

Artificial Intelligence in EP: Current State and Future Promise

How smart is the ECG?



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Disclosure

Relationships with commercial interests:

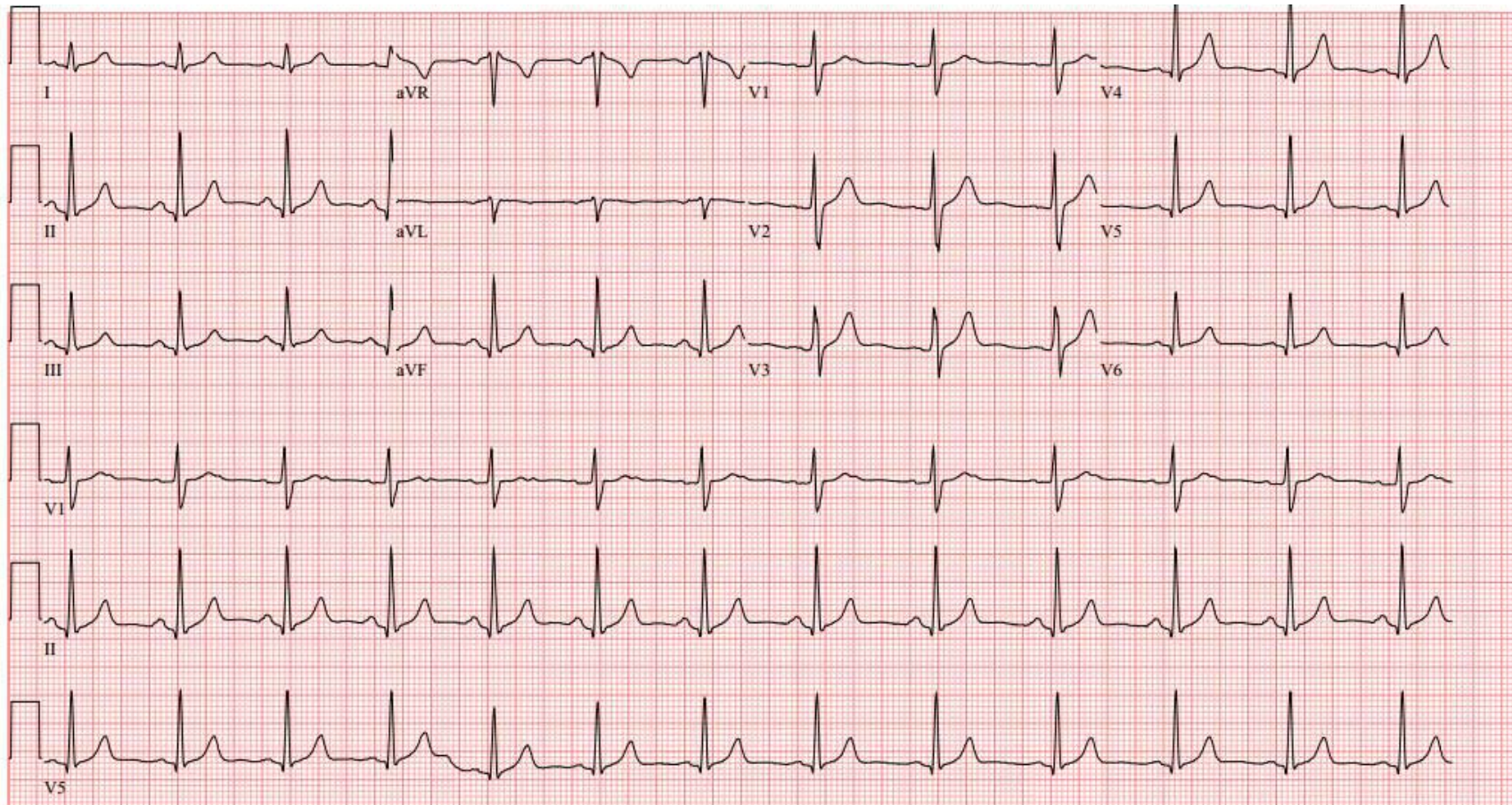
- Grants/Research Support: None
- Speakers Bureau/Honoraria: None
- Consulting Fees: None
- Other: Co-inventor of an AI ECG algorithm for detection of HCM that is licensed to Anumana, Inc.

17-NOV-1979 (39 yr)
Male

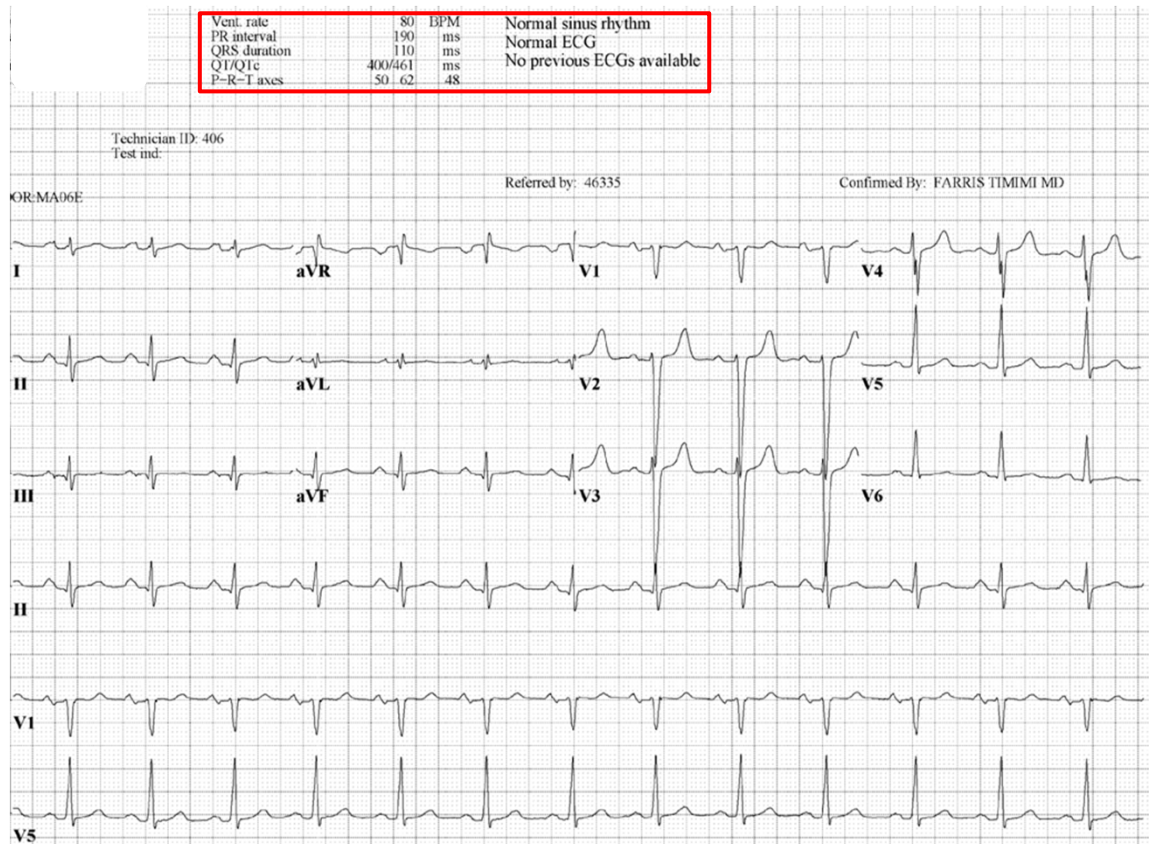
Room:
Loc:1

Vent. rate	76	BPM
PR interval	156	ms
QRS duration	100	ms
QT/QTc	376/423	ms
P-R-T axes	74 76	63

Estimated age:	37.3 yrs
Probability male:	98.6%
Estimated EF:	58.1%
Probability of low EF:	0.3%
Probability of undetected AF:	0.2%
Probability of HCM:	0.1%



35M PRESENTS AFTER HIS SISTER DIES SUDDENLY



AI ECG OUTPUT:

Positive for low EF
(76% probability
of having Low EF)

Echocardiogram

EF: 18%

Found to have familial cardiomyopathy

Seeing beyond human interpretation...3 examples



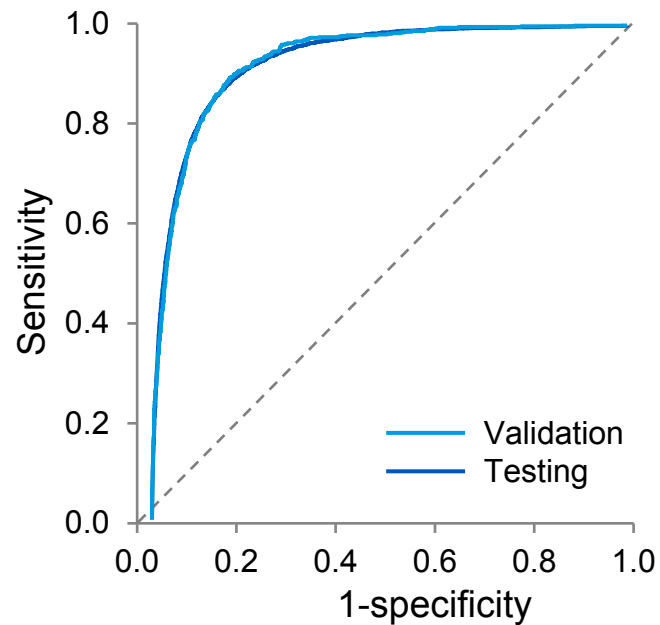


1

Low ejection fraction



DETECTION OF LOW EJECTION FRACTION



Area under curve of EF

AI ECG = 0.93

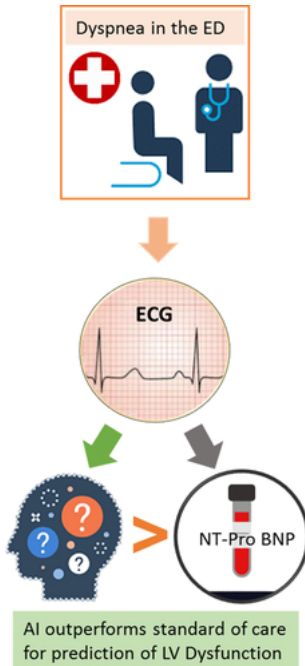
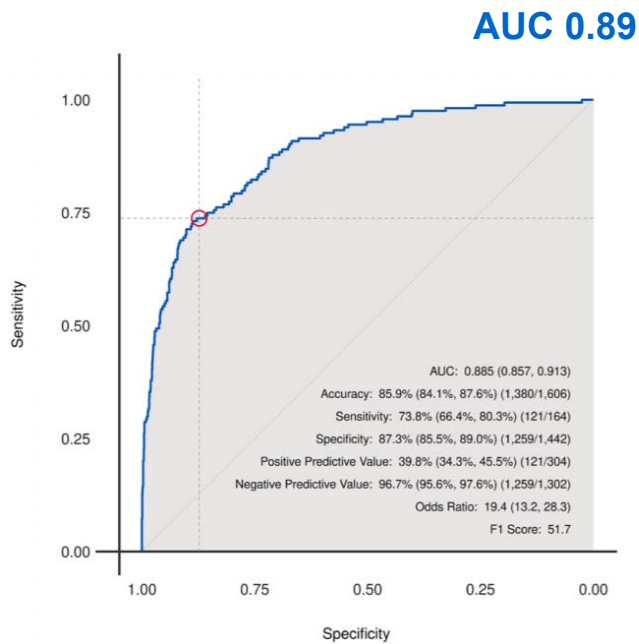


Validated
In other populations

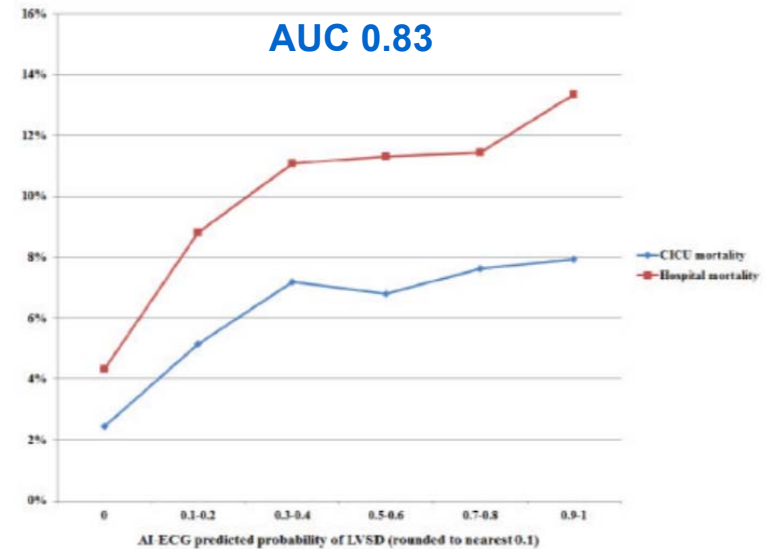
Nat Med 2019
JACC sup 2020

VALIDATION IN OTHER CLINICAL SETTINGS

- Emergency Department (pts present with dyspnea)



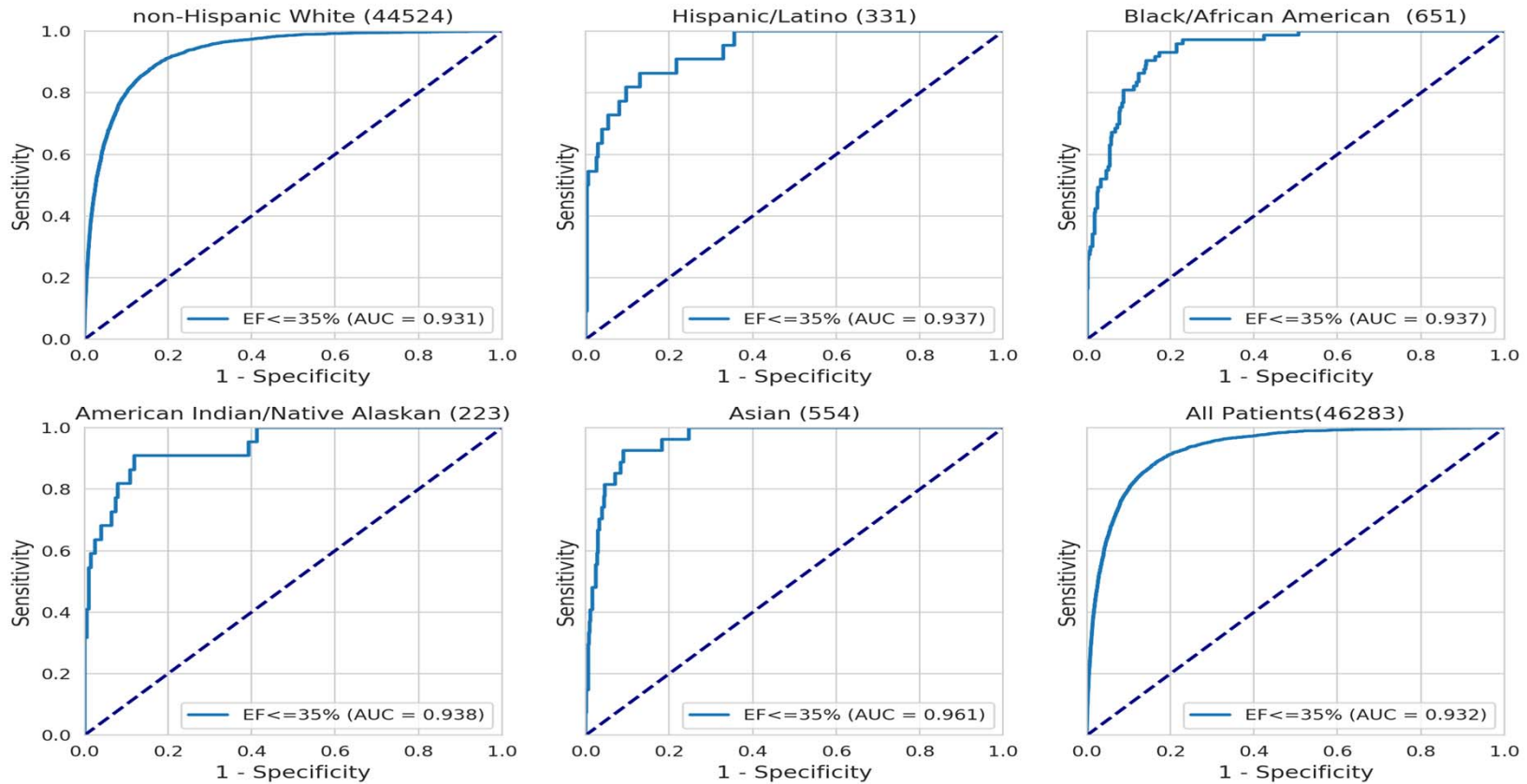
- Cardiac Critical Care Unit



Circ AE 2020

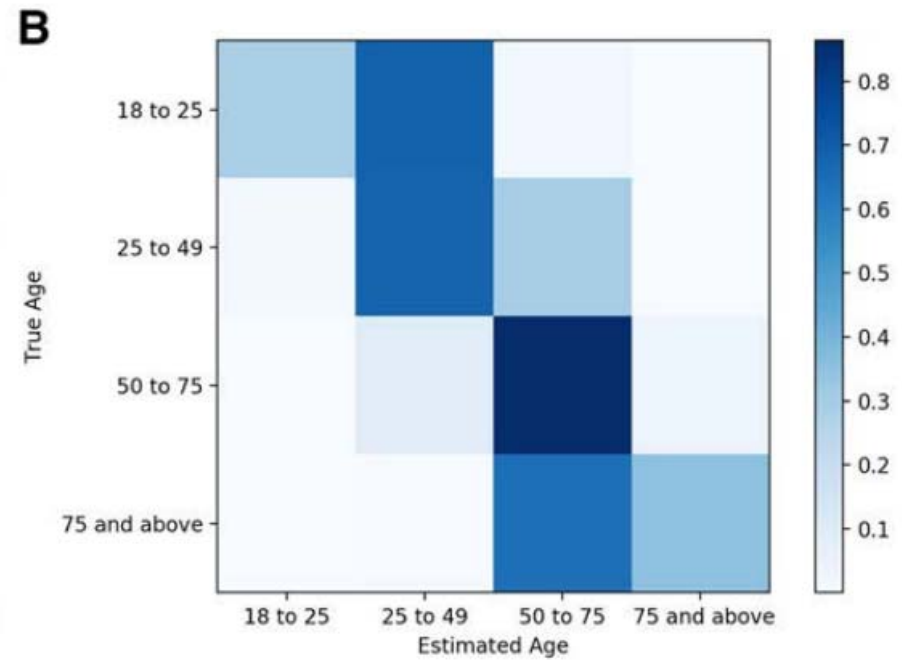
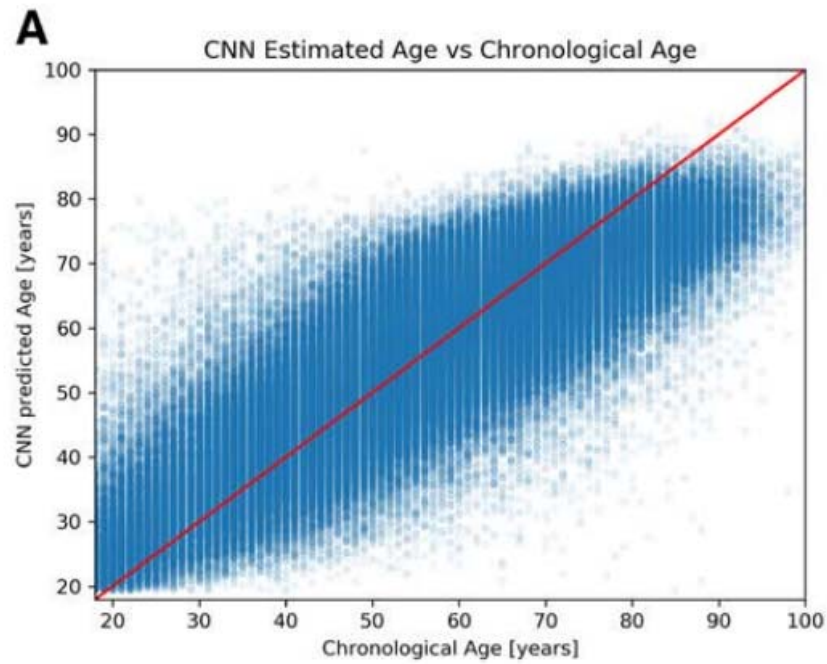
EHJ ACC 2020

CONSISTENT MODEL PERFORMANCE ACROSS RACIAL GROUPS



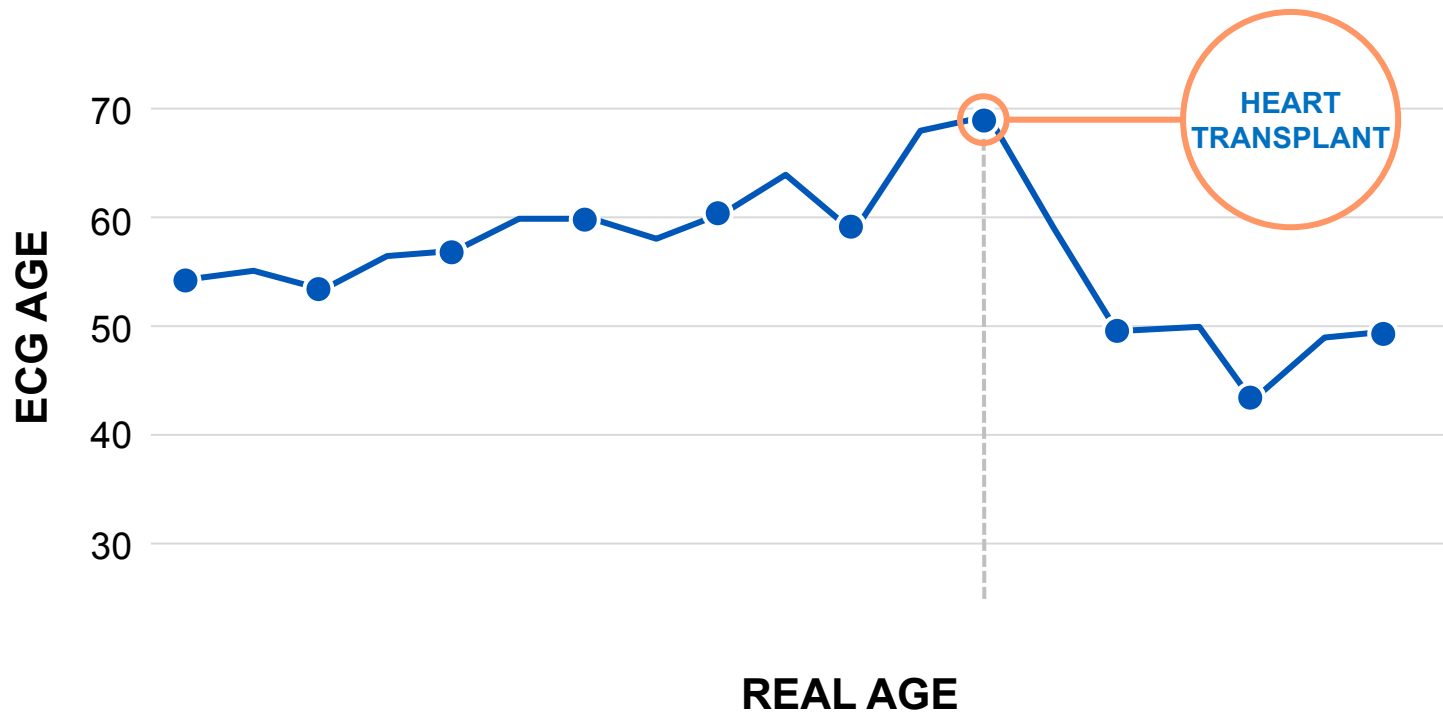
Circ AE 2019

CHRONOLOGIC VS PHYSIOLOGIC AGE



Circ AE 2019

PROGRESSION OF ECG AGE OVER TIME....





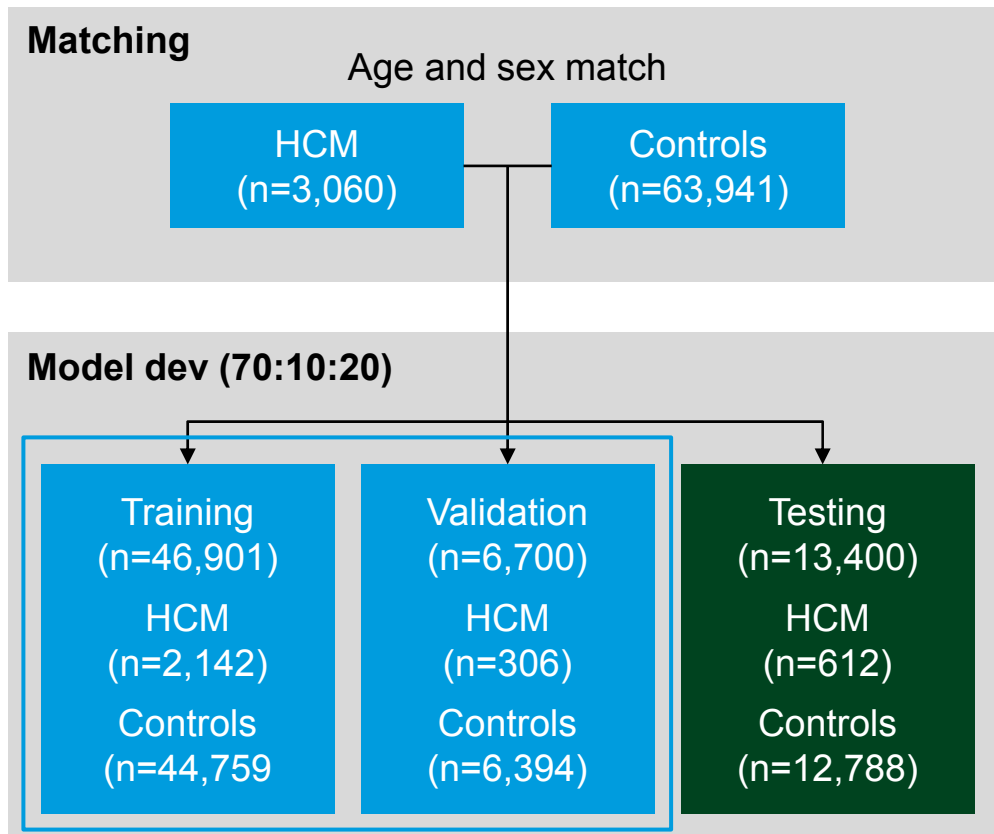
2



Hypertrophic Cardiomyopathy

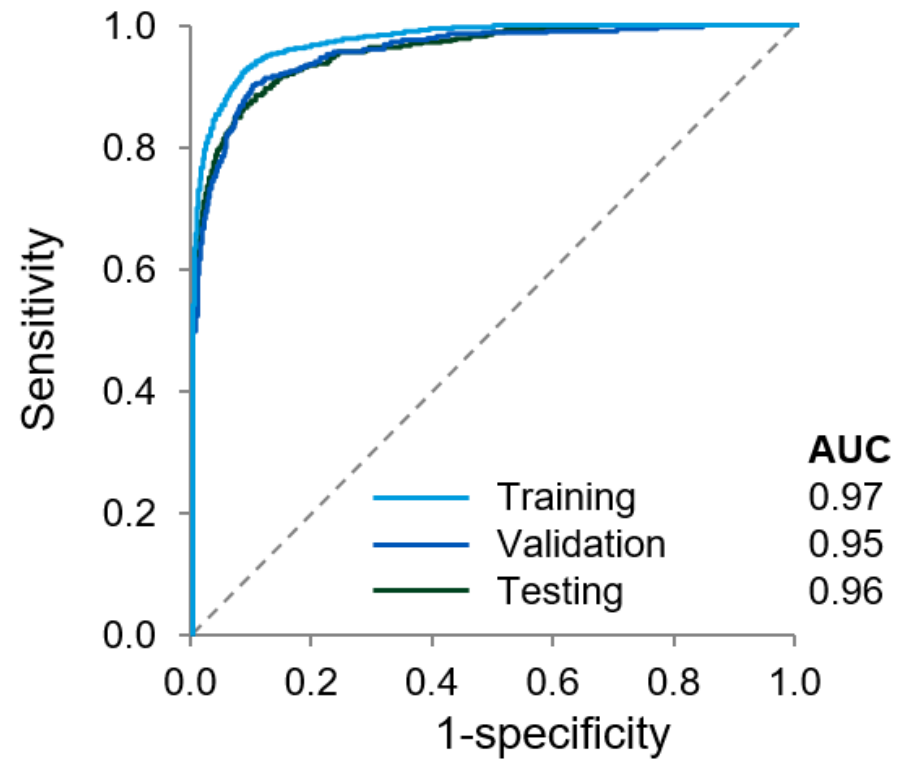
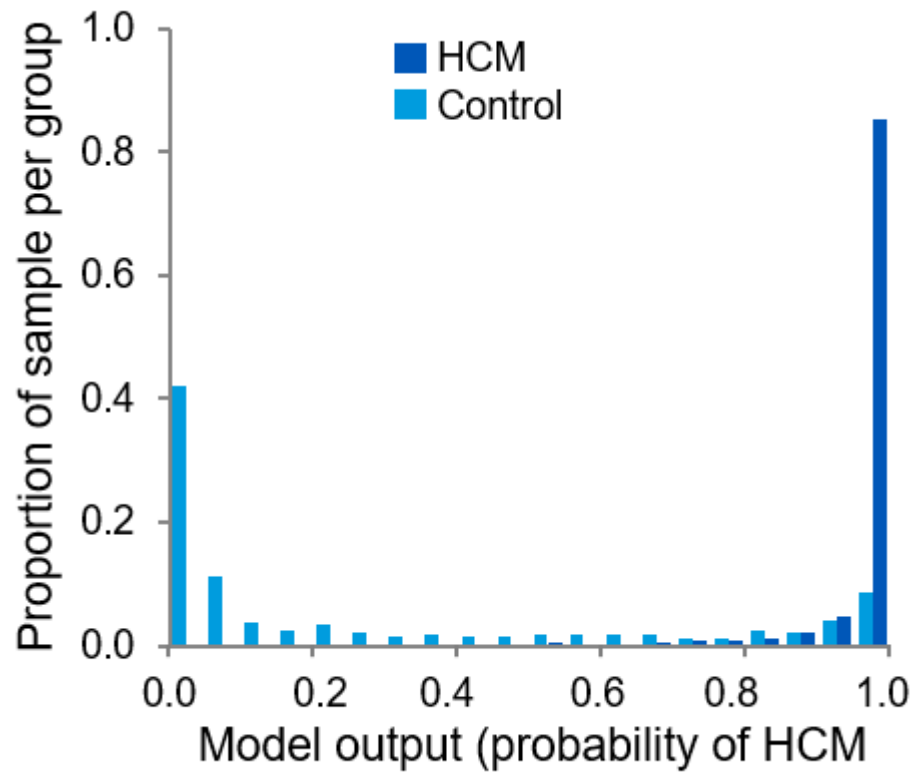


HYPERTROPHIC CARDIOMYOPATHY



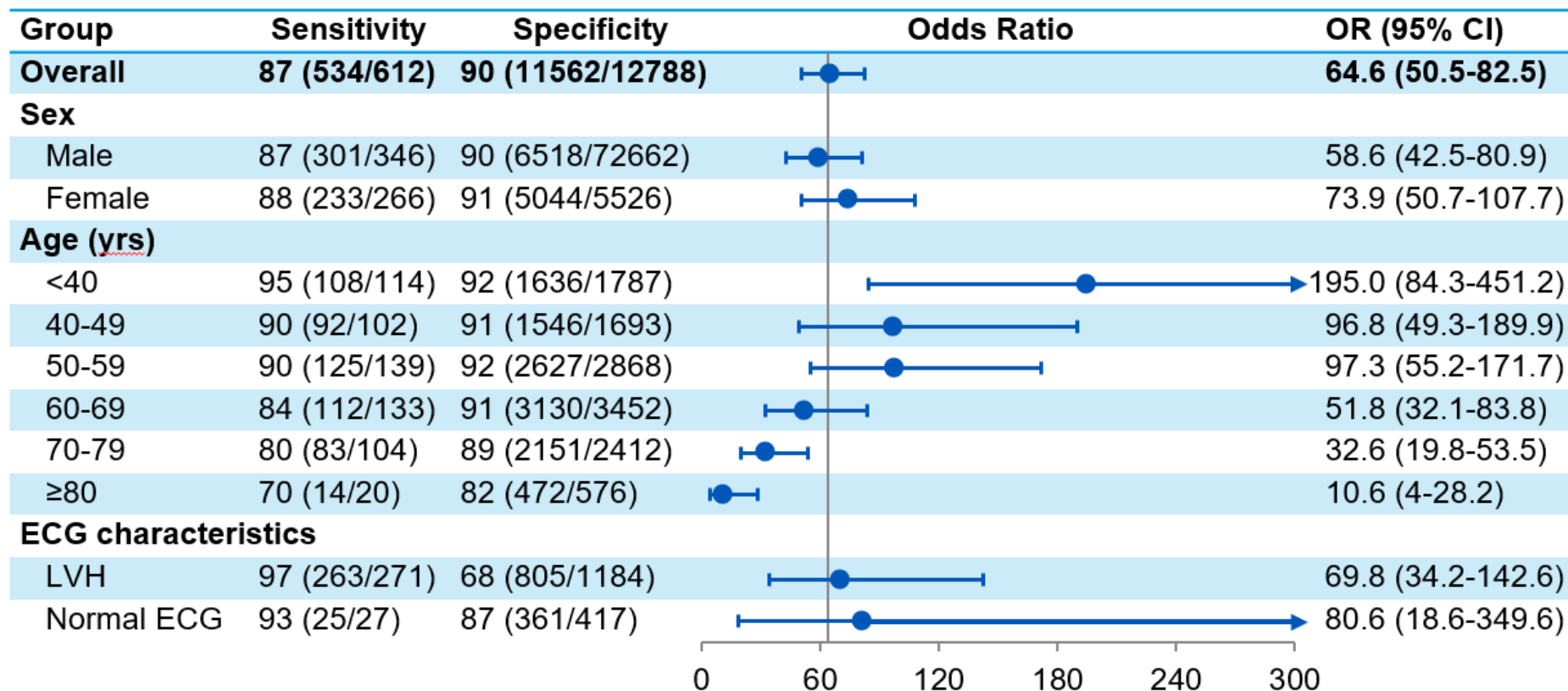
JACC 2020

HCM: MODEL PERFORMANCE



JACC 2020

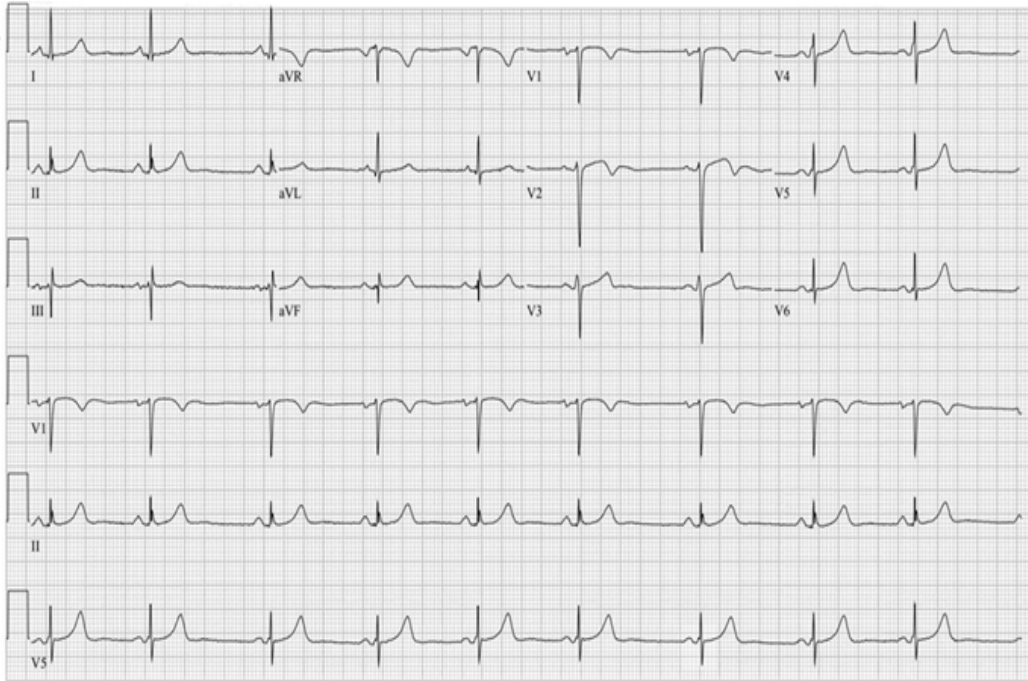
HCM: SUBGROUP PERFORMANCE



Results in genotyped patients?

- With sarcomeric mutation (n=286): 97% (IQR 80-99%), 3.5% false neg
- Without sarcometic mutation (n=574): 96% (IQR 70-99%), 8% false neg

CLINICAL CASE: 25-YEAR-OLD WOMAN WITH HCM

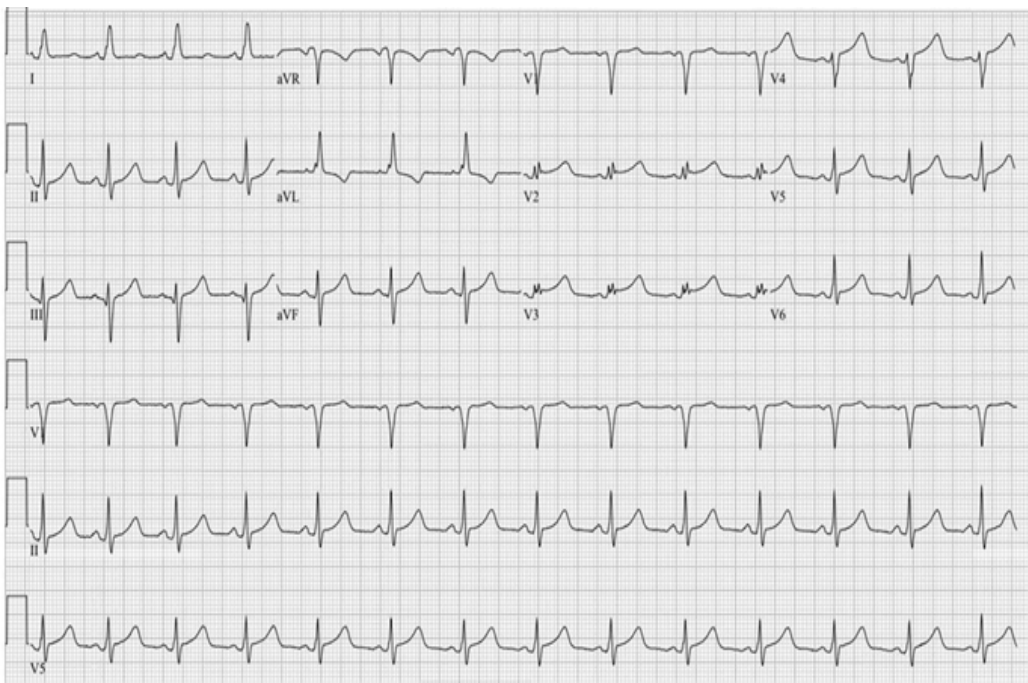


72.6% probability of HCM!



JACC 2020

POST-OP: PATIENT UNDERGOES SEPTAL MYECTOMY



ECG becomes more 'abnormal' but now AI calculates a 2.5% probability of HCM!





3

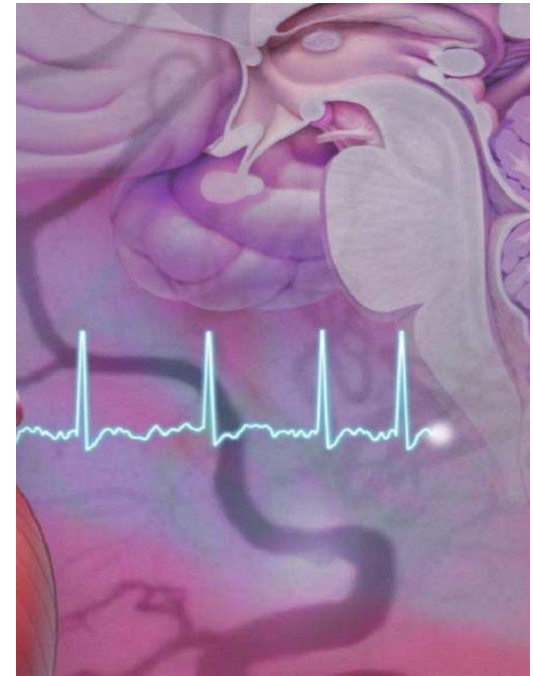


Atrial fibrillation

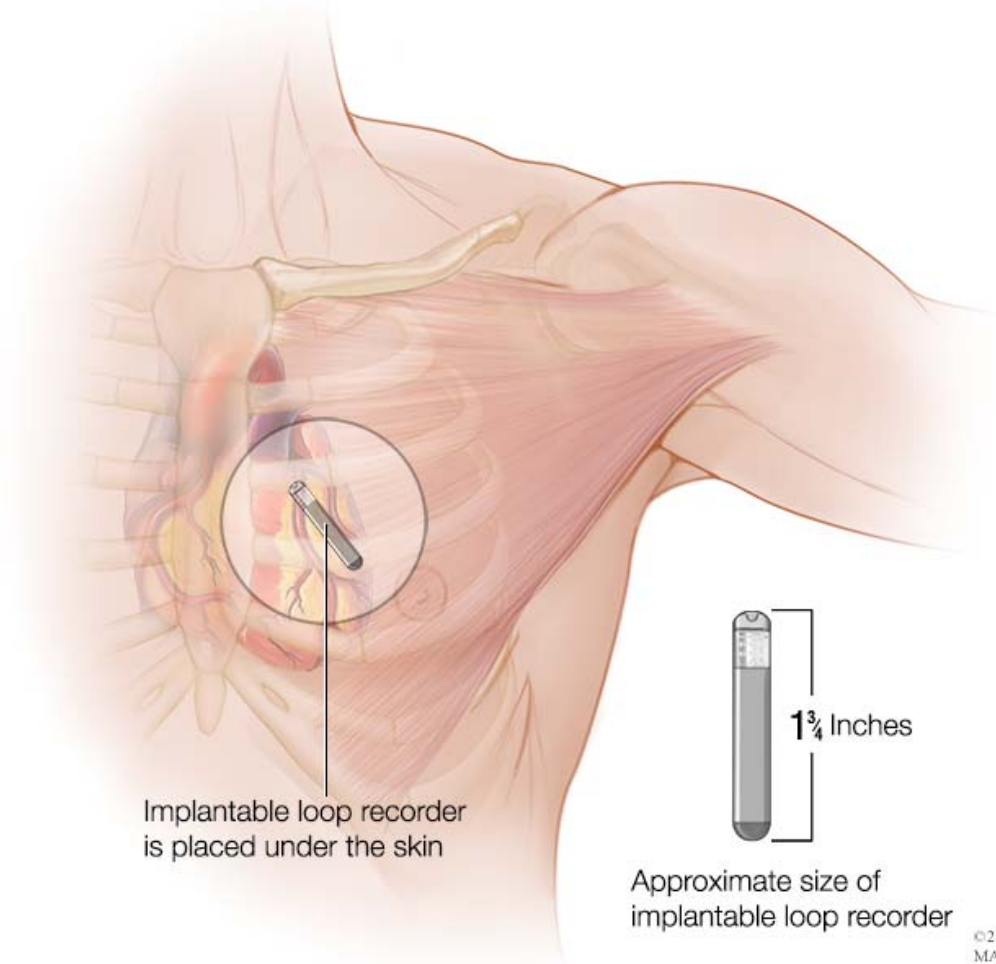


ATRIAL FIBRILLATION

- Often fleeting
- Sometimes asymptomatic
- Can have major consequences: Stroke

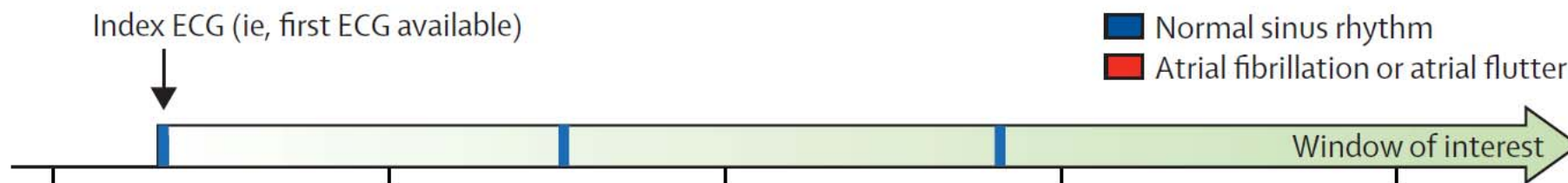


CURRENT MEANS FOR ASYMPTOMATIC AF DETECTION

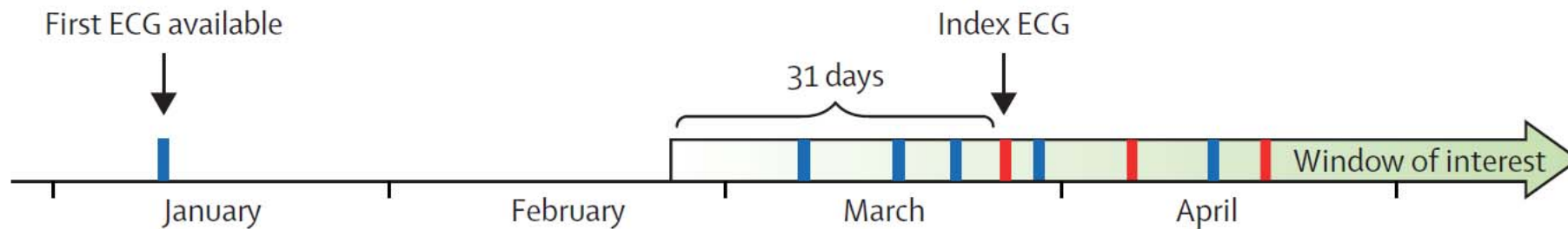


ATRIAL FIBRILLATION RISK

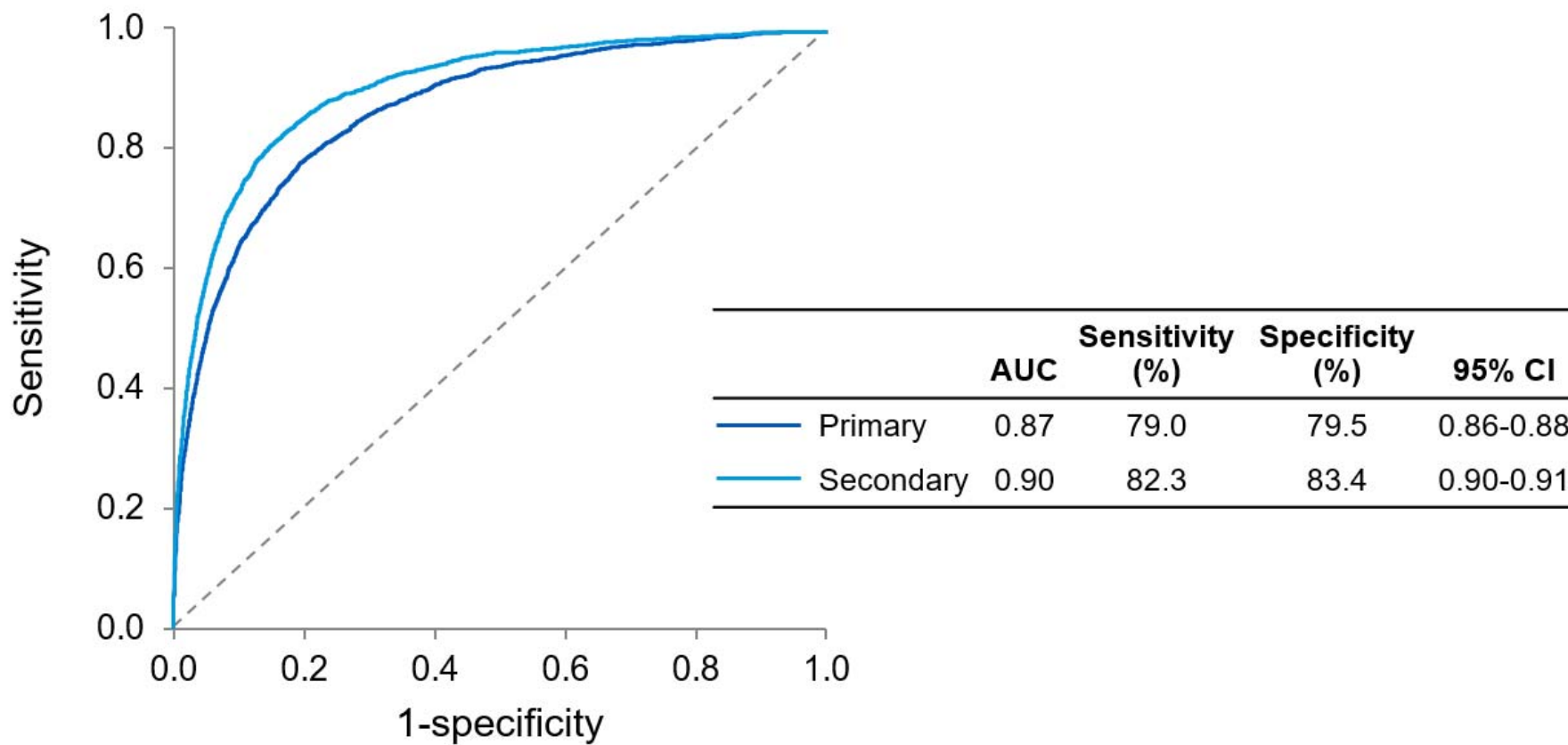
Patient with no atrial fibrillation rhythms recorded



Patient with at least one atrial fibrillation rhythm recorded

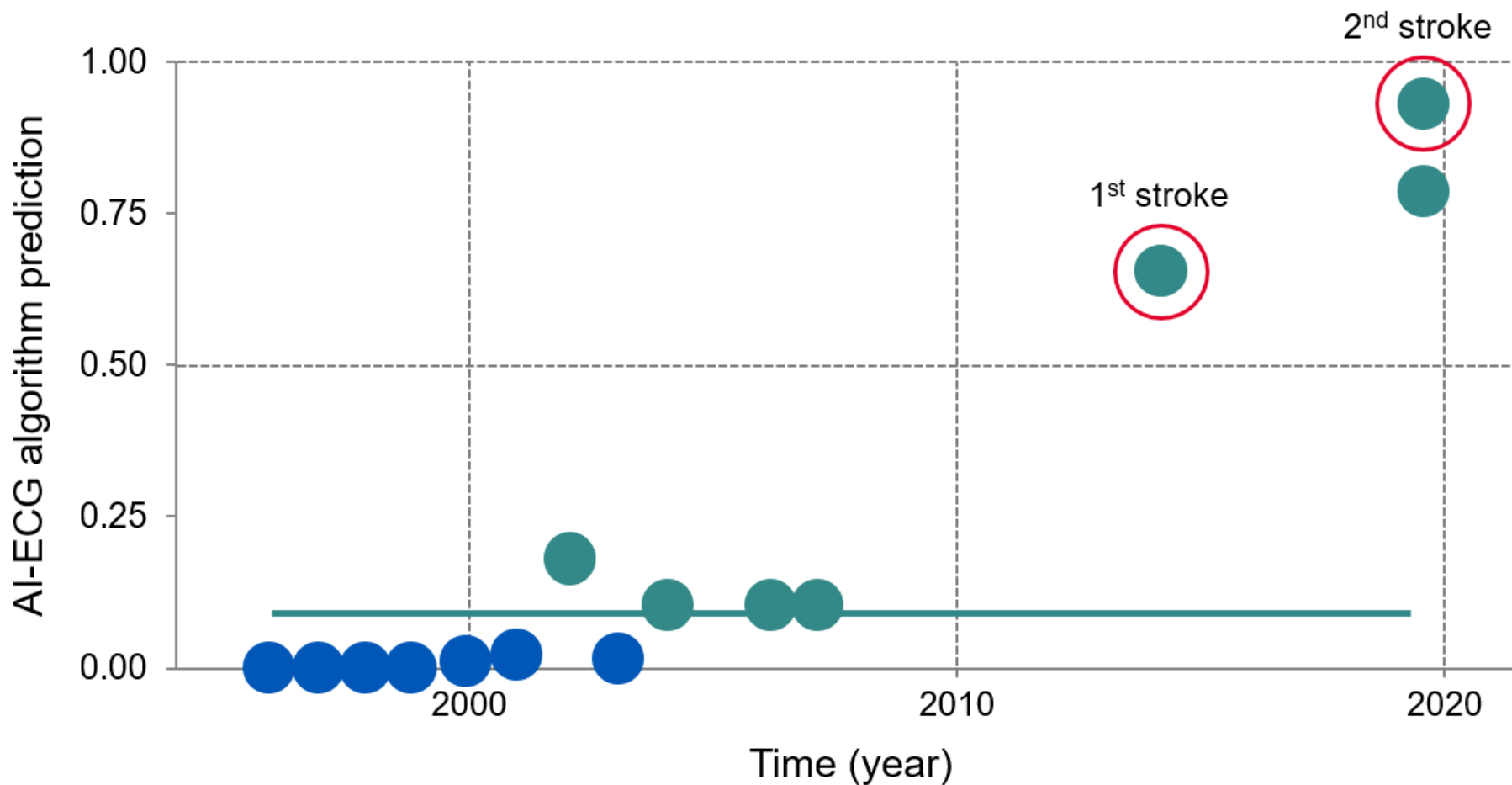


ATRIAL FIBRILLATION RISK



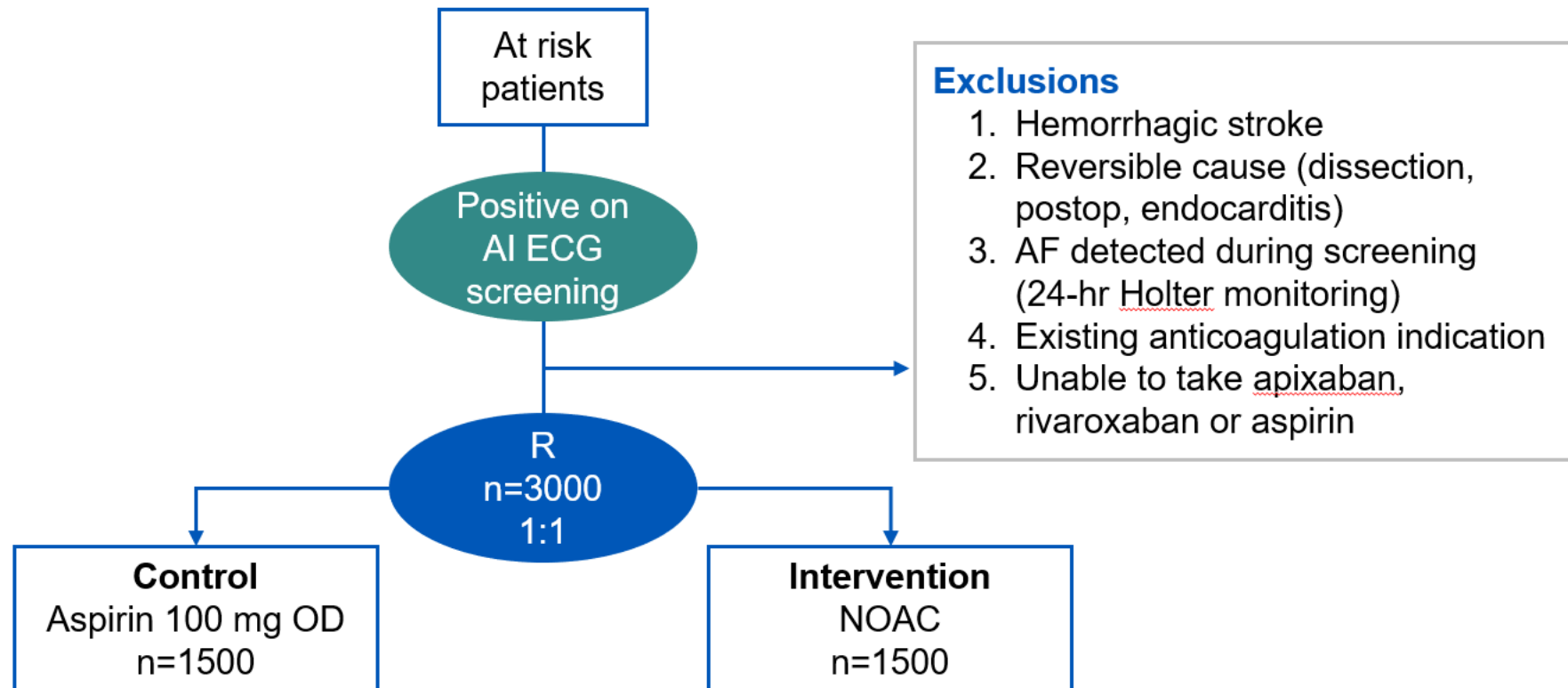
Lancet 2019

CASE: COULD AI HAVE PREVENTED A STROKE?



HRCR 2019

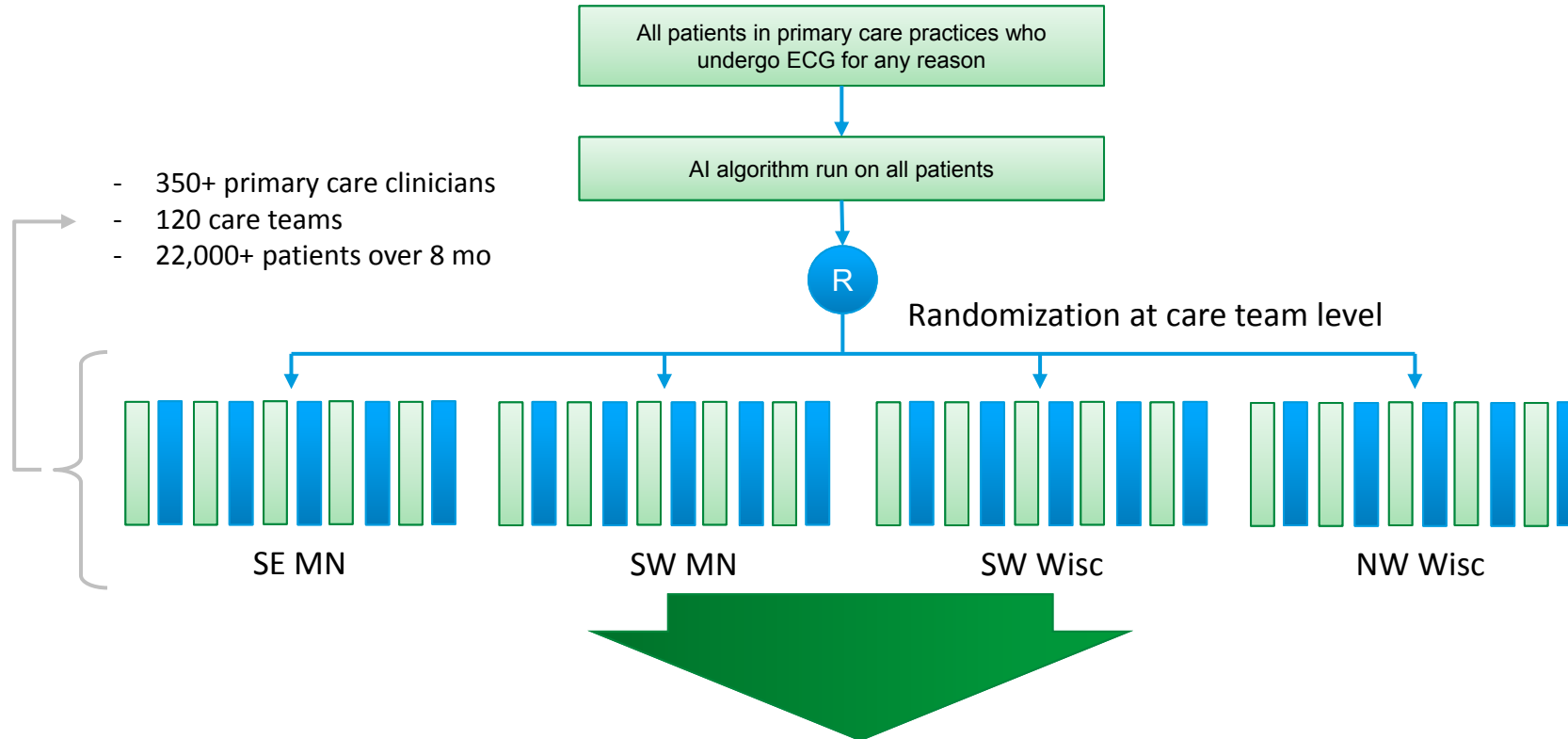
PROPOSED RCT: TREATMENT/STROKE PREVENTION



TRANSLATION TO PRACTICE



EAGLE: Cluster-randomized, pragmatic design



Outcomes: 1. New low EF diagnosis, 2. Treatment patterns, 3. Qualitative assessment

Nature Med 2021 (in press)

Clinicaltrials.gov NCT04000087

Epic
Patient Lookup
Appts
Patient Station
Reading Work List
Study Review
Status Board
Prep for Case
Remind Me
Personalize
Place Future Orders
AskMayoExpert
My Reports
SlicerDicer
Sign My Visits
Communication

Coverage, Fin Class: MEDICARE, Medicare
 Mayo PCP: None, Not Defined

Allergies: Oxycodone
 Device: Yes
 Code: Not on file
 Adv Directive: None

FYI: SOGI
 Height: 176 cm
 Weight: 97.8 kg
 BMI: None

Registries: Adult Obesity...
 Interp: No, English

BestPractice Advisory: None
 Portal: Active
 HM: Due

18.0.1.48

OnBase Patient Window

FILTER

Date of Service	Document Type
5/24/2019	Diagnostic Report - ECG with AHI enhanc
5/17/2019	OSM Clinical Notes and Results
5/24/2019	Diagnostic Report - ECG
5/11/2019	OSM Clinical Notes and Results
5/17/2019	OSM Clinical Notes and Results
5/17/2019	OSM Clinical Notes and Results
7/18/2018	OSM Clinical Notes and Results
6/14/2018	Diagnostic Report - Holter Monitor
	Insurance Card
6/14/2018	Diagnostic Report - Echo
6/14/2018	Diagnostic Report - ECG
3/3/2018	HIM ROI Authorization
2/27/2018	Anesthesia Record
2/21/2018	Correspondence
2/13/2018	Diagnostic Report - ECG
2/12/2018	Diagnostic Report - Cath/EP
2/9/2018	Anesthesia Record
	Authorizations and Service Terms
	Diagnostic Report - Echo
	Diagnostic Report - Echo
2/9/2018	Auth - Adult - Family and Friends
11/3/2003	Patient Provided Information
2/9/2018	Diagnostic Report - ECG
2/9/2018	Consent Form
2/9/2018	Consent Form

ECG Artificial Intelligence-Guided Screening for Low Ejection Fraction (EAGLE)

ALGORITHMIC RESULTS

Screening result: NEGATIVE
 Recommendation: No further testing unless indicated by other symptoms or conditions

*Results generated from ECG-based AI algorithm

[AskMayoExpert: Reduced Ejection Fraction](#)

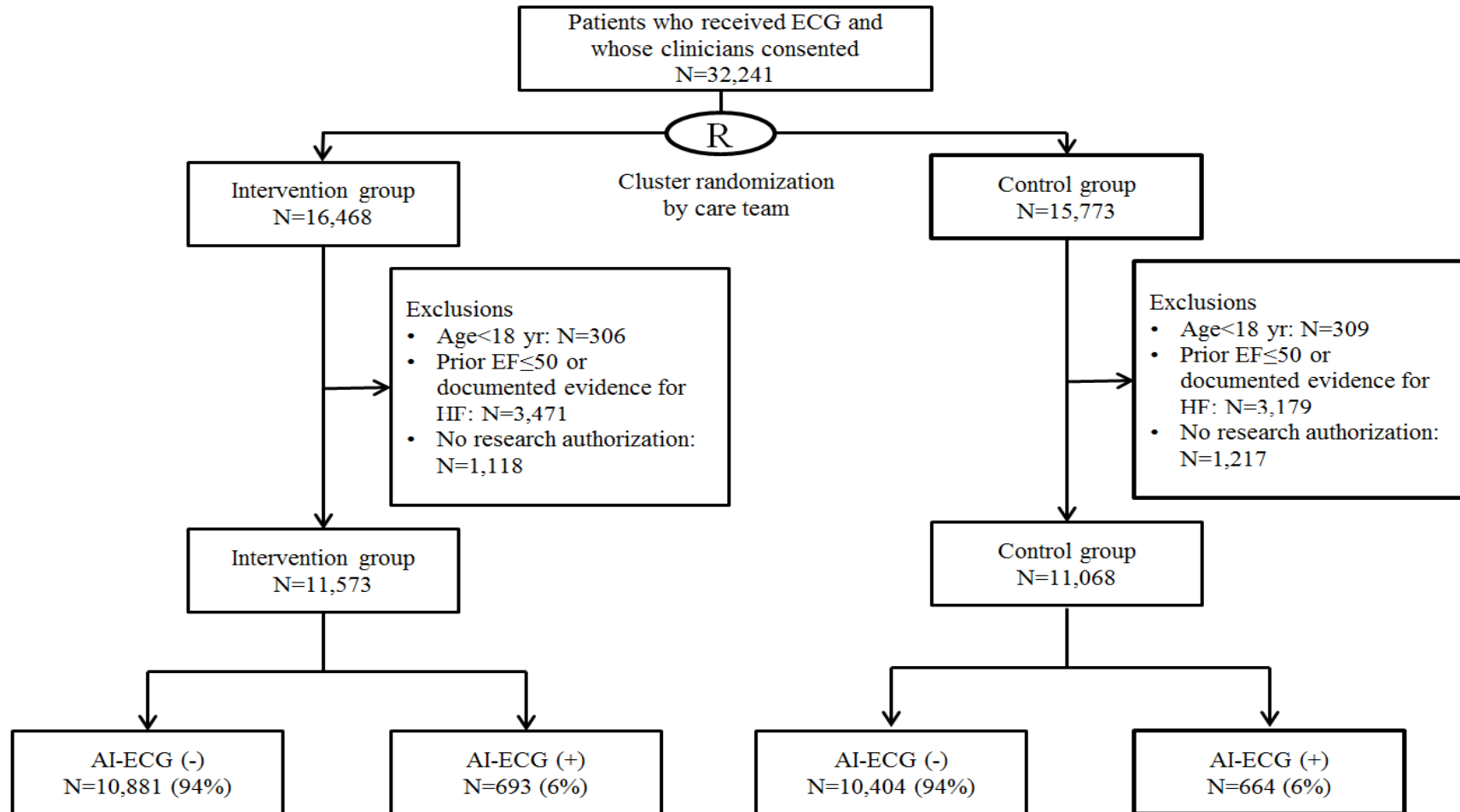
The algorithm is being applied in order to screen for asymptomatic left ventricular systolic dysfunction in patients who have no other indication for echocardiography. Among patients with established heart failure, heart failure symptoms, or other indications for an echocardiogram, this algorithm should not affect your decision to order an echocardiogram.

Risk factors for heart failure, such as hypertension, obesity, diabetes, dyslipidemia, atherosclerotic disease, smoking, and alcohol abuse, should also be evaluated and managed to prevent heart failure.

The prediction algorithm was derived from a sample of Mayo Clinic patients who underwent both ECG and echocardiography. The model demonstrated a c statistic of 0.92, a sensitivity of 82.5%, a specificity of 86.8%, and an accuracy of 86.5% in a prospective validation.

[Link to Nature Medicine publication](#)

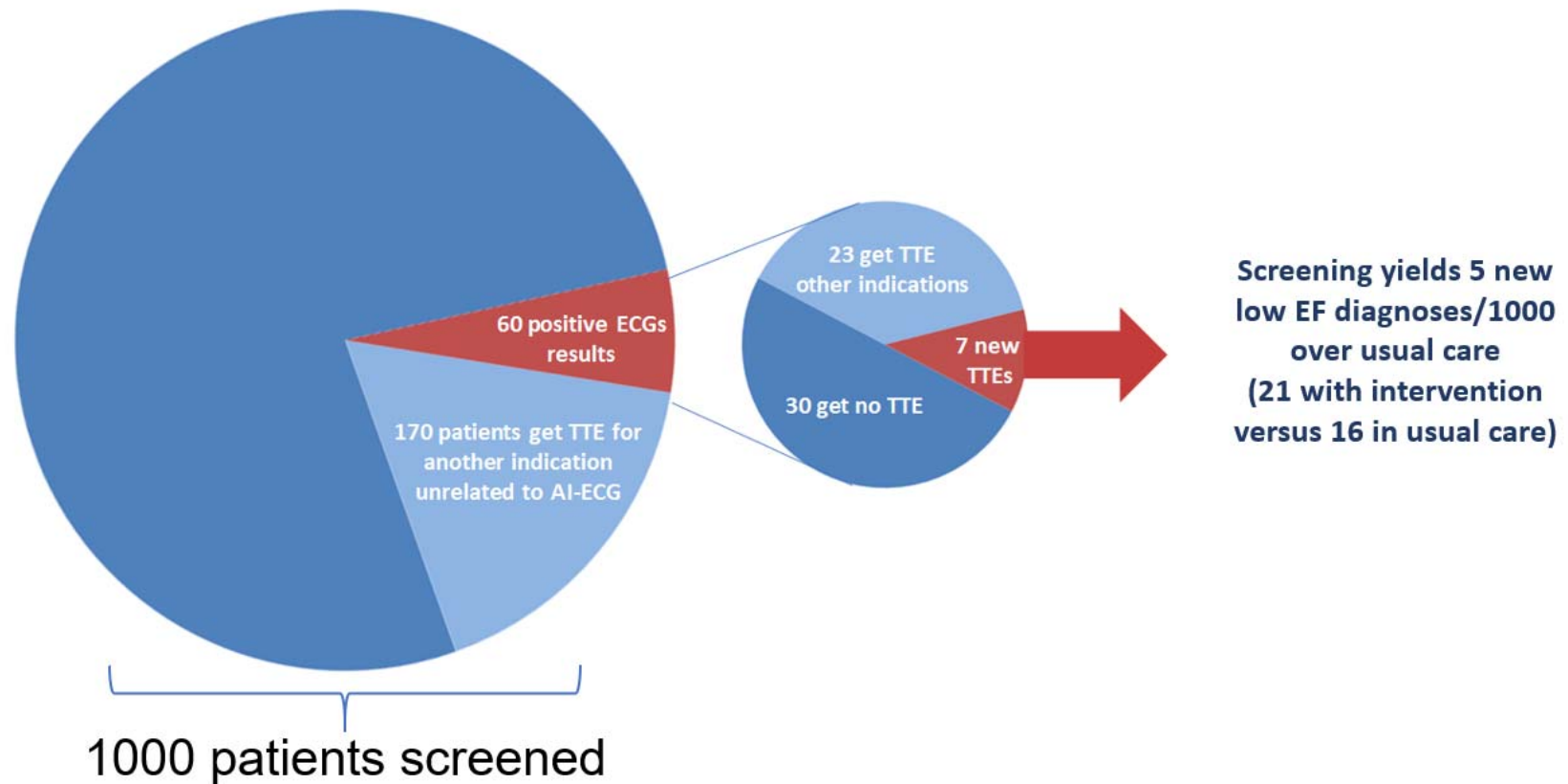
FLOW DIAGRAM/ENROLLMENT



PRIMARY FINDINGS

- The intervention increased the diagnosis of low EF in the overall cohort (1.6% vs. 2.1%, odds ratio [OR] 1.32 [1.01-1.61], $p=0.007$)
- Clinicians in the intervention group obtained more echocardiograms for patients with + AI-ECG (38.1% control vs. 49.6% intervention, $p<0.001$)
 - Overall echocardiogram utilization was similar (18.2% vs. 19.2%, $p=0.17$)









OVERALL DIAGNOSTIC YIELD

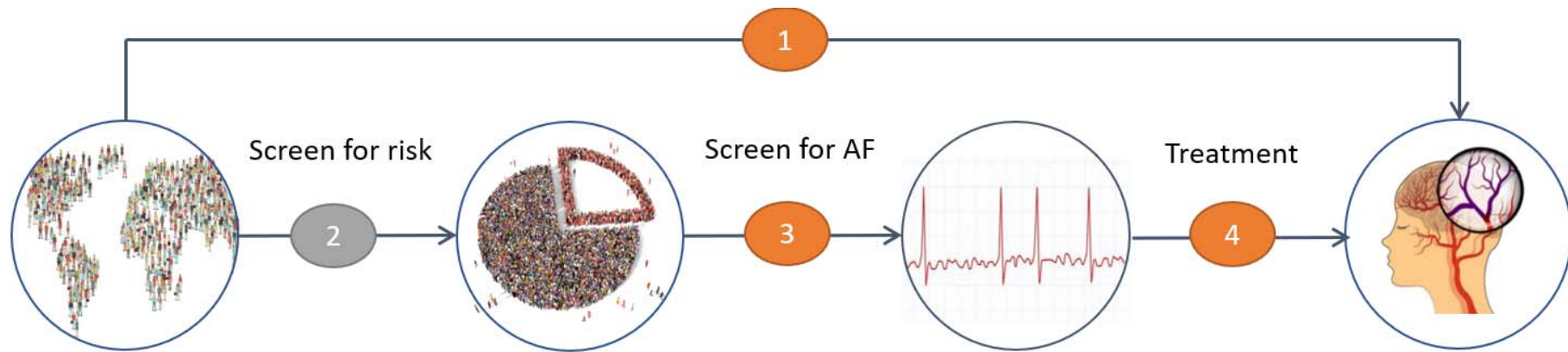


Nature Med 2021 (in press)



Artificial intelligence-enabled electrocardiograms for identification of patients with low ejection fraction: a pragmatic, randomized clinical trial

Xiaoxi Yao ^{1,2} , David R. Rushlow³, Jonathan W. Inselman¹, Rozalina G. McCoy^{1,4}, Thomas D. Thacher ³, Emma M. Behnken⁵, Matthew E. Bernard³, Steven L. Rosas⁶, Abdulla Akfaly⁷, Artika Misra⁸, Paul E. Molling⁹, Joseph S. Krien¹⁰, Randy M. Foss ¹¹, Barbara A. Barry¹, Konstantinos C. Siontis², Suraj Kapa², Patricia A. Pellikka ², Francisco Lopez-Jimenez², Zachi I. Attia ², Nilay D. Shah¹, Paul A. Friedman ² and Peter A. Noseworthy ²

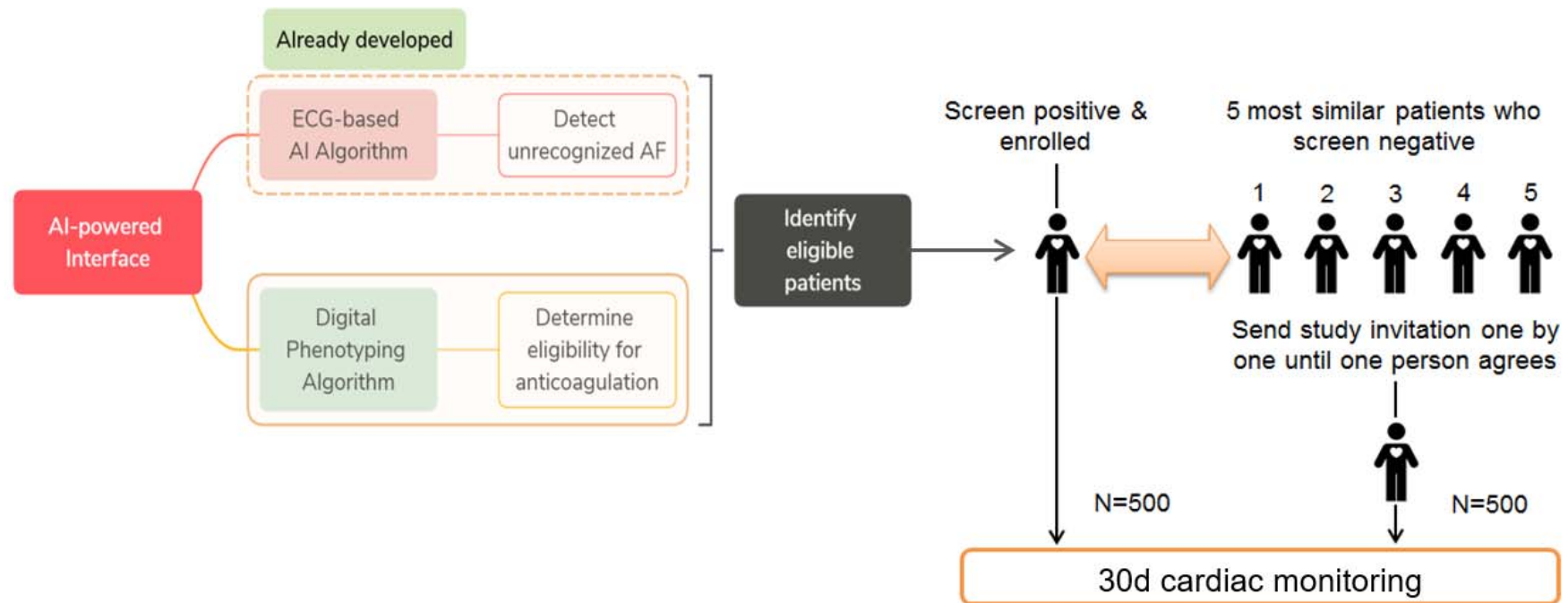


What is **known** and **unknown** about AF screening and treatment?

- 1 Is AF screening useful?
- 2 Can we identify AF risk?
- 3 How to best monitor for AF in at risk patients?
- 4 Do we anticoagulate patients or not?

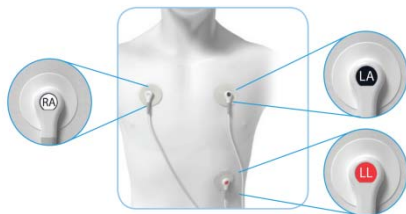
EHR INTEGRATION FOR SITE-LESS PRAGMATIC RCT

BATCH ENROLLMENT FOR AN ARTIFICIAL INTELLIGENCE-GUIDED INTERVENTION TO LOWER NEUROLOGIC EVENTS IN PATIENTS WITH UNDIAGNOSED ATRIAL FIBRILLATION (BEAGLE) (NCT04208971)



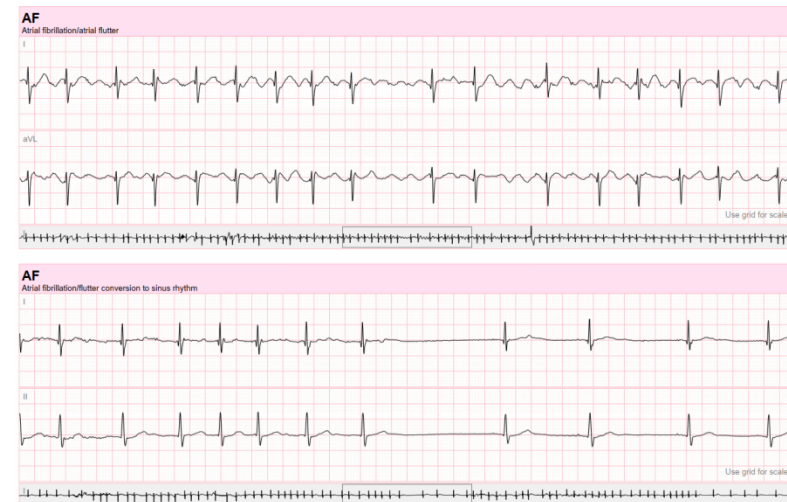
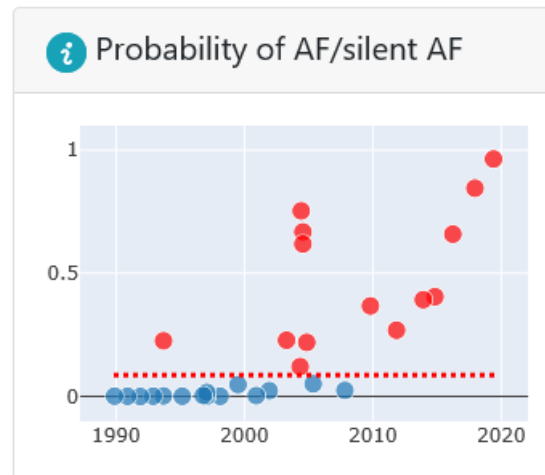
PILOT STUDY: EHR INTEGRATION FOR SITE-LESS PRAGMATIC RCT

BATCH ENROLLMENT FOR AN ARTIFICIAL INTELLIGENCE-GUIDED INTERVENTION TO LOWER NEUROLOGIC EVENTS IN PATIENTS WITH UNDIAGNOSED ATRIAL FIBRILLATION (BEAGLE) (NCT04208971)



CASE EXAMPLE:

- Retired MD with diabetes, HTN, and chronic kidney disease
- 30 NSR ECGs at Mayo Clinic



TRANSLATION TO PRACTICE: GETTING RESULTS TO PATIENTS AND CLINICIANS



Performed	Exam	Performed Proc	Ordered By	Performed By	Images	Attachment	Status	Accession #	Ord/Expecte
01/23/2019	ECG 12 Lead	ECG 12 Lead					Final result		01/23/2019

Male, 40 y.o., 11/17/1979

«Search»

Coverage & Financial Info
 Mayo Employee
 Infection: None
 Care Team: No PCP
Allergies: No Known Allergies
 Next Appt: None
 Social Determinants: Not on file

Height: 188 cm >365 days
 Weight: 78 kg >30 days
 Blood Pressure: 128/66 >1 day

LAST 10 VISITS
 CIM, DER (3), FAM, PED CAM, Unknown (4)
 Lab (2)
 Micro (3)
 Imaging (4)

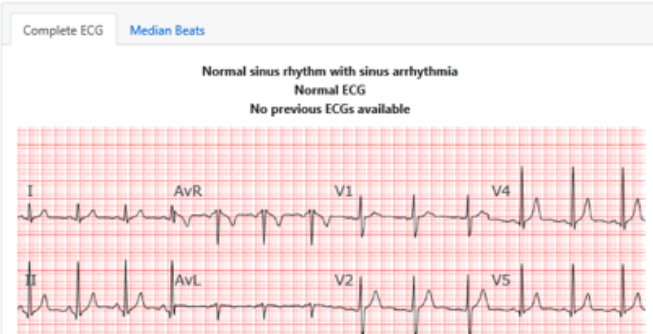
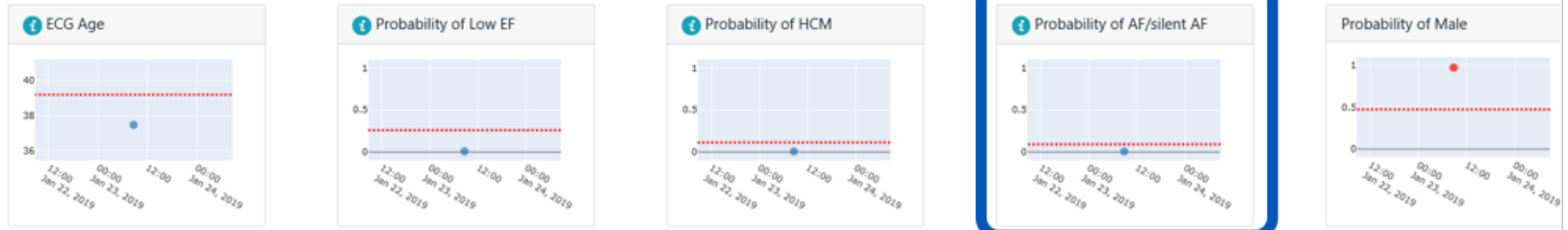
IMPLANTS
 None

Care Gaps: 4

CARDIOLOGY PROBLEMS (0)
 Other problems (0)

Outpatient Medications: 2

Registries (5)



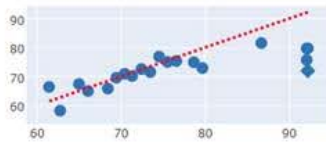
Results [Compare ECGs](#)

ECG Date	Main Rhythm	Heart Rate	QT/QTc	Real Age	ECG Age	P of Male (%)	P of Low EF (%)	P of AF (%)	P of HCM (%)
2019-Jan-23 08:42:18	Normal sinus rhythm	76	376/423	39.19	37.46	97.81	0.35	0.10	0.13

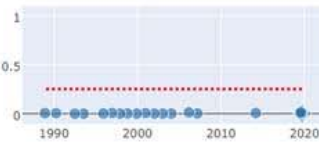
ECG tests for 4164581

AI DASHBOARD

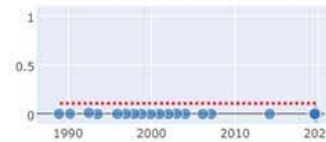
ECG Age



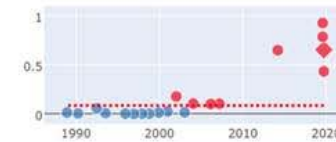
Probability of Low EF



Probability of HCM

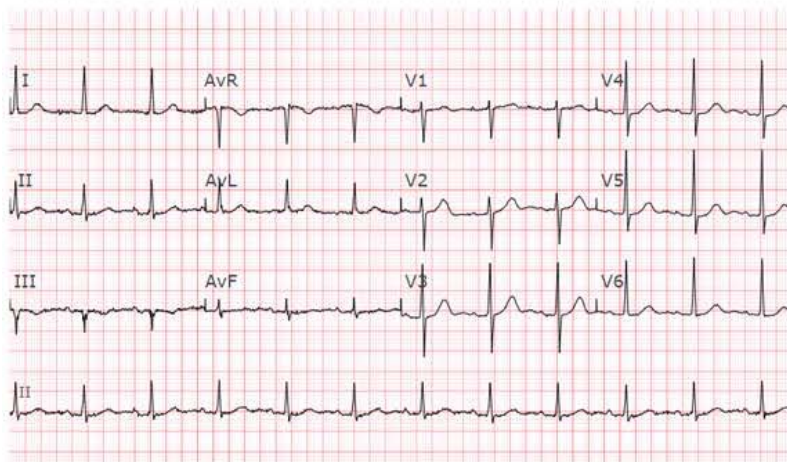


Probability of AF/silent AF



Complete ECG Median Beats

Normal sinus rhythm with 1st degree A-V block Otherwise normal ECG



Results

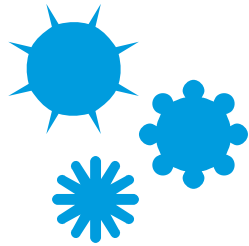
Compare ECGs

Print Report

Download Results

ECG Date	Main Rhythm	Heart Rate	QT/QTc	Real Age	ECG Age	P of Male (%)	P of Low EF (%)	P of AF (%)	P of HCM (%)
09/19/2019 5:38 AM	Atrial flutter	116	326/453	92.202739726	72.0	17.42%	0.59%	65.63%	0.01%
09/18/2019 8:03 PM	Sinus tachycardia	109	356/477	92.2	79.7	16.35%	0.93%	43.52%	0.01%
07/31/2019 8:35 AM	Normal sinus rhythm	79	426/488	92.0712328767	79.7	7.77%	0.39%	92.94%	0.03%
07/30/2019 6:50 AM	Sinus rhythm	92	398/492	92.0684931507	75.7	7.55%	1.87%	78.84%	0.22%
03/10/2014 5:37 PM	Normal sinus rhythm	69	434/465	86.6712328767	81.5	1.04%	1.11%	65.15%	0.10%
03/08/2007 9:08 AM	Normal sinus rhythm	63	456/466	79.6657534247	72.9	0.57%	0.75%	10.56%	0.18%
03/01/2006 9:25 AM	Normal sinus rhythm	69	436/463	78.6493150685	74.9	2.94%	1.77%	10.28%	0.08%
01/26/2004 9:19 AM	Normal sinus rhythm	63	448/454	76.5506849315	75.3	2.99%	0.63%	10.71%	0.18%
01/13/2003 9:50 AM	Normal sinus rhythm	68	436/460	75.5150684932	75.0	0.13%	0.57%	1.75%	0.35%

CONCLUSIONS



Clinical utility
with current workflow



Predict and detect
disease



Massively **scalable**



Driving practice
innovation



Thank You!

Siontis.konstantinos@mayo.edu

