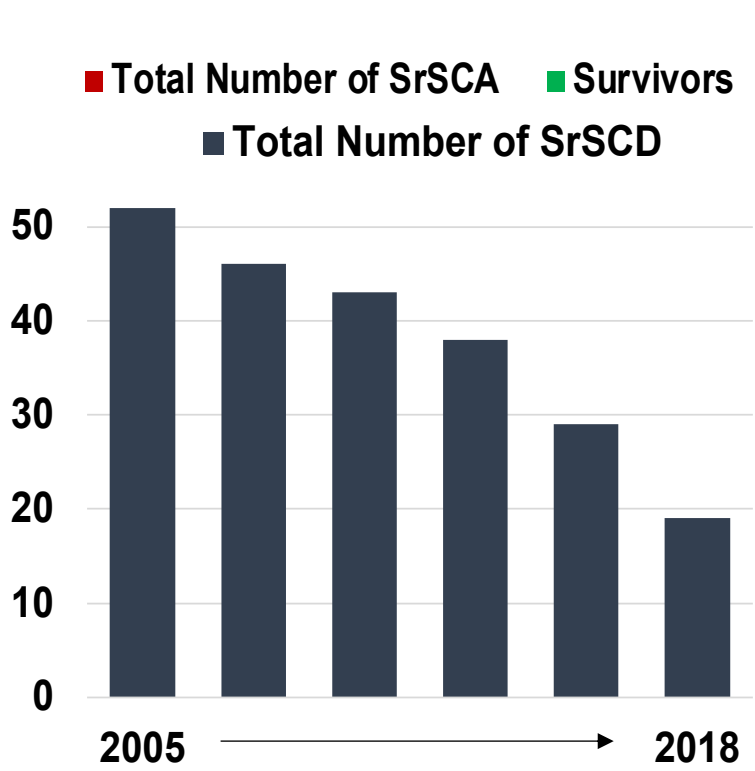
Sports-related SCA Surveillance Program in Paris

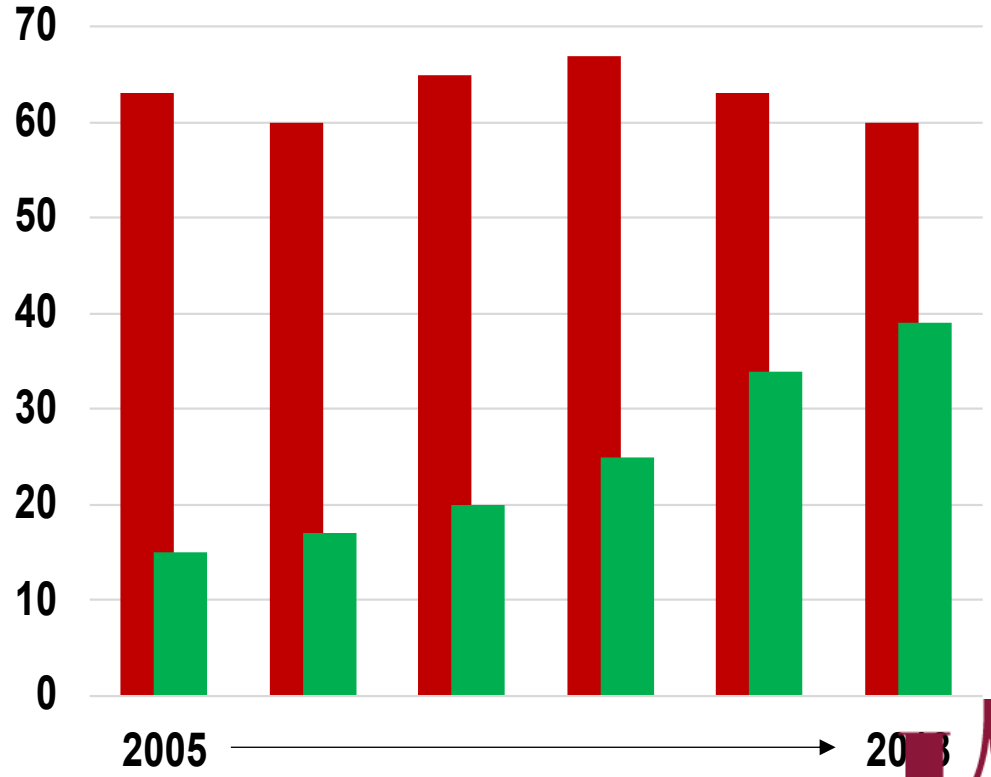




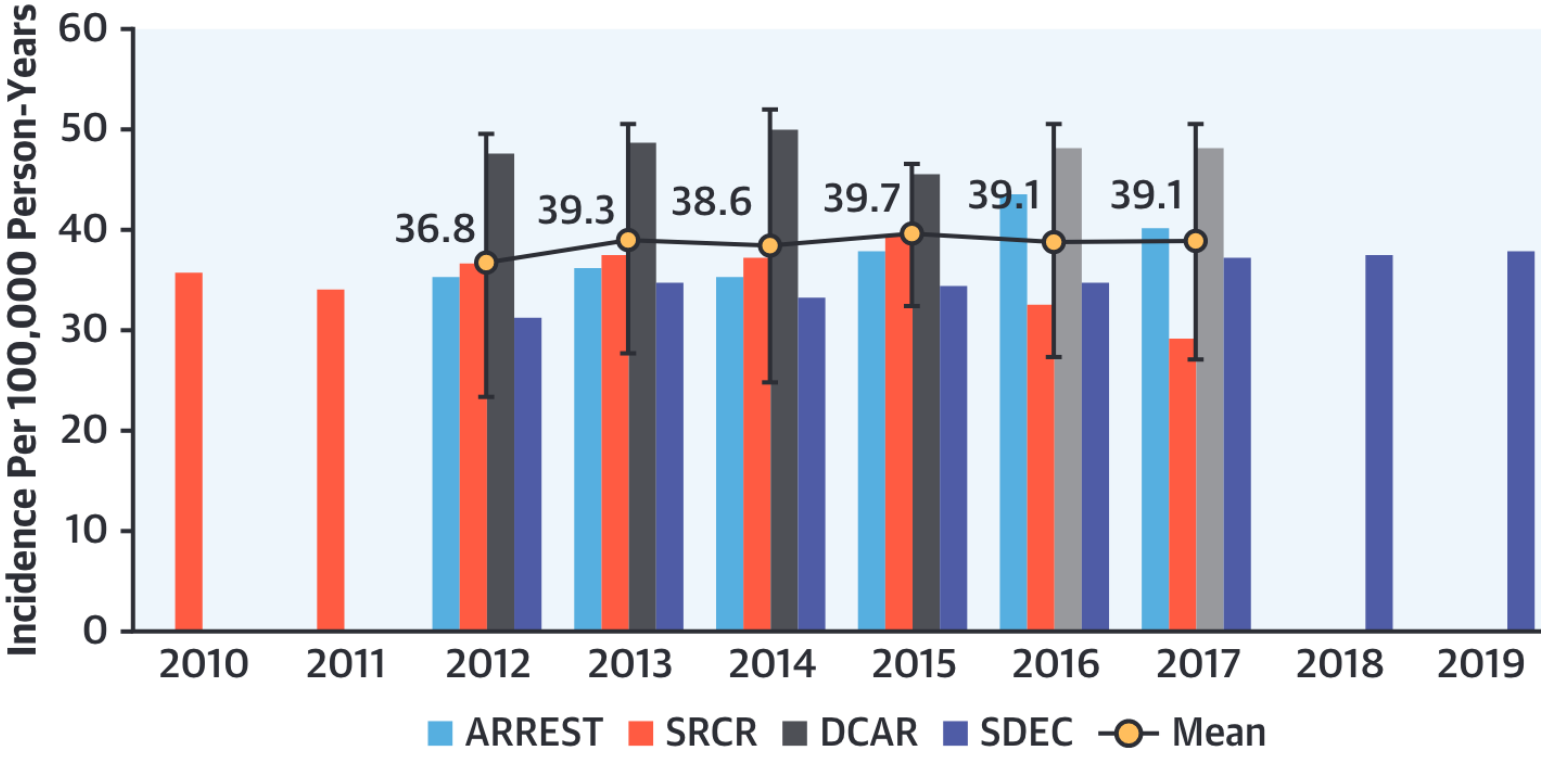
Marijon et al. Circulation 2011 & JACC 2022

Sports-related SCA Surveillance Program in Paris





Many Preventive Efforts, Limited Impact



ESCAPE NET Investigators JACC 2022

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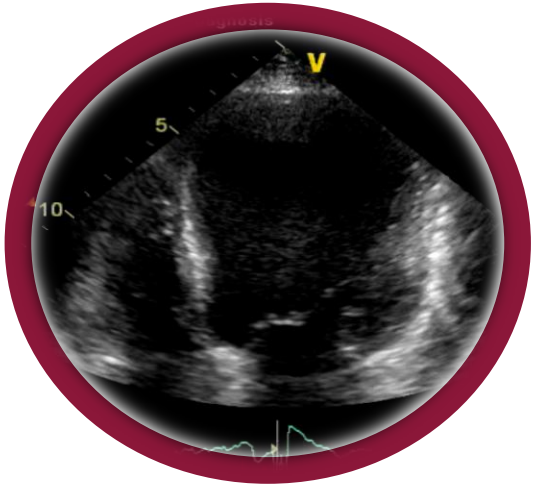
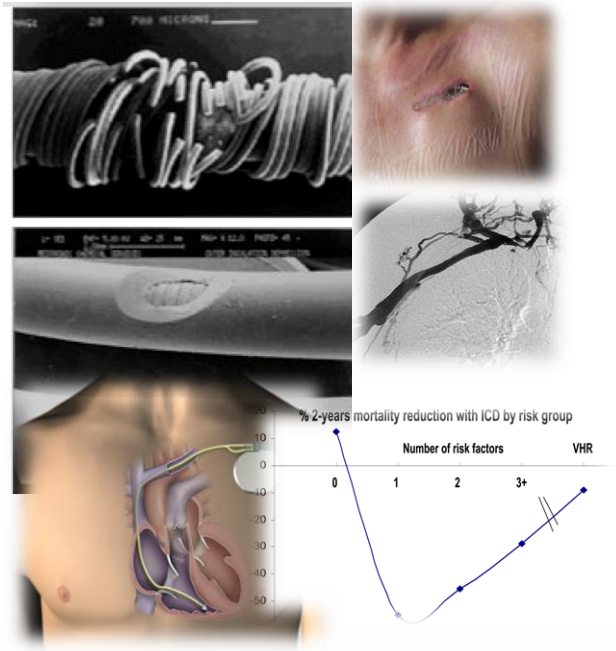
Challenges for Traditional SCD Prevention

Majority of SCD in the GP

Majority of cases, poor risk Stratification



Non-optimal solution for high-risk patients



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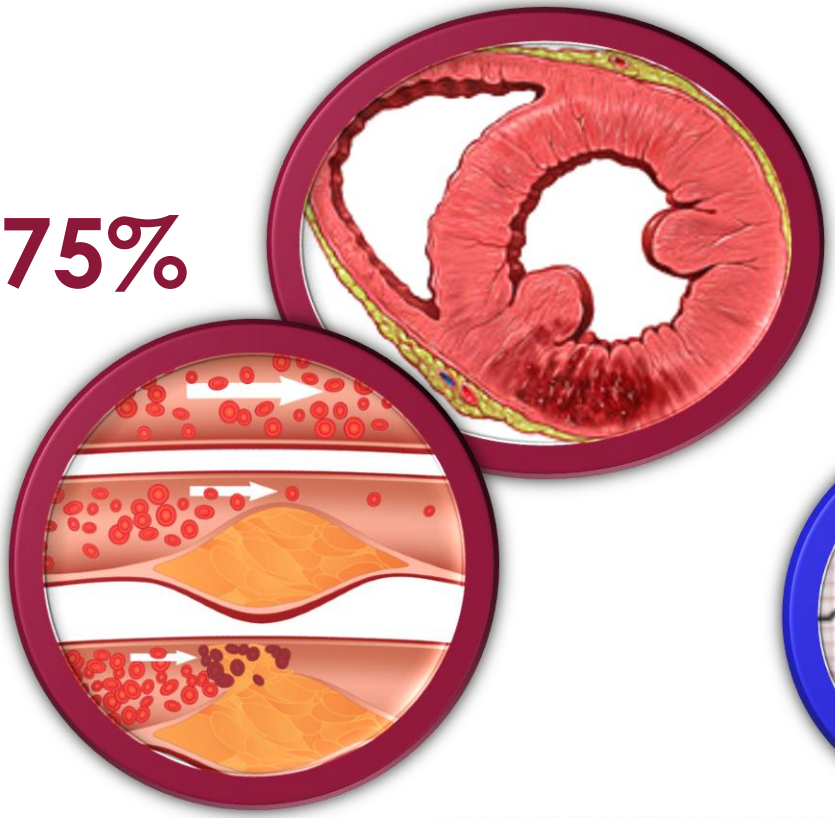
Prediction & Risk Stratification

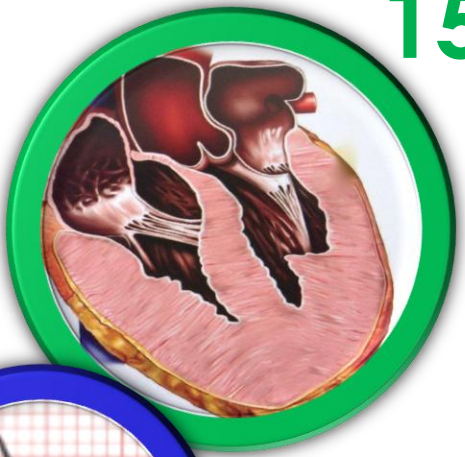
Two Main Scenarios

- Predict SCD in a patient with known heart disease
- **Predict SCD in the gnl population (without known heart disease)**

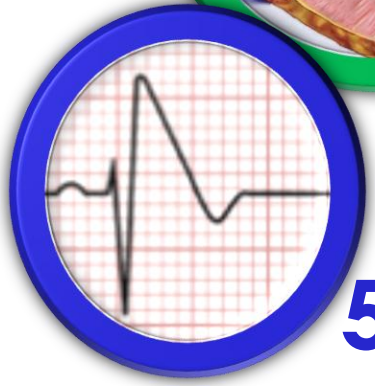
Sudden Cardiac Death



75%



15-20%



5-10%

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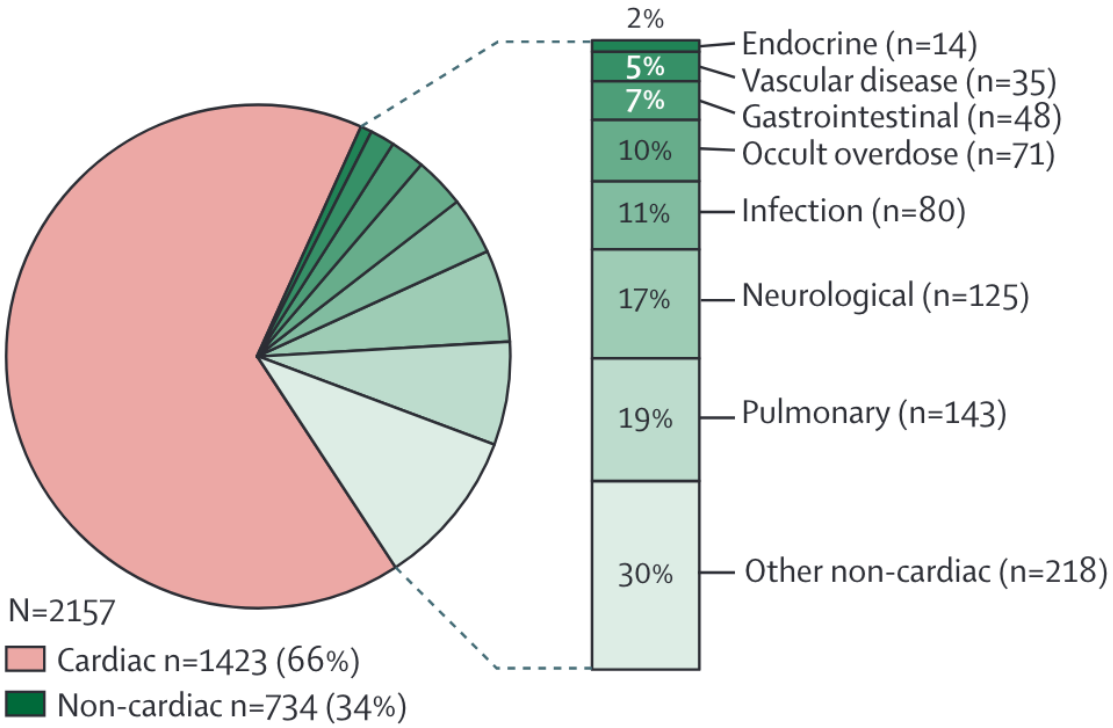
Sudden *[Cardiac]* Death



The *Lancet* Commission on SCD 2023

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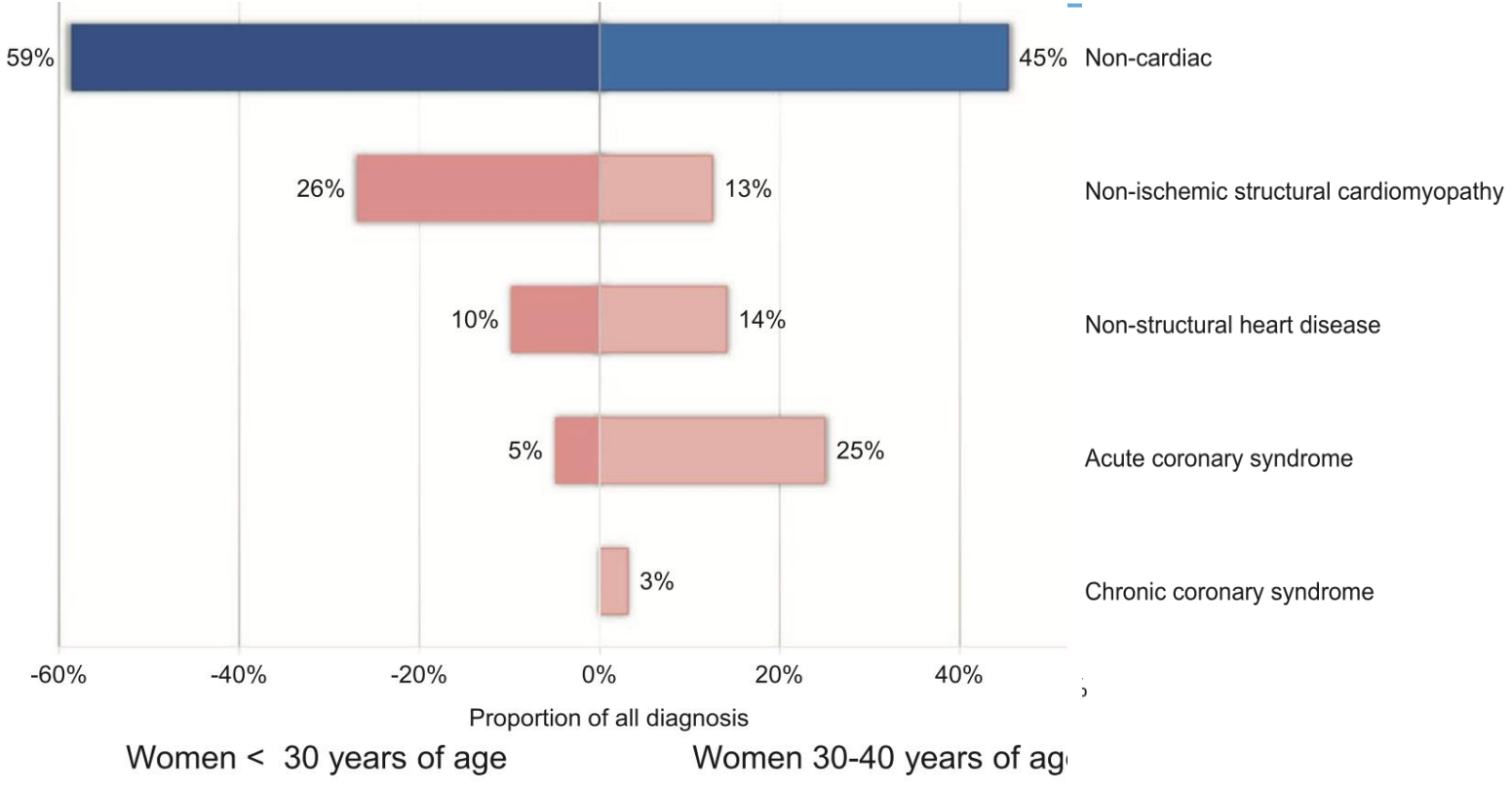

Weizman et al. Circulation 2021

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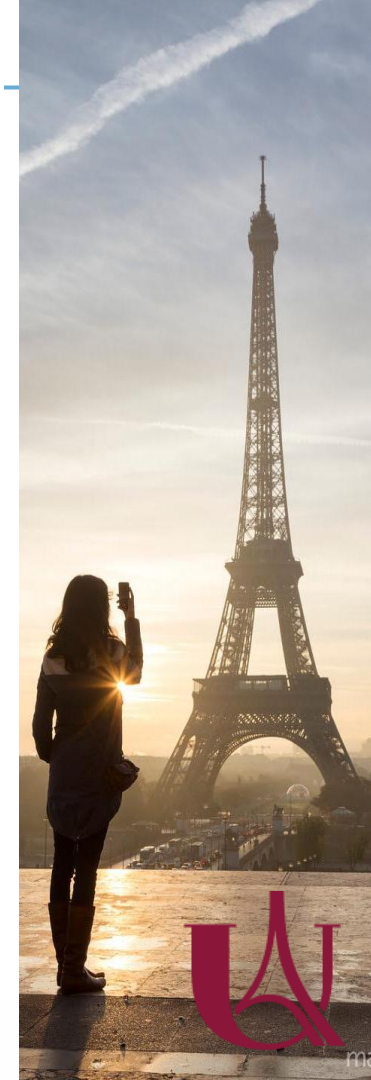
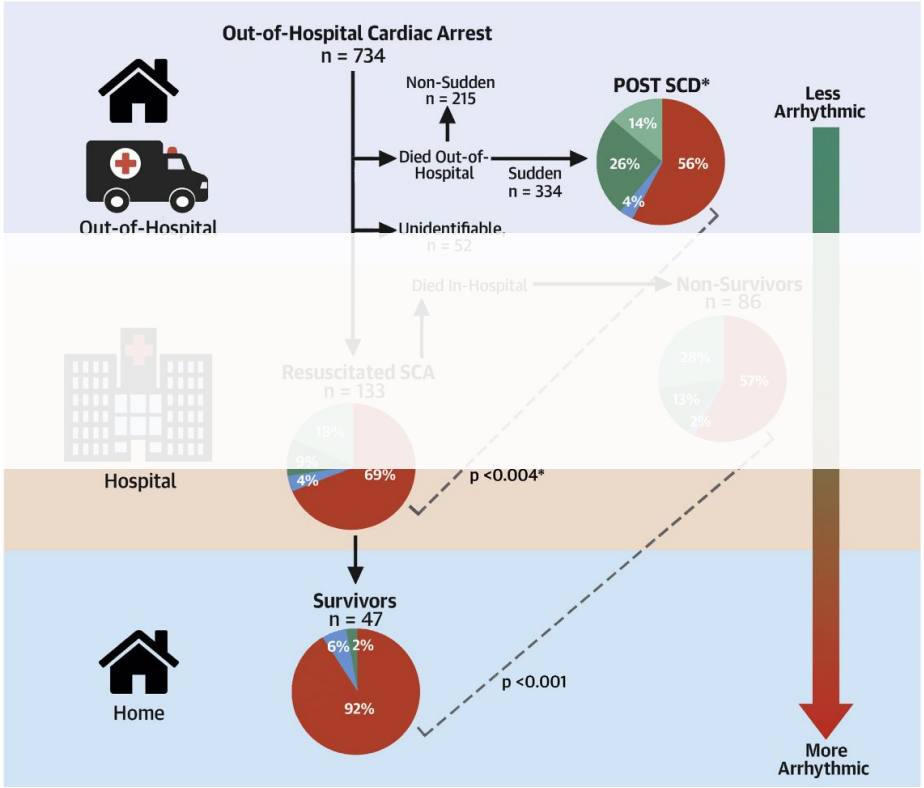


Sudden [Cardiac] Death...



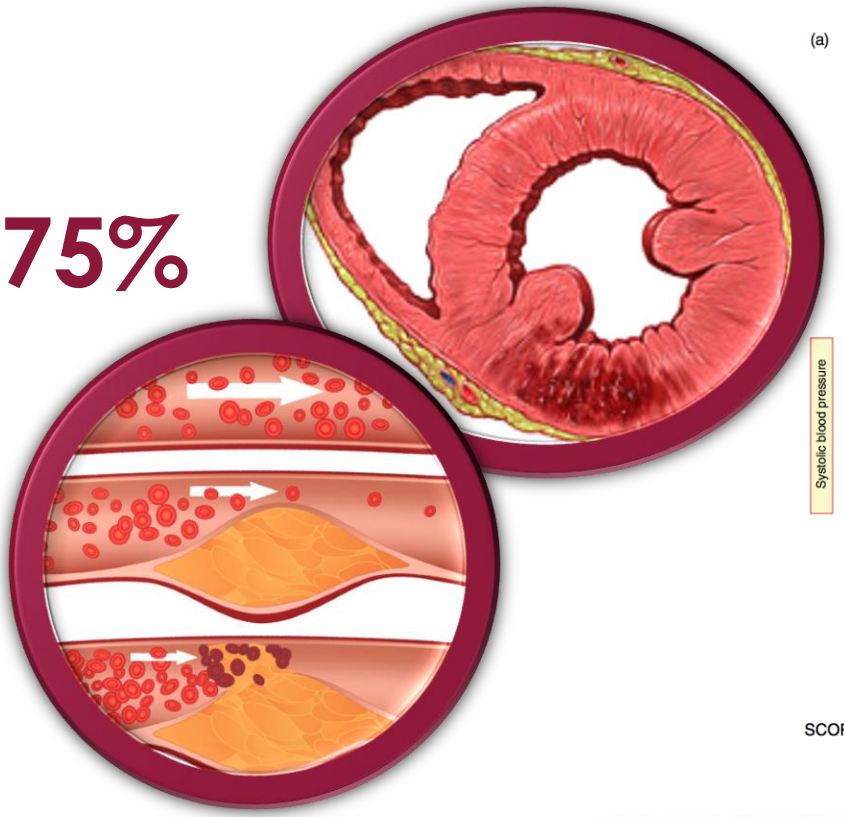
POST SCD

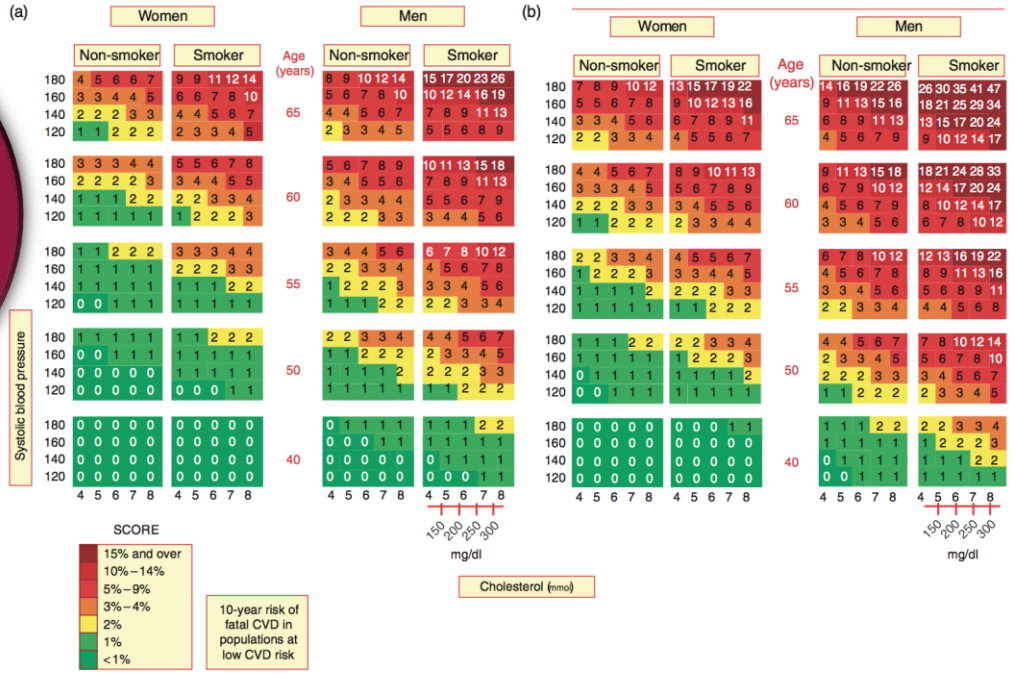
- Arrhythmic
- Cardiac, Non-Arrhythmic
- Other Non-Cardiac
- Neurologic

Ricceri S et al. J Am Coll Cardiol 2021

Challenges for Traditional SCD Prediction

75%





SCORE risk in low (a) or high-risk (b) countries. CVD, cardiovascular disease.

Risk Stratification

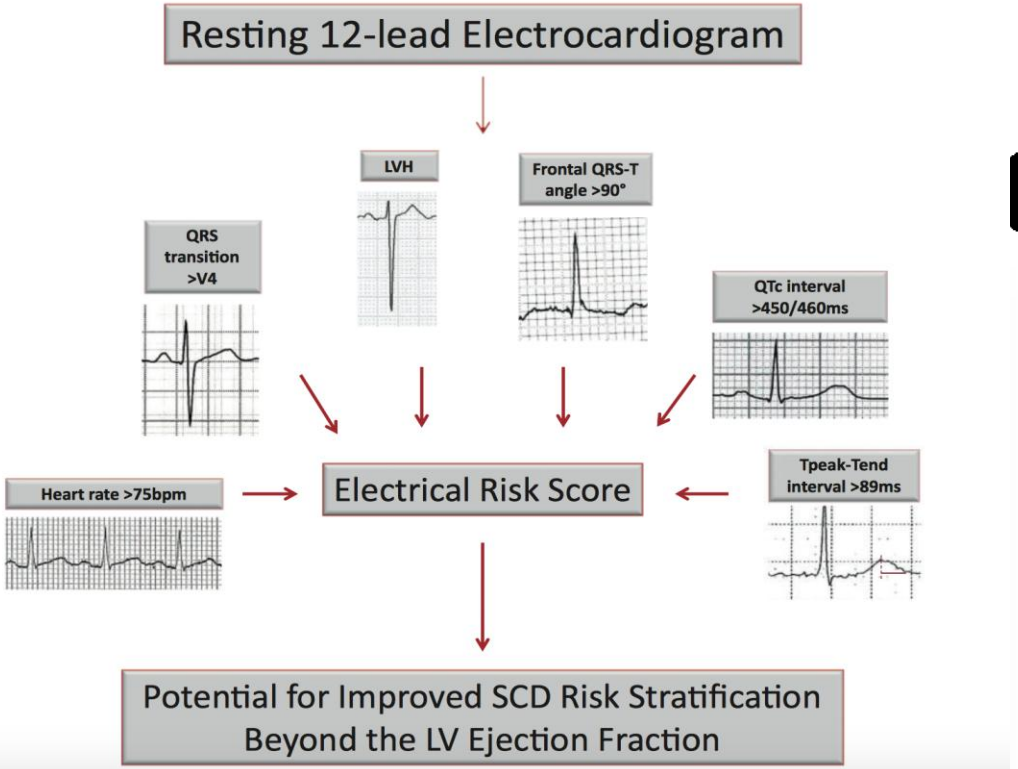
In the General Population

	ARIC	CHS
Sudden cardiac death		
SCD prediction score		
C-statistic (95% CI)	0.820 (0.785, 0.854)	0.745 (0.701, 0.789)
Calibration χ^2 (*P* value)	11.46 (0.25)	13.74 (0.088)
ACC/AHA CVD risk equation		
C-statistic (95% CI)	0.808 (0.772, 0.844)	0.743 (0.700, 0.768)
Calibration χ^2 (*P* value)	851.0 (<0.001)	24.71 (0.003)

Deo et al. Circulation 2016

Risk Stratification

In the General Population



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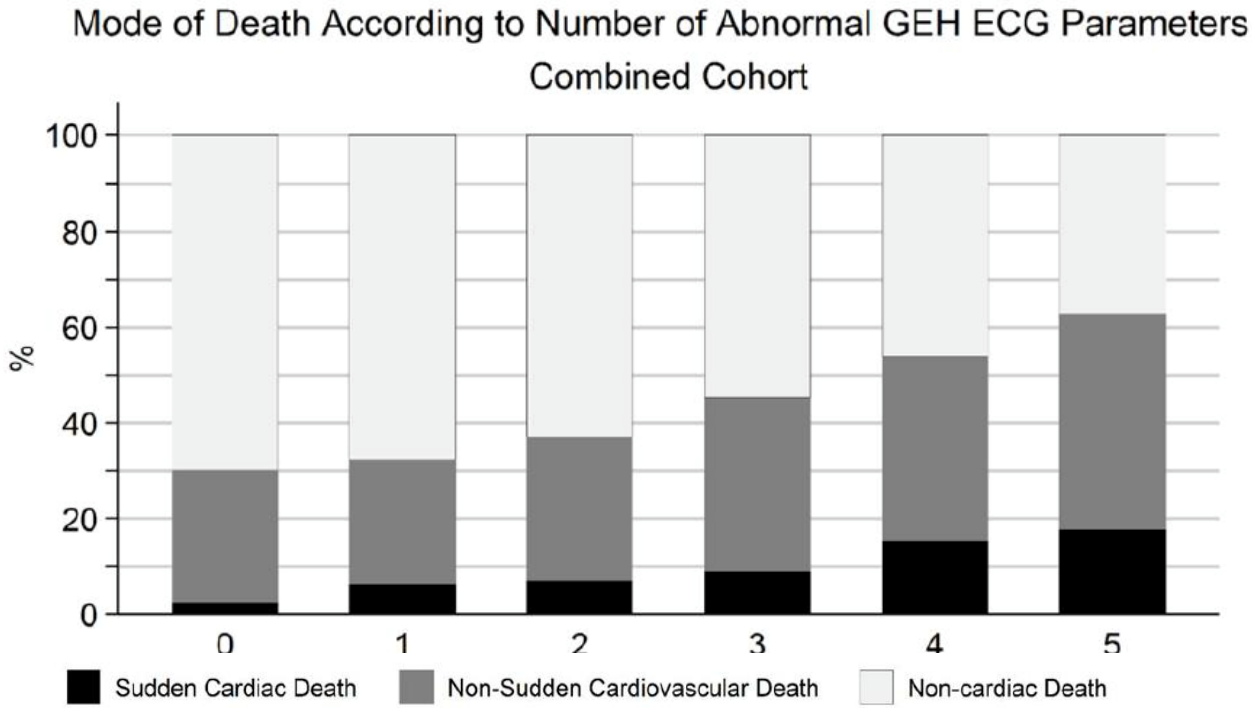
Oregon SUDS

Waks JW et al. Circulation 2016
Aro AL et al. EHJ 2017

Risk Stratification

In the General Population



Waks JW et al. Circulation 2016

Risk Stratification
In the General Population

Circulation

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10-Year Risk Model of SCD Among Healthy Middle Age Population Using clinical, biological and ECG data

ORIGINAL RESEARCH ARTIC

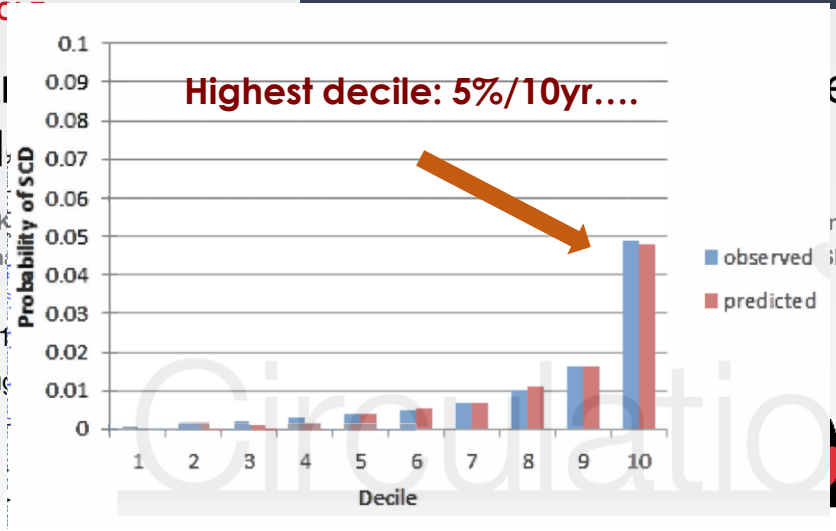
Development a… eath Prediction Mod…

Rajat Deo, Faye L. Norby, Ronit K… nbaum, Lin Y. Chen, Susan R. Heckbert, Aaron R. Folsom, Richa… hlipak and Alvaro Alonso

DOI http://dx.doi.org/10.1161…

Published Ahead of Print: Aug…

CrossMark click for updates



ARIC CHS

Deo R et al. Circulation 2016

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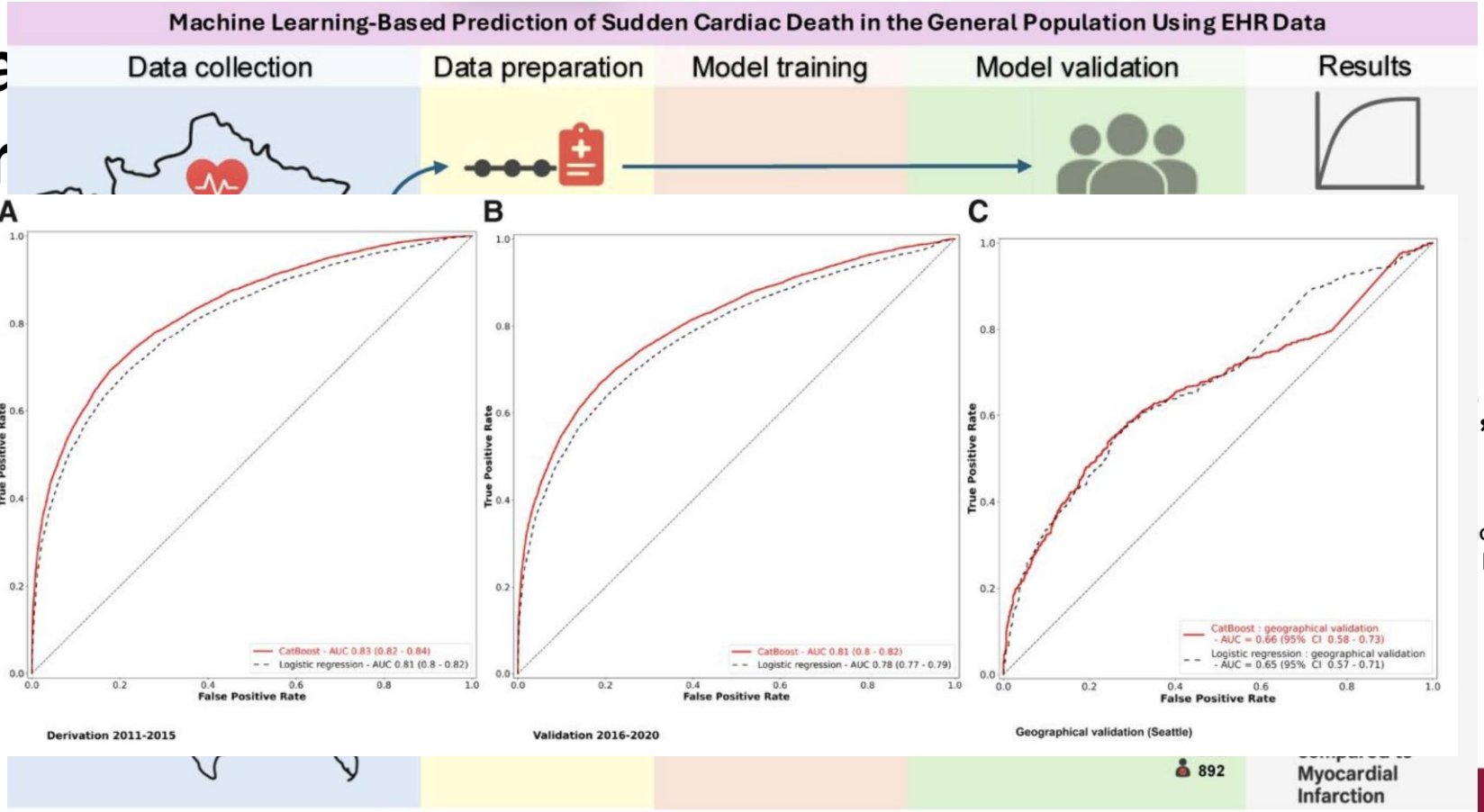


Need for Specificity!

Resting heart rate and risk of sudden cardiac death in the general population: Influence of left ventricular systolic dysfunction and heart rate-modulating drugs

Carmen Teodorescu, MD, PhD,[*] Kyndaron Reinier, MPH, PhD,[*] Audrey Uy-Evanado, MD,[*]
Karen Gunson, MD,[†] Jonathan Jui, MD, MPH,[‡] Sumeet S. Chugh, MD, FHRS[*]

From the [*]Heart Institute, Cedars-Sinai Medical Center, Los Angeles, California, Departments of [†]Pathology and [‡]Emergency Medicine, Oregon Health and Science University, Portland, Oregon.

http://dx.doi.org/10.1016/j.hrthm.2013.05.009

BACKGROUND Higher levels of resting heart rate (HR) have been associated with sudden cardiac death (SCD) but mechanisms are poorly understood. We hypothesized that severe left ventricular systolic dysfunction (LVSD) and HR-modulating drugs explain the HR-SCD relationship.

OBJECTIVE To evaluate the relationship between HR, severe LVSD, HR-modulating drugs, and SCD in the community by using a case-control approach.

METHODS From the ongoing Oregon Sudden Unexpected Death Study, SCD cases ($n = 378$) aged ≥ 35 years and with electrocardiogram-documented resting HR were compared to 378 age- and gender-matched control subjects with coronary artery disease (mean age 68 $\pm$ 13 years; 69% man). Associations with SCD were assessed by using multivariable logistic regression.

RESULTS Mean resting HR was significantly higher among SCD cases compared to controls (7.5 beats/min difference; $P < .0001$). HR was a significant determinant of SCD after adjustment for significant comorbidities and medications (odds ratio for 10 beats/min increase 1.26; 95% confidence interval 1.14–1.38; $P < .0001$). After

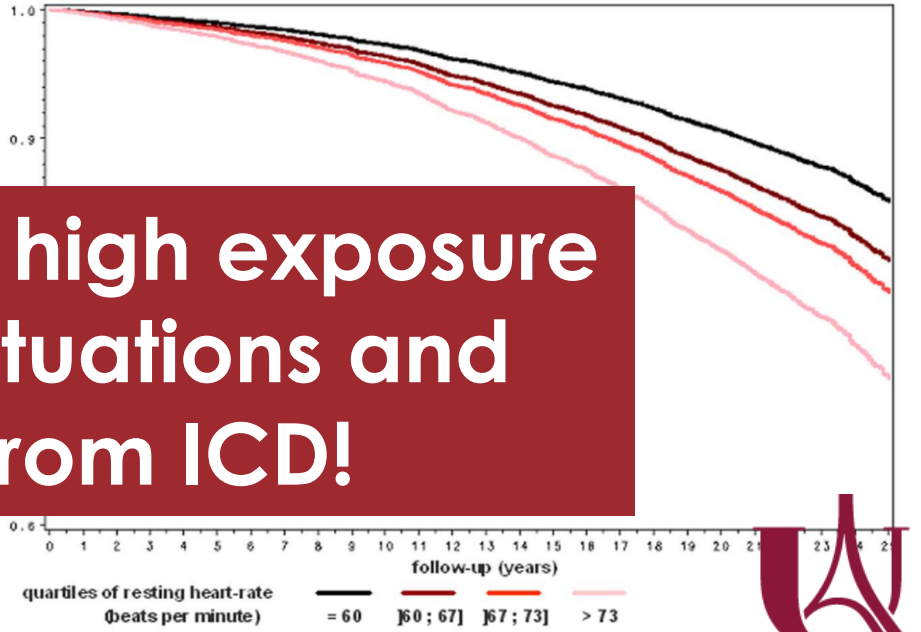
OPEN ACCESS Freely available online

PLoS one

Heart Rate and Risk of Cancer Death in Healthy Men

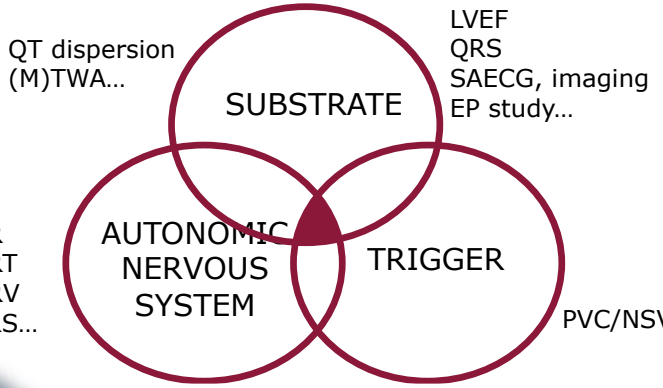
**Xavier Jouven[1,2]*, Sylvie Escolano[1], David Celerma
Hermine[4], Michel Desnos[5], Marie-Cécile Perier[1], El**

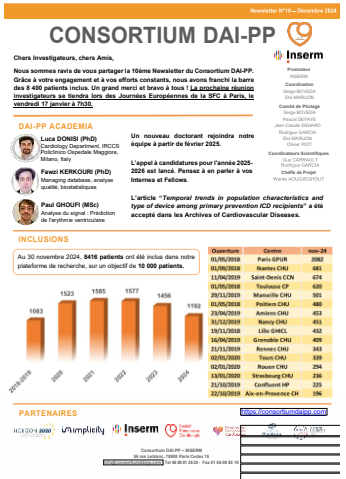
1 INSERM PARCC University Paris Descartes UMR-S970, Paris, France, **2** AP-HP HE
4 Department of Adult Hematology CNRS UMR 8147, Hopital Necker Enfants-Mal



Otherwise, we face a high exposure to competing risk situations and limited benefit from ICD!

Time for a Comeback — Retesting Old Hypotheses With Modern Continuous Tools (ICDs)





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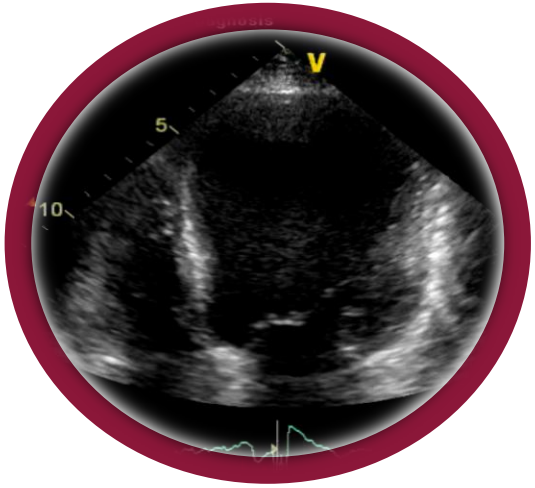
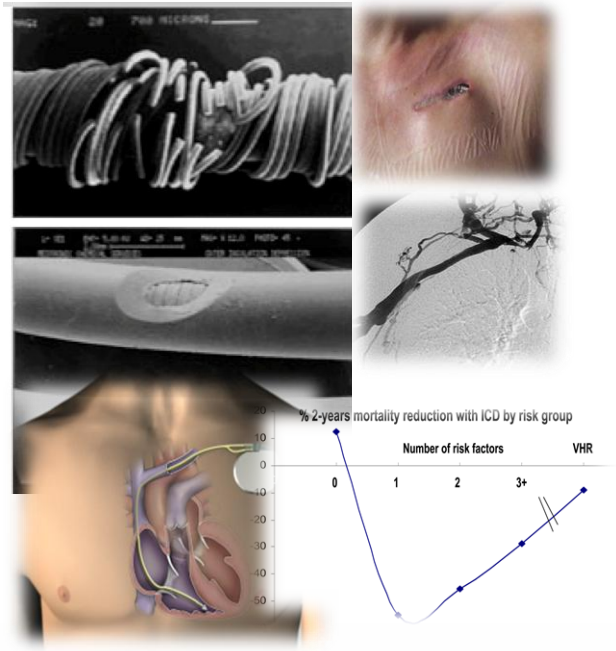
Challenges for Traditional SCD Prevention

Majority of SCD in the GP

Majority of cases, poor risk Stratification



Non-optimal solution for high-risk patients



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Prediction & Risk Stratification
In a Patient With Known Heart Disease

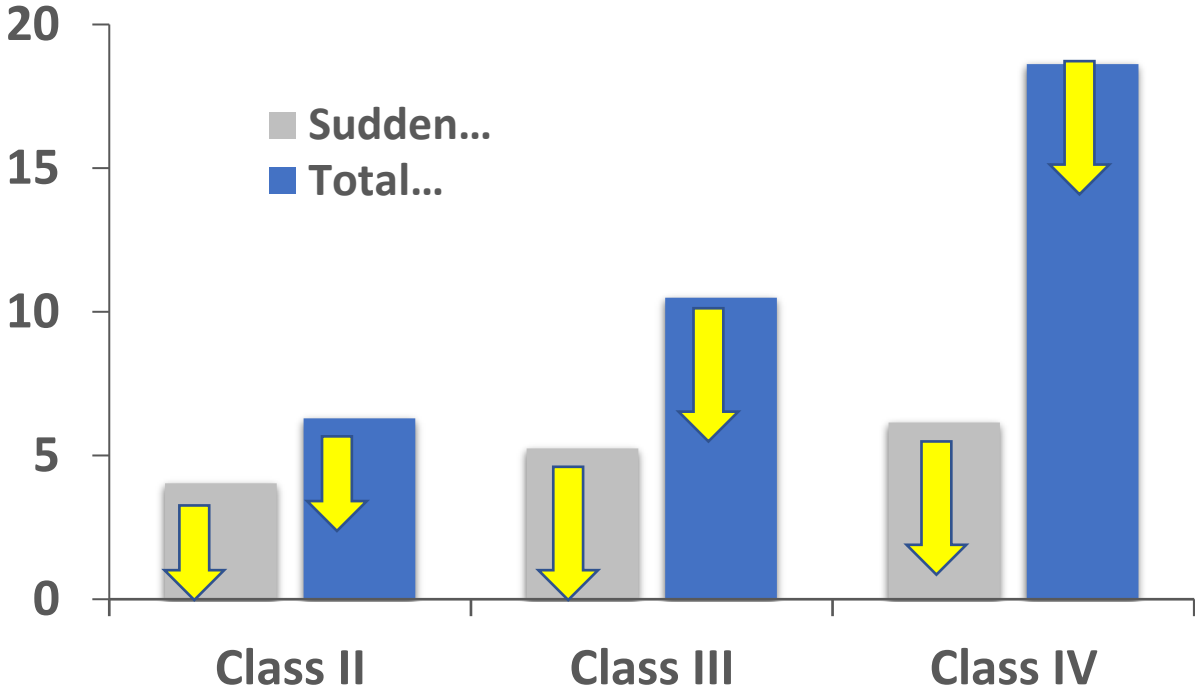
Two categories

We commonly use absolute risk to determine candidacy for therapy in CVD.
(eg. in patients with AF, annualized stroke estimates guide decision making for anticoagulation…)

The goal must be the identification of patients the most likely to benefit from ICD therapy (who are not sytematically those at higher risk of SCD)

Competing risk situation…

Competing Risk Situation
Absolute and Proportional Risks



MERIT-HF. The Lancet 1998

Competing Risk Situation (Applied to CAD)

Illustration Using MADIT-II

Journal of the American College of Cardiology
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Published by Elsevier Inc.

Vol. 51, No. 3, 2008
ISSN 0735-1097/08/$34.00
doi:10.1016/j.jacc.2007.08.058

Risk Stratification for Primary Implantation of a Cardioverter-Defibrillator in Patients With Ischemic Left Ventricular Dysfunction

Ilan Goldenberg, MD,* Anant K. Vyas, MD, MPH,† W. Jackson Hall, PHD,‡ Arthur J. Moss, MD,* Hongyue Wang, PHD,‡ Hua He, MA,‡ Wojciech Zareba, MD, PHD,* Scott McNitt, MS,* Mark L. Andrews, BBA,* for the MADIT-II Investigators

Rochester and Buffalo, New York

Goldenberg et al. JACC 2008

Competing Risk Situation (Applied to CAD)

Illustration Using MADIT-II

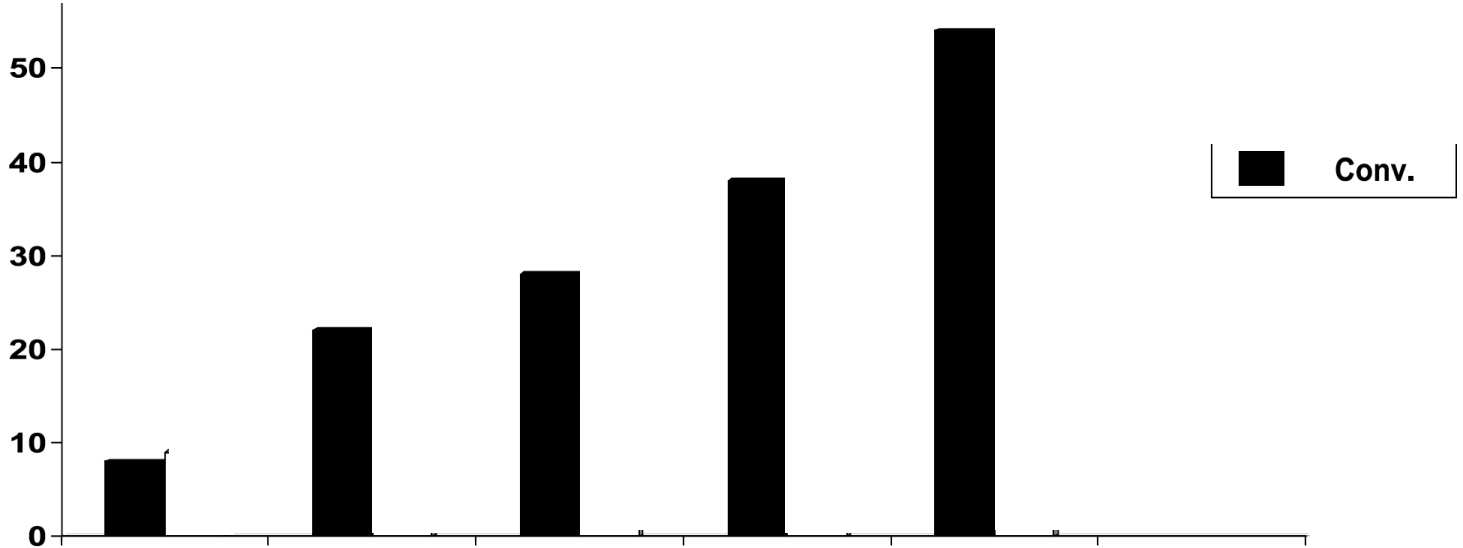
1,232 patients with documented previous MI and EF 30% were randomized to receive a prophylactic ICD or conventional medical therapy in a 3:2 ratio and were followed over a mean 2-yr period

Mortality Score

Risk Factor	HR	95% Confidence Interval	p Value
NYHA functional class >II	1.87	1.23–2.86	0.004
Atrial fibrillation‡	1.87	1.05–3.22	0.034
QRS >120 ms	1.65	1.08–2.51	0.020
Age >70 yrs	1.57	1.02–2.41	0.042
BUN >26 mg/dl (and <50 mg/dl)	1.56	1.00–2.42	0.048

Competing Risk Situation (Applied to CAD)

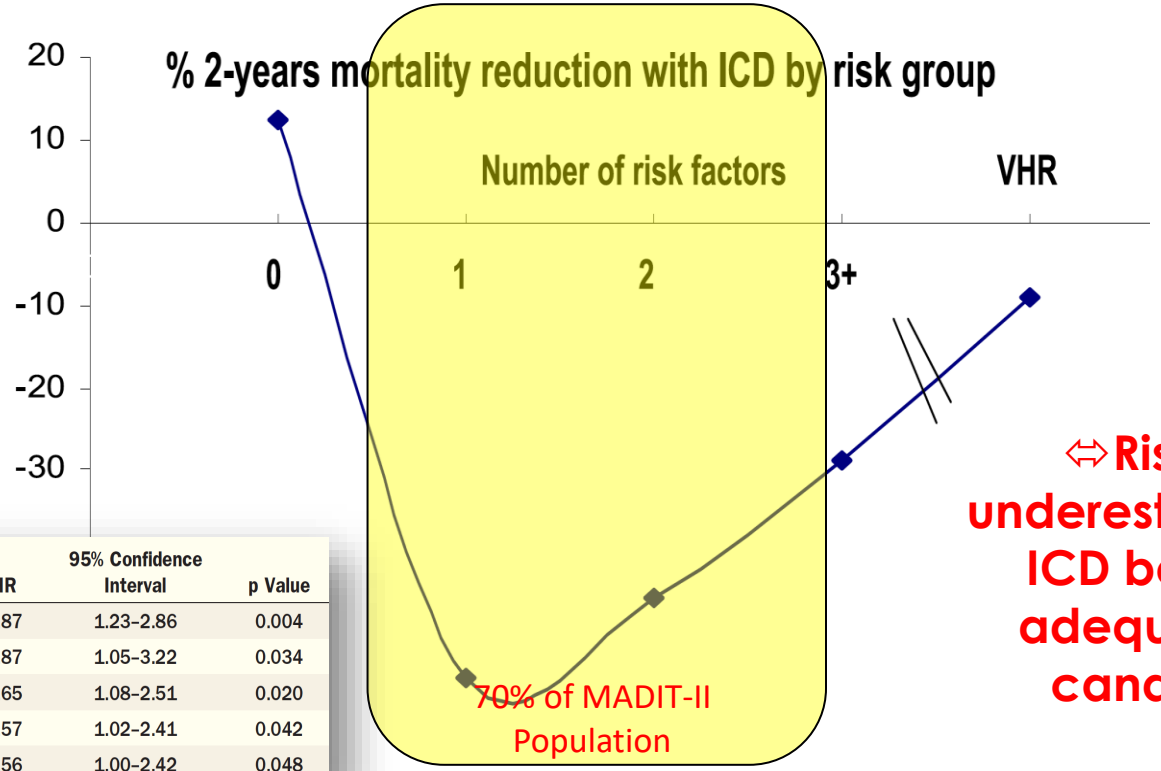
Illustration Using MADIT-II



% Pts at risk	29%	28%	24%	14%	5%

Competing Risk Situation (Applied to CAD)

Illustration Using MADIT-II



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⇔**Risk of underestimation of ICD benefit in adequate ICD candidates**

PREVENTION

Optimal but very challenging!!

RESUSCITATION

Not optimal but may be highly efficient

New Window of Opportunity?

PREVENTION

Optimal but very challenging!!

RESUSCITATION

Not optimal but may be highly efficient

Near-Term Prevention of SCD

New Window of Opportunity?

PREVENTION

Optimal but very challenging!!

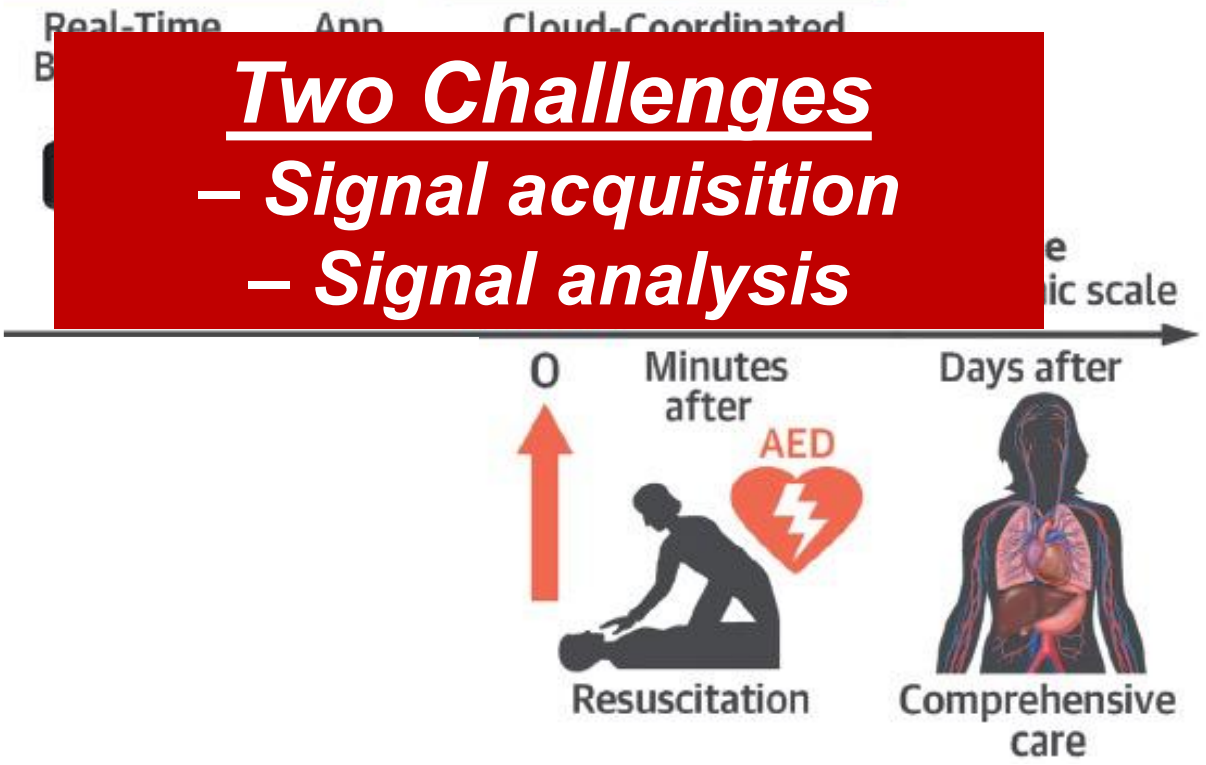
RESUSCITATION

Not optimal but may be highly efficient

Sensors that can detect SCA quickly → Alarm → Rapid deployment of AED

Smart Device
Early DETECTION of SCA
(AED shock, SCD averted)

Room for Developing Early Detection



Two Challenges

– Signal acquisition

– Signal analysis

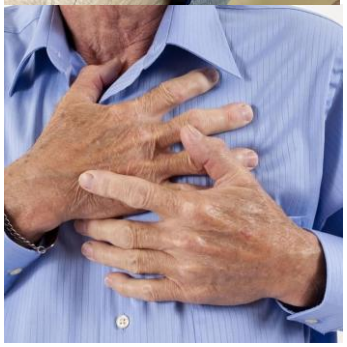
“Active” biosensor technology…

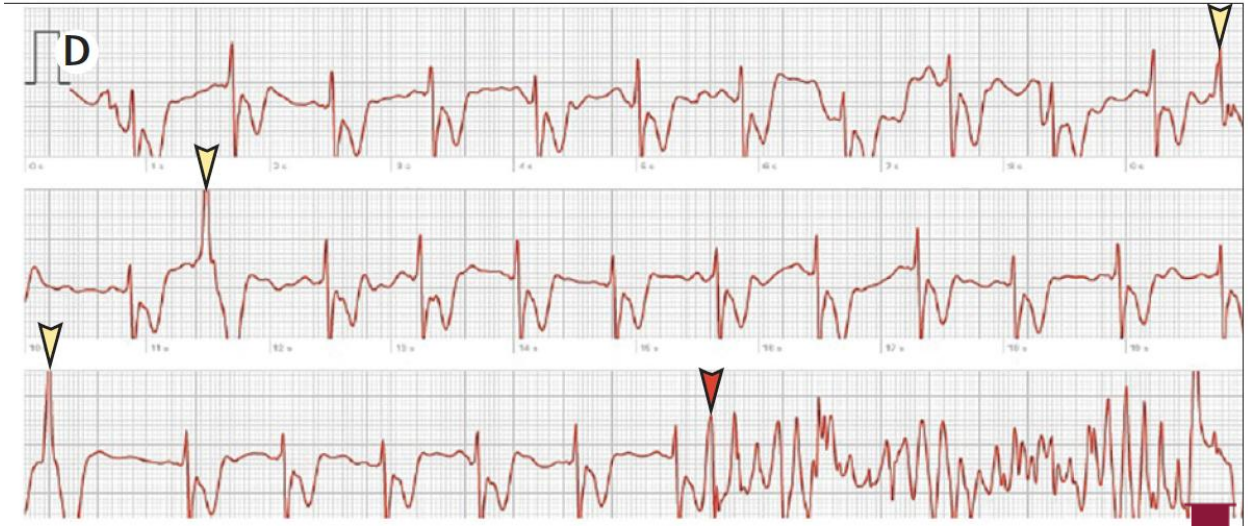
Lancet 2022; 400: e12

Smartwatch electrocardiogram records ST depression, premature ventricular complexes, and ventricular fibrillation

Andrés Provencio, Miguel Ángel Cobos Gil

Instituto Cardiovascular, Hospital Clínico San Carlos, Madrid, Spain (A Provencio MD, M Á Cobos Gil PhD)



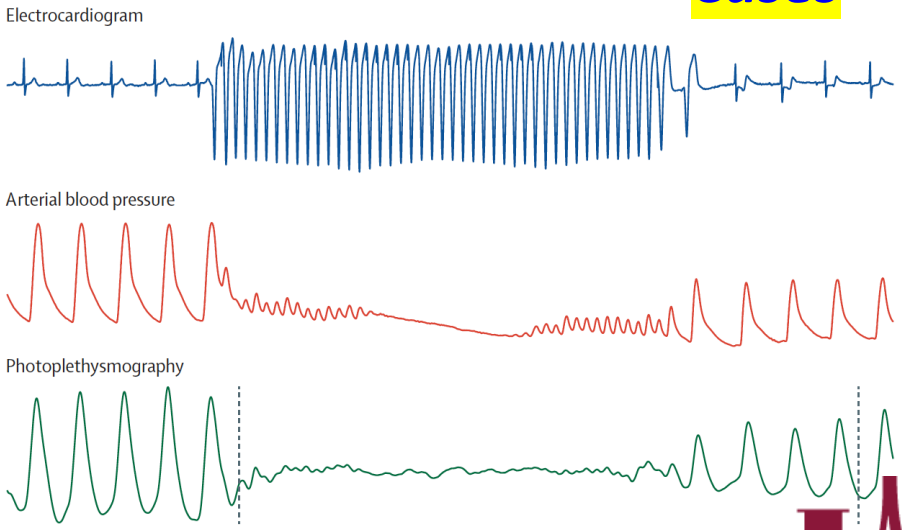


“Passive” biosensor technology…

Open the Room on Unwitnessed Cases

Automated cardiac arrest detection using a photoplethysmography wristband: algorithm development and validation in patients with induced circulatory arrest in the DETECT-1 study

Roos Edgar, Niels T B Scholte, Kambiz Ebrahimkheil, Marc A Brouwer, Rypko J Beukema, Masih Mafi-R
Eelko Ronner, Nicolas van Mieghem, Eric Boersma, Peter C Stas, Niels van Royen, Judith L Bonnes



Edgar R et al. Lancet Digit Health 2024

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Get help in an emergency.

The first watch able to detect loss of pulse then call for help

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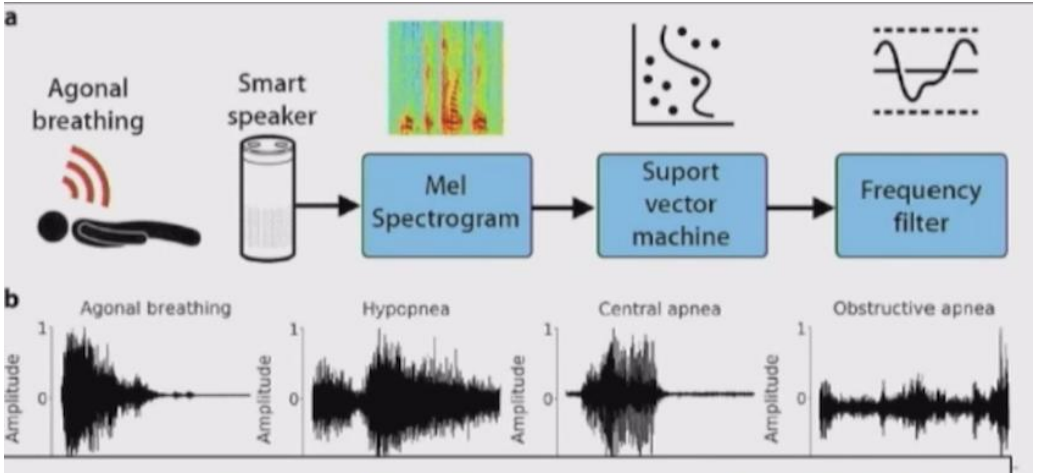
Not Only "HR Approach"…



- Agonal breathing- brainstem reflex in SCA
- Under-appreciated audible biomarker
- Different frequency from sleep sounds
- A smart speaker can detect agonal breathing

Chan J et al. NPJ Digital Med. 2019

Not Only “HR Approach”…

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Welcome to E-Vone, smart shoes for elderly people!

New Window of Opportunity?

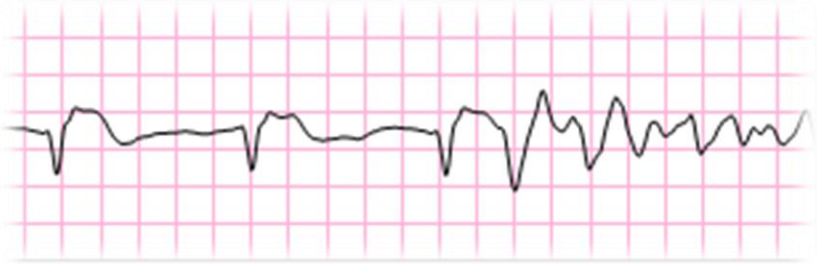
PREVENTION

Optimal but very challenging!!

Smart Algorithm
Early PREDICTION of Imminent SCA
(early management, SCA averted)

RESUSCITATION

Not optimal but may be highly efficient



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SCD May Not Be As Sudden As We Think

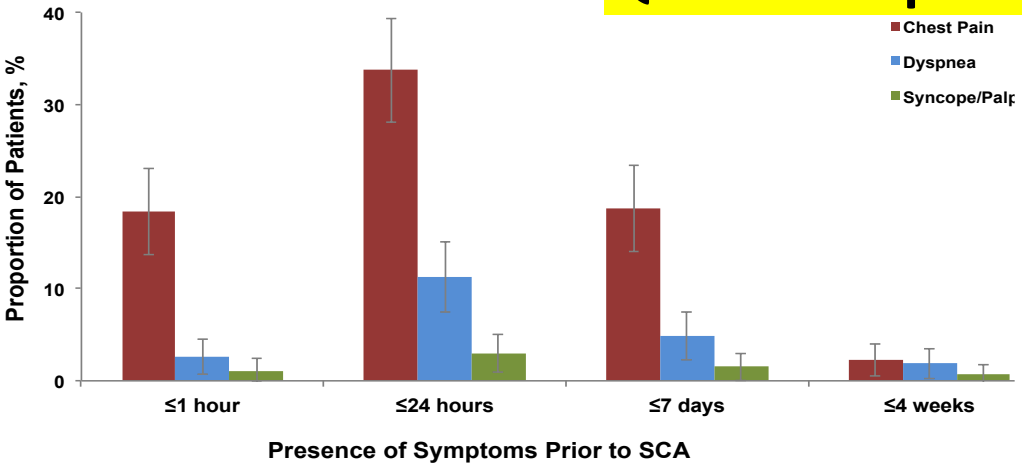
Annals of Internal Medicine

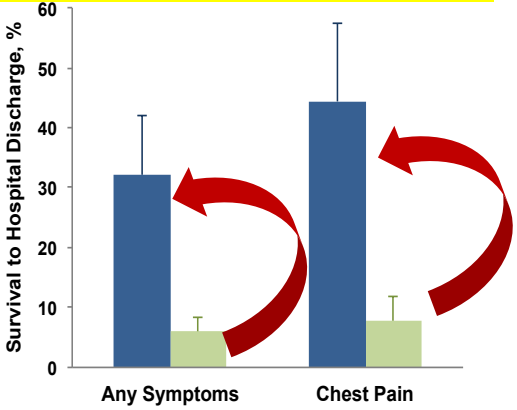
ORIGINAL RESEARCH

Warning Symptoms Are Associated With Survival From Sudden Cardiac Arrest

Eloi Marijon, MD, PhD*; Audrey Uy-Evanado, MD
Kyndaron Reinier, MPH, PhD; Carmen Teodorescu

Quicker response = Better survival





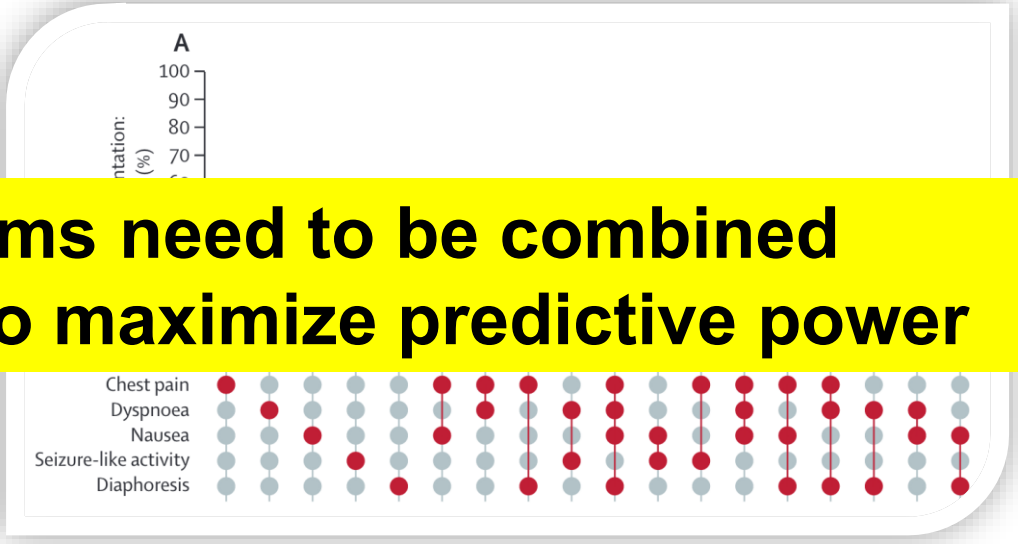
OREGON-SUDS. Ann Int Med. 2016

www.forumeuropeen.com

SCA Warning Symptoms Vs. Non-SCA Pts

- Symptoms before imminent SCA (n=411) vs. symptoms for non-SCA (n=1171)
- Sex specific
- Successfully replicated (427 cases, 1238 controls)

Warning symptoms need to be combined with other features to maximize predictive power



Reinier K et al. Lancet Digital Health 2023

Identifying Patients at Risk for Prehospital Sudden Cardiac Arrest at the Early Phase of Myocardial Infarction

The e-MUST Study (Evaluation en Médecine d'Urgence de
Thérapeutiques des infarctus du myocarde)

Sex Ma
- Age (years) [ ]
- Onset of chest pain (hours (24h), minutes) [/]
- Chest pain intensity (1 to 10) [ ]
- Chest pain Location
  - Chest ☐ Shoulders ☐ Arms ☐ Back ☐
- Are you short of breath? No ☐ Yes ☐
- Are you a current smoker? No ☐ Yes ☐
- Have you been treated previously for CAD? No ☐ Yes ☐
- Has anybody in your family been treated for CAD? No ☐ Yes ☐
- Are you diabetic or treated for diabetes? No ☐ Yes ☐
- Do you have HBP or are you treated for HBP? No ☐ Yes ☐
- Do you have dyslipidemia or are you treated for dyslipidemia? No ☐ Yes ☐
- What is your approximative weight (kg) and height (cm)

Les registres de cardiologie de l'ARS Île-de-France
e-MUST et CARDIO-ARSIF

Demographics & Clinical Profile

www.forumeuropeen.com

Paris SDEC. Circulation 2016

Identifying Patients at Risk for Prehospital Sudden Cardiac Arrest at the Early Phase of Myocardial Infarction

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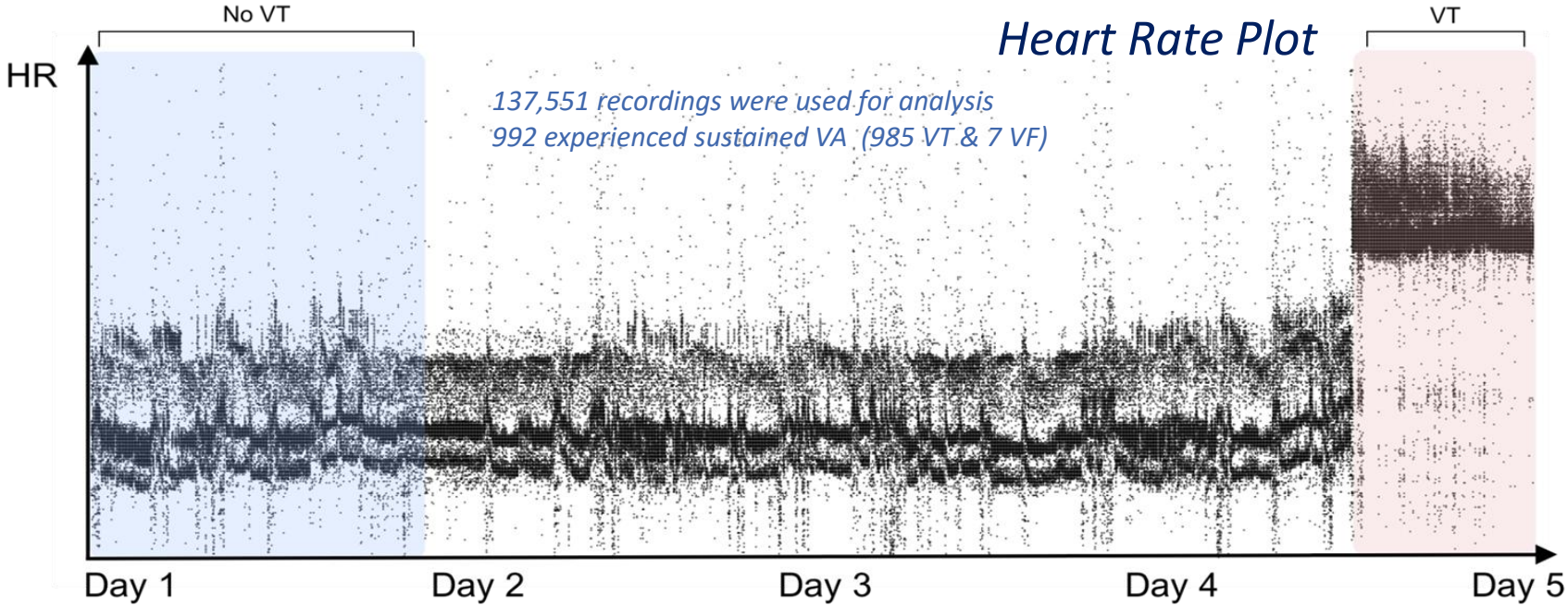
Score	OR (95%CI)	Score
Age <40yo	2.5 (1.5-4.4	9
No diabetes	1.6 (1.0-2.6)	5
No obesity	10.5 (7.1-15.4)	5
Delay ≤30min	2.8 (1.9-4.0)	10
Heart Failure	10.5 (7.1-15.4)	23
TOTAL		/52

Demographics & Clinical Profile

Paris-SDEC investigators. Circulation 2016

www.forumeuropeen.com

Predicting VF/VT within the days prior *using single lead ambulatory ECG*

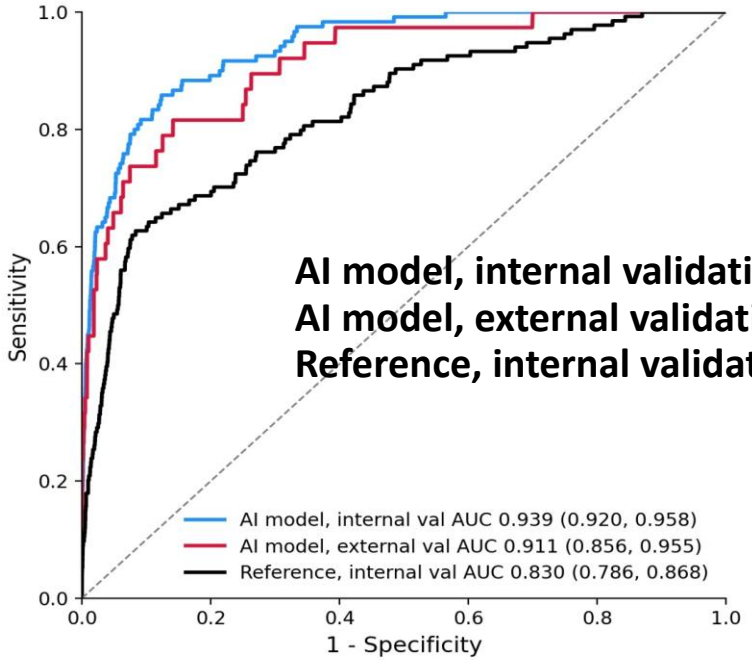


First 24 hours (w/o VT) used as input to a deep learning model

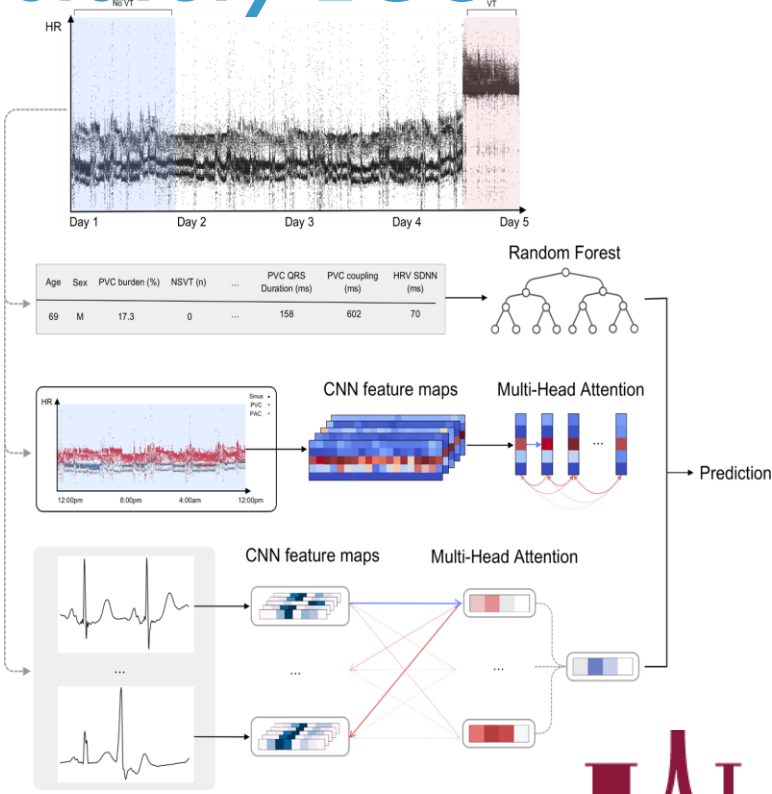
Each recording were labelled according to whether there is any VT documented in the following 13 days & used it as output for the algorithm

Fiorina L et al. Eur Heart J 2025

Predicting VF/VT within the days prior *using single lead ambulatory ECG*

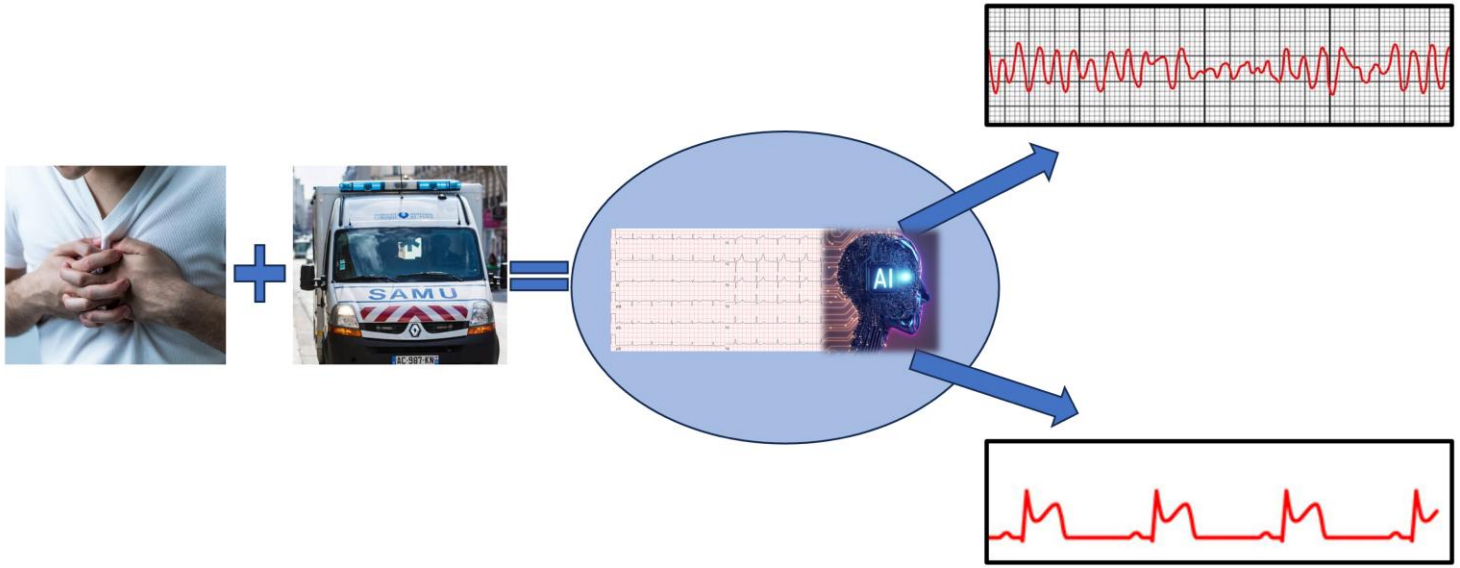


AI model, internal validation AUC 0.939
AI model, external validation AUC 0.911
Reference, internal validation AUC 0.830



Fiorina L et al. Eur Heart J 2025

ARTIFICIAL INTELLIGENCE FOR ALTERNATIVE PREVENTION



LANCET COMMISSION
SUDDEN CARDIAC DEATH

FIBRILLATE Study

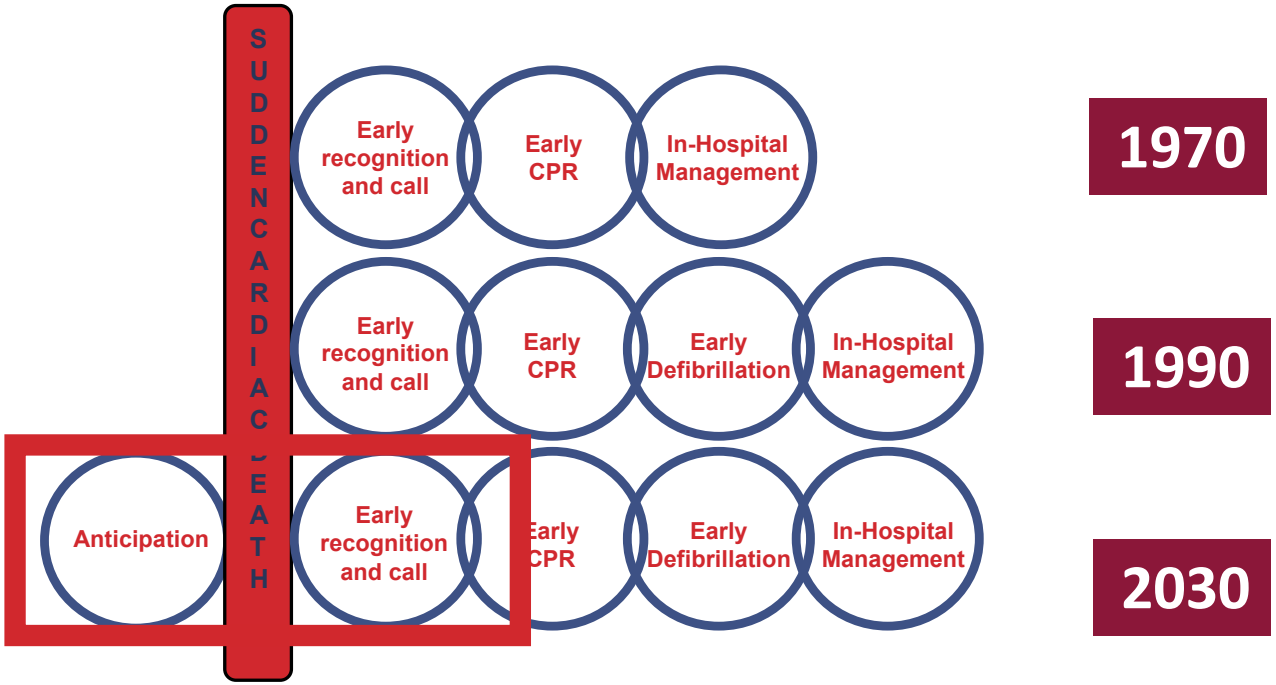
IA pour prédire la mort subite

TAKE-HOME MESSAGES

- Vers de meilleures PREDICTION/PROTECTION & REANIMATION
- IA aidera mais attention aux erreurs de raisonnement !!
- Améliorer la prediction à long terme & developer le concept de prevention à court terme….

Adding a Link to Chain of Survival??

An Early Link that Would Actually Link Prevention & Resuscitation!!



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