Unlocking the hidden rhythms:

Artificial intelligence-powered prediction of paroxysmal atrial fibrillation in patients with embolic stroke of undetermined source using sinus rhythm electrocardiograms

Min Soo Cho[2], Minsu Kim[3], Ju Youn Kim[4], Ji Hyun Lee[1], Youngjin Cho[1], Joonghee Kim[1], Il-Young Oh[1]

[1] Seoul National University Bundang Hospital, Republic of Korea, [2] Asan Medical Center, Republic of Korea, [3]Chungnam National University Sejong Hospital, Republic of Korea, [4]Samsung Medical Center, Republic of Korea

Jina Choi, M.D.

Seoul National University Bundang Hospital


내가 왕이 될 상인가?
관상


DEATH.
TEMPERANCE.
THE DEVIL.
THE TOWER.
THE STAR.
THE MOON.

Maybe…

Accuracy?

You have 81.2% chance of...

Maybe...

Accuracy?

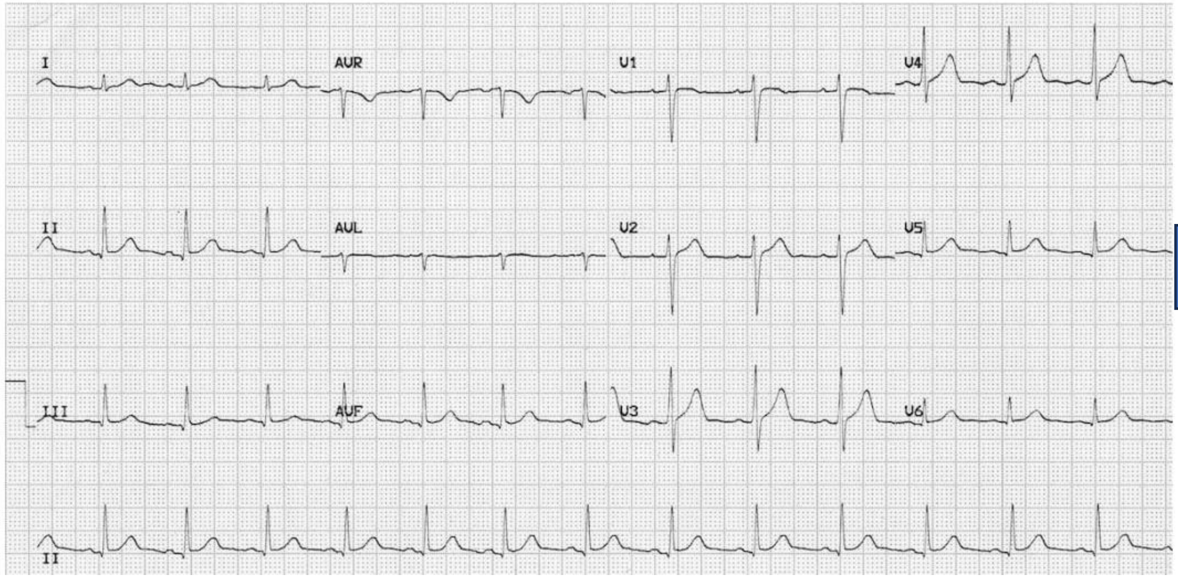
Artificial intelligence-based prediction models

Hidden truth

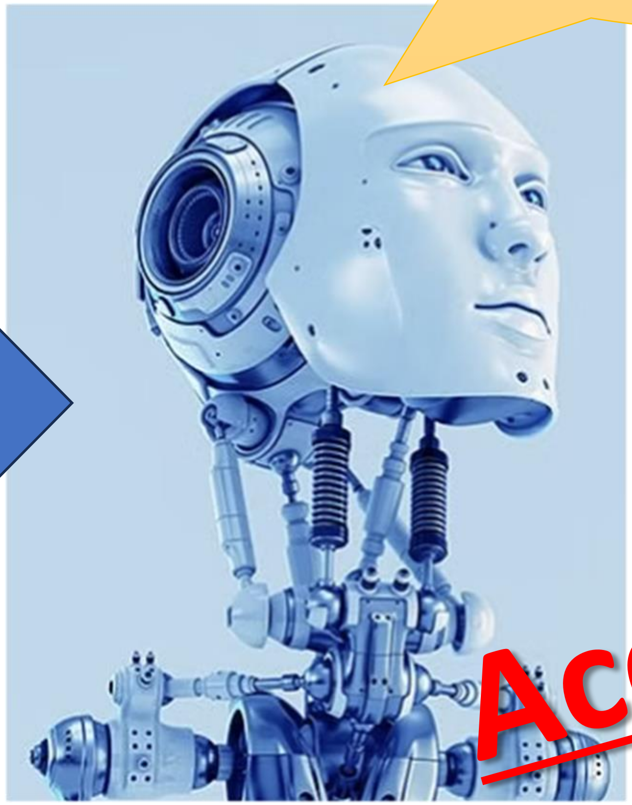
Evidence-based
Deep learning
Validation

Your chance of having paroxysmal AF is…

12-lead ECG: normal sinus rhythm



Artificial intelligence-powered prediction of paroxysmal atrial fibrillation in patients using SR ECGs

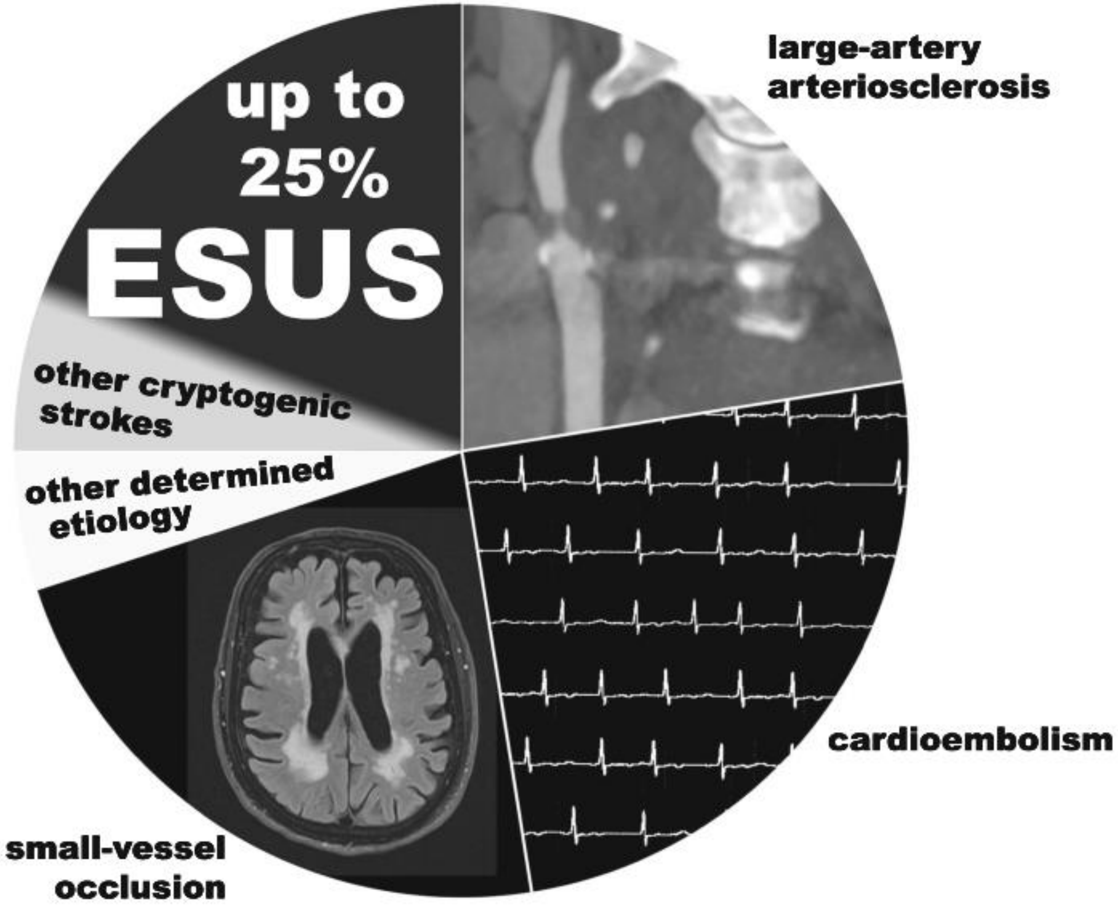


Accuracy?

Artificial intelligence

Introduction

Embolic stroke with undetermined source (ESUS)



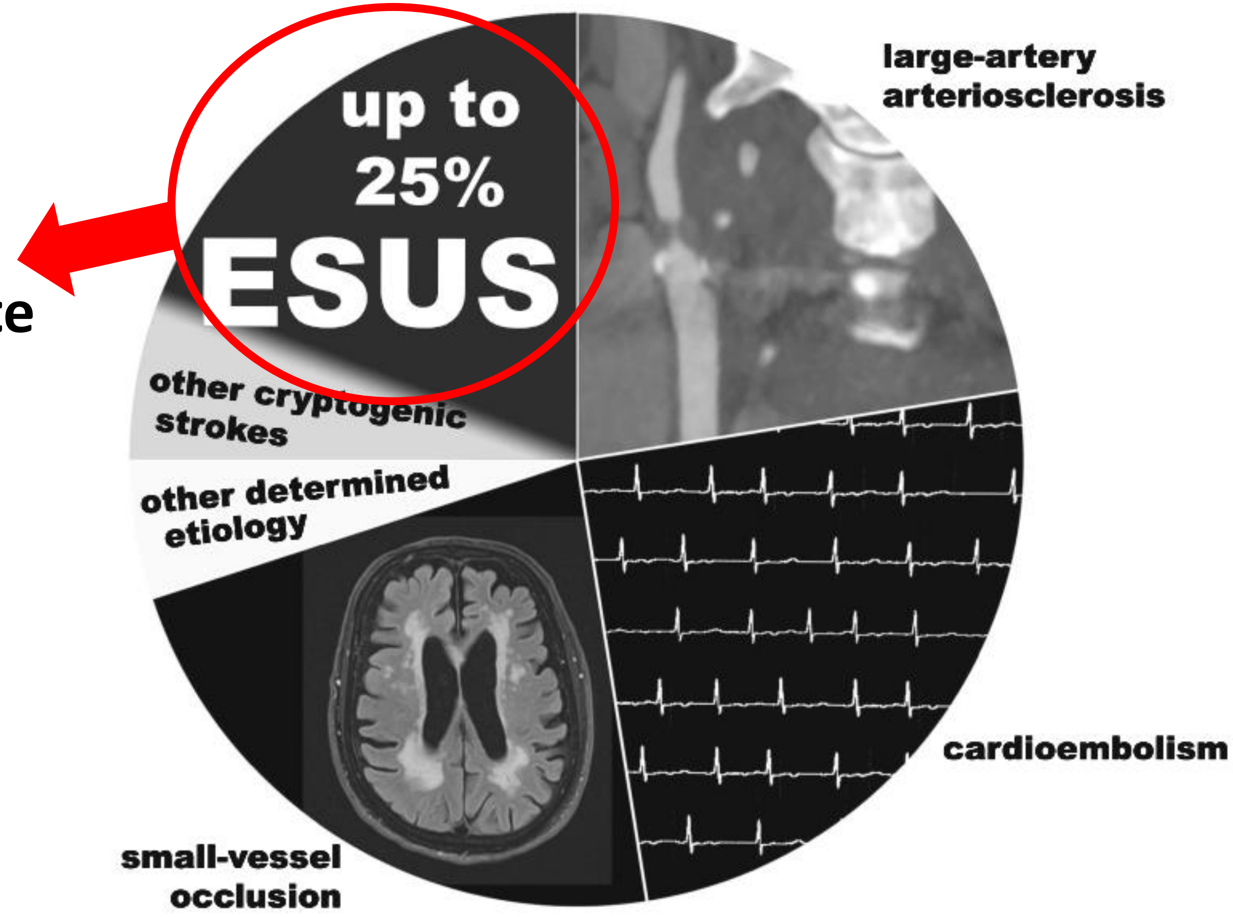
Etiology of ischemic strokes

N Engl J Med 2014; 370:2478-2486

Introduction

Embolic stroke with undetermined source (ESUS)

Stroke recurrence rate
: 4.5%/year



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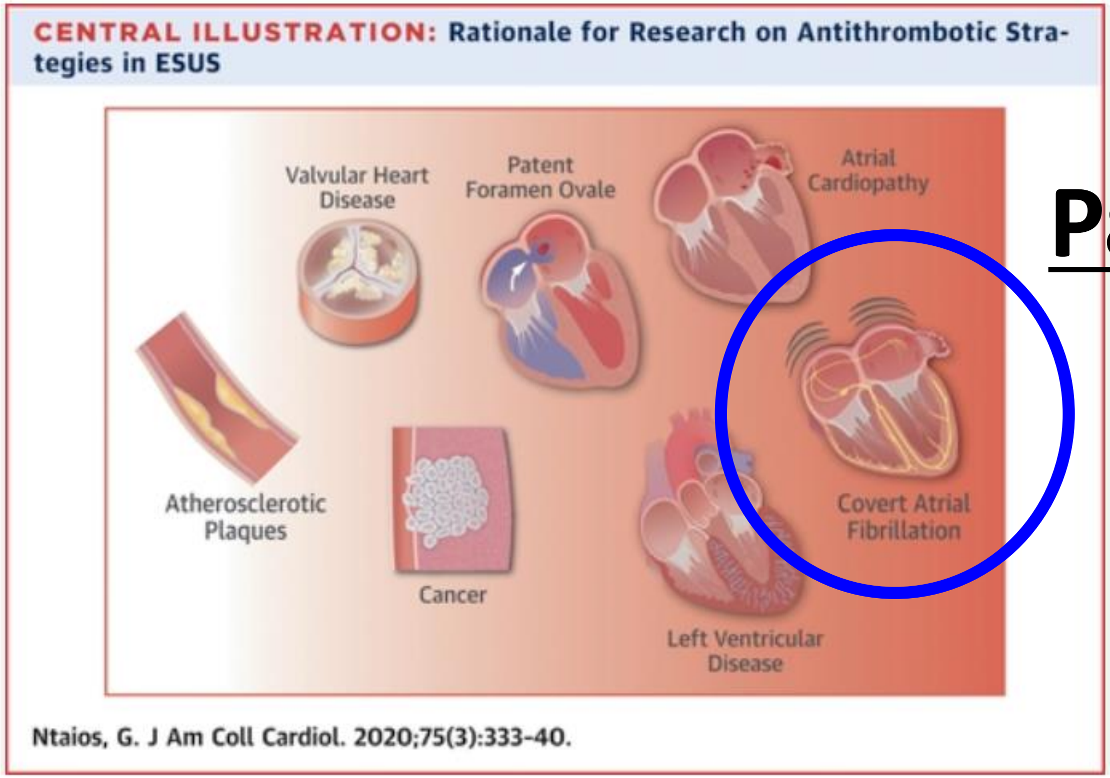
Introduction

Embolic stroke with undetermined source (ESUS) & Atrial fibrillation



Possible cardiogenic causes for ESUS

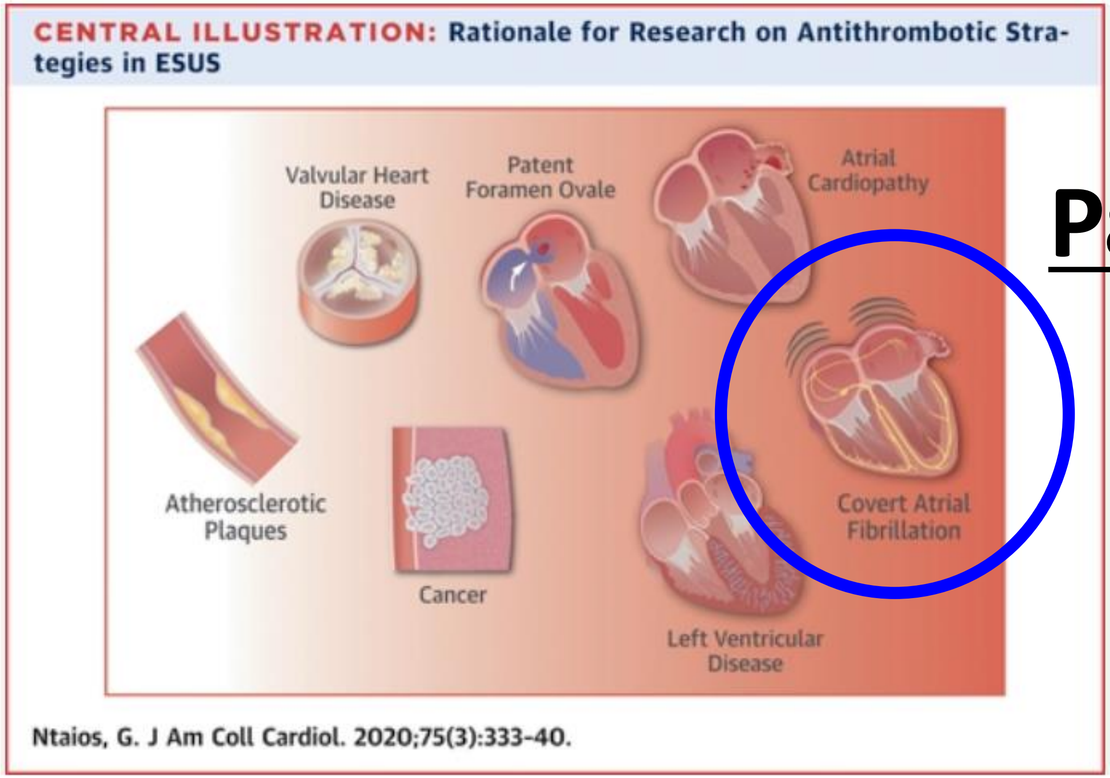
<u>Paroxysmal</u> atrial fibrillation

- Major potential cause of ESUS
- Remains challenging to identify!

J Am Coll Cardiol. 2020 Jan, 75 (3) 333–340

Introduction

Embolic stroke with undetermined source (ESUS) & Atrial fibrillation



Possible cardiogenic causes for ESUS

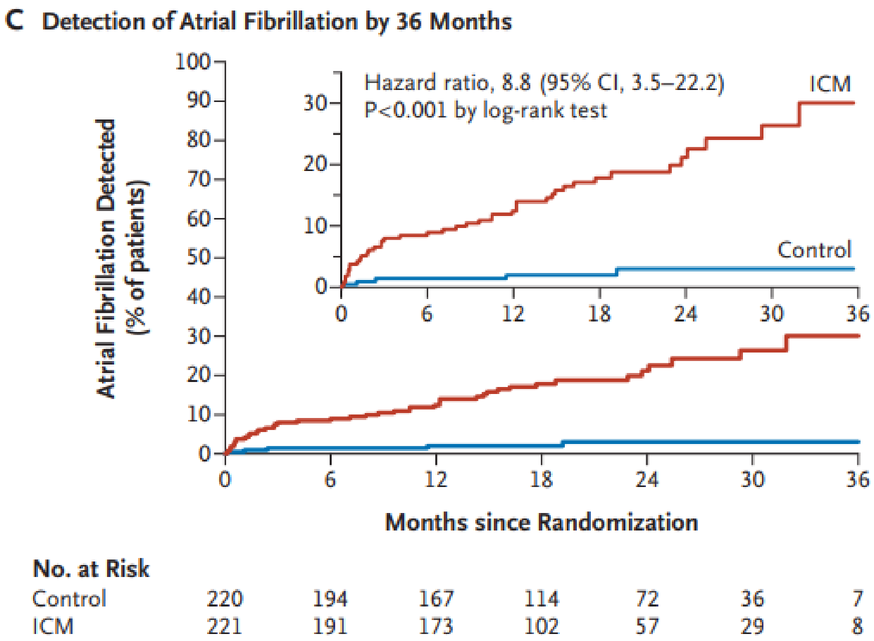
Paroxysmal atrial fibrillation

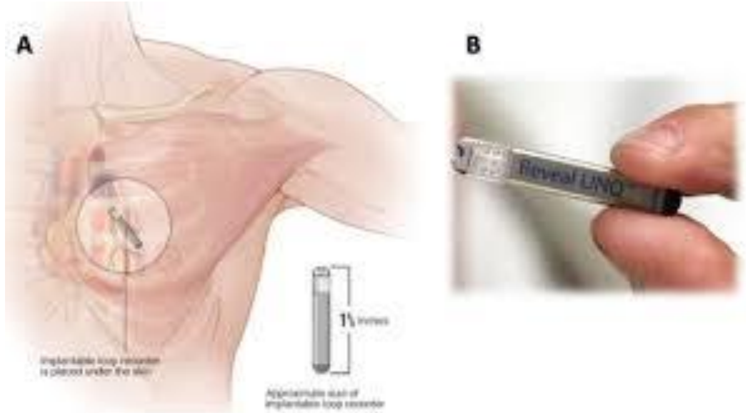
- Major potential cause of ESUS
- Remains challenging to diagnose !

HOW ?

Introduction

CRYSTAL AF Study





After embolic stroke of undetermined source

ECG monitoring after ESUS with…

Insertable cardiac monitor (ICM)

vs.

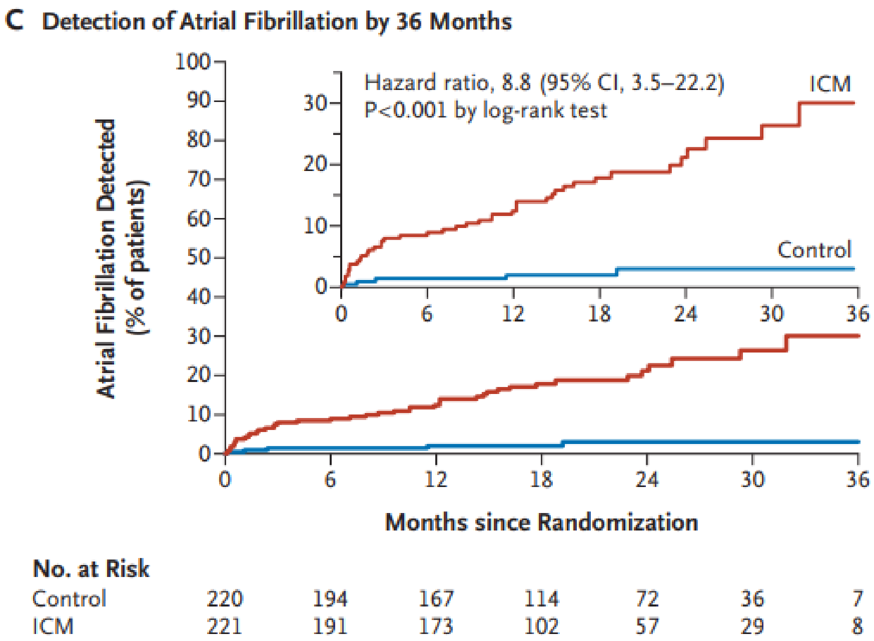
Conventional follow up

in AF detection

N Engl J Med 2014; 370:2478-2486

Introduction

CRYSTAL AF Study



ECG monitoring after ESUS with…

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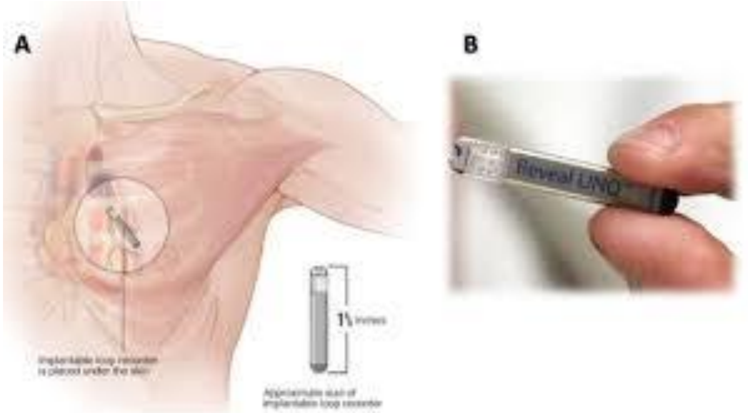


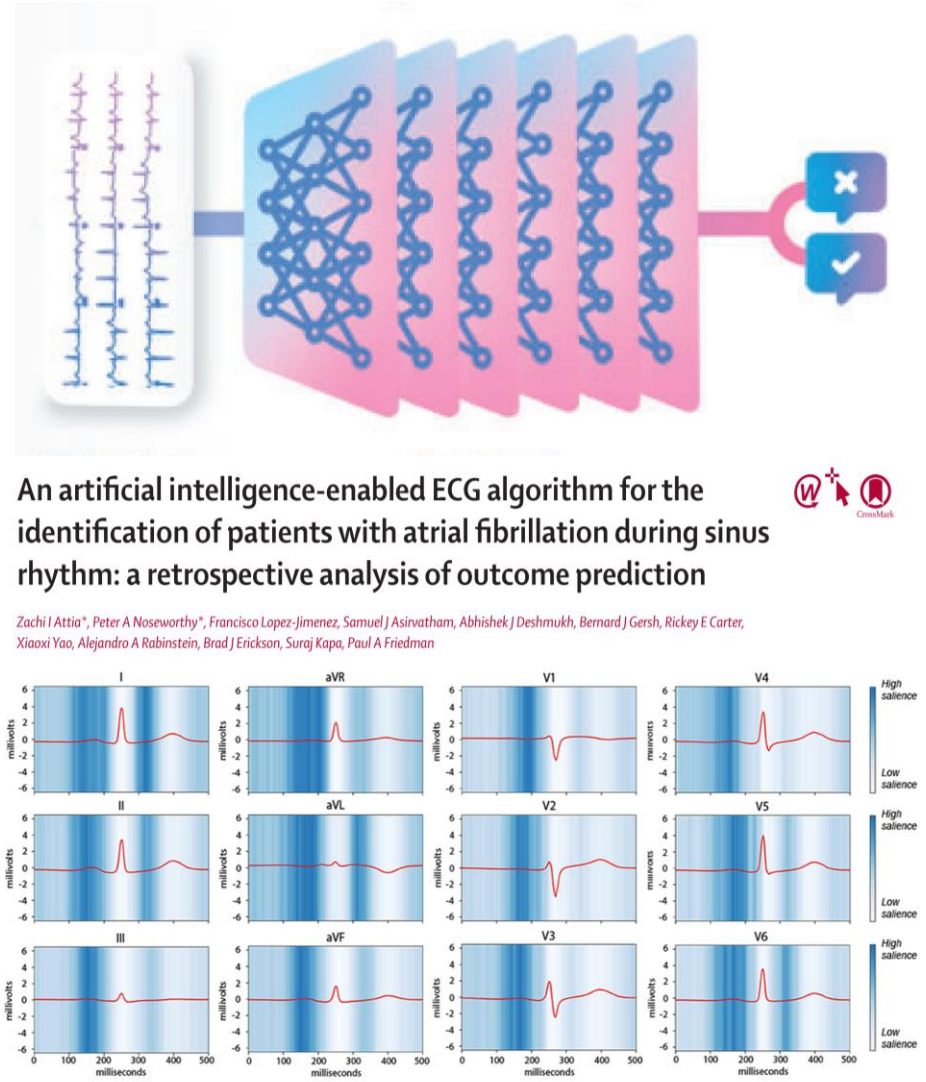
After embolic stroke of undetermined source

- Sensitivity of AF detection by ICM : 95%!
- Limited application due to **invasive nature**

N Engl J Med 2014; 370:2478-2486

Introduction

What we can identify by using 12-lead ECG and deep learning…


An artificial intelligence-enabled ECG algorithm for the identification of patients with atrial fibrillation during sinus rhythm: a retrospective analysis of outcome prediction

Zachi I Attia*, Peter A Noseworthy*, Francisco Lopez-Jimenez, Samuel J Asirvatham, Abhishek J Deshmukh, Bernard J Gersh, Rickey E Carter, Xiaoxi Yao, Alejandro A Rabinstein, Brad J Erickson, Suraj Kapa, Paul A Friedman

Cardiac

- LV dysfunction, cardiomyopathy
- Valvular heart diseases
- Ischemic heart diseases and arrhythmias

Non-Cardiac

- Electrolyte abnormalities or renal impairment
- Anemia
- Age
- Sex

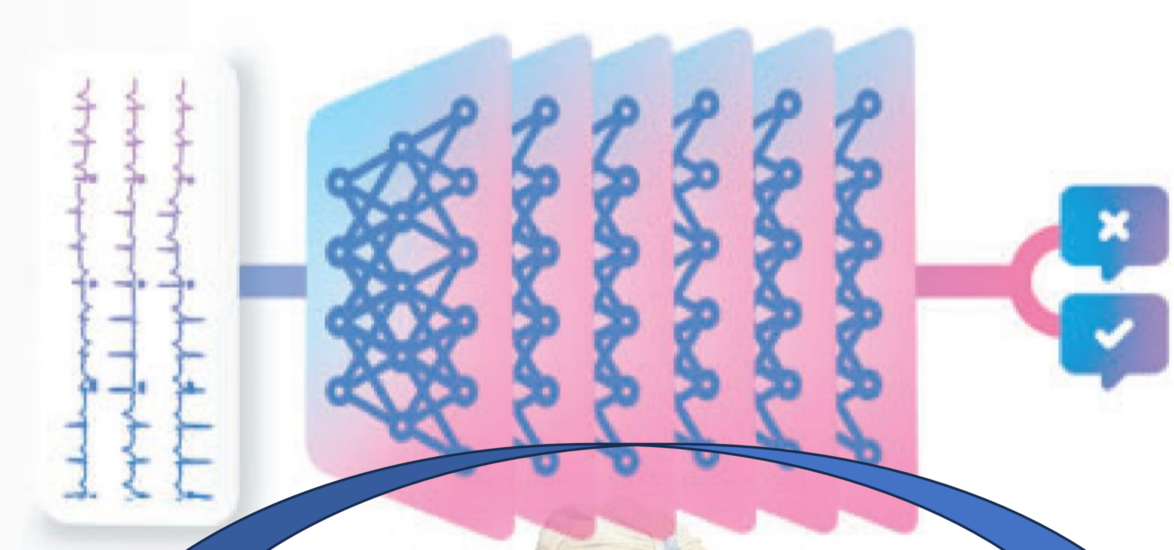
Lancet. 2019;394:861-867.
Circulation. 2022;145:122–133

The Aim of the Study

AI model

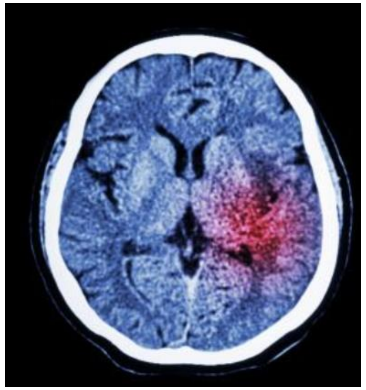
based on Convolutional Neural Network

12-lead ECG
during sinus rhythm



Paroxysmal AF

Validation



Predicted Data vs. ICM data

Hidden AF in ESUS patients ?

Methods

Step I. Development of AI algorithm for predicting paroxysmal AF

678,322 SR ECGS from 93,573 adults

350,333 ECGs
AF

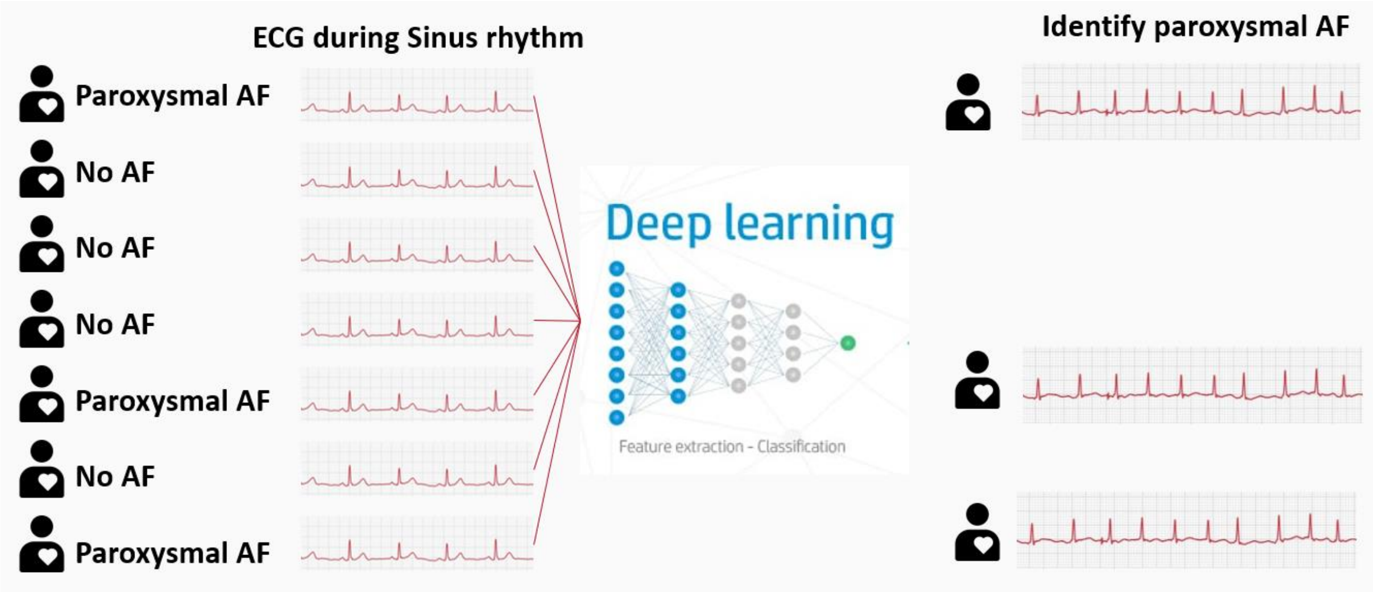
327,989 ECGs
No AF

Algorithm Development 90%
617,892 ECGs
(AF: 317,468, No AF: 300,424)

Internal validation 10%
55,076 ECGs
(AF: 30,103 , No AF: 24,973)

Previous AF hx./ecg or AF within 2 years as +
No rhythm except pacing was excluded

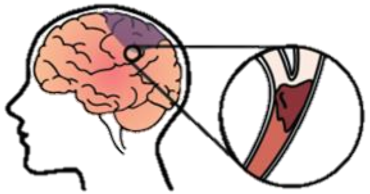
Non-sinus rhythm excluded
Diagnosis only cases excluded
Includes cases with remote AF occurrence as +



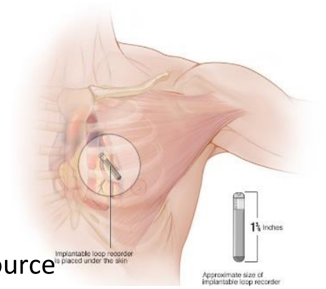
Internal validation: AUC 0.863

Methods

Step II. Validation with ESUS patients



Embolic stroke of undetermined source



Recruited…

345 ESUS patients with ICM

345 SR ECGs (345 patients)

Follow up at least 6 mo.

AF detection by ICM

5 min, 1 hr, 12 hrs or 24 hrs

ICM registry from four tertiary hospitals

- Seoul National University Bundang Hospital
- Samsung Medical Center
- Asan Medical Center
- Chungnam National University Sejong Hospital

Methods

Step II. Validation with ESUS patients

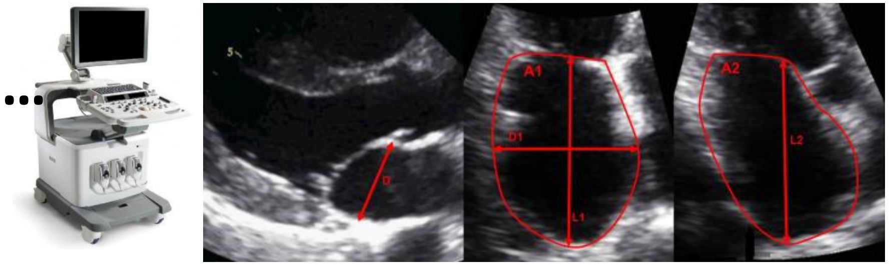
345 ESUS patients with ICM

345 SR ECGs (345 patients)

AF detection by ICM

- **Demographic data**

- **Echocardiographic Data**
  - ➢ LA volume index, LVEF…



- **Holter data**
  - ➢ Atrial ectopic burden (AEB)

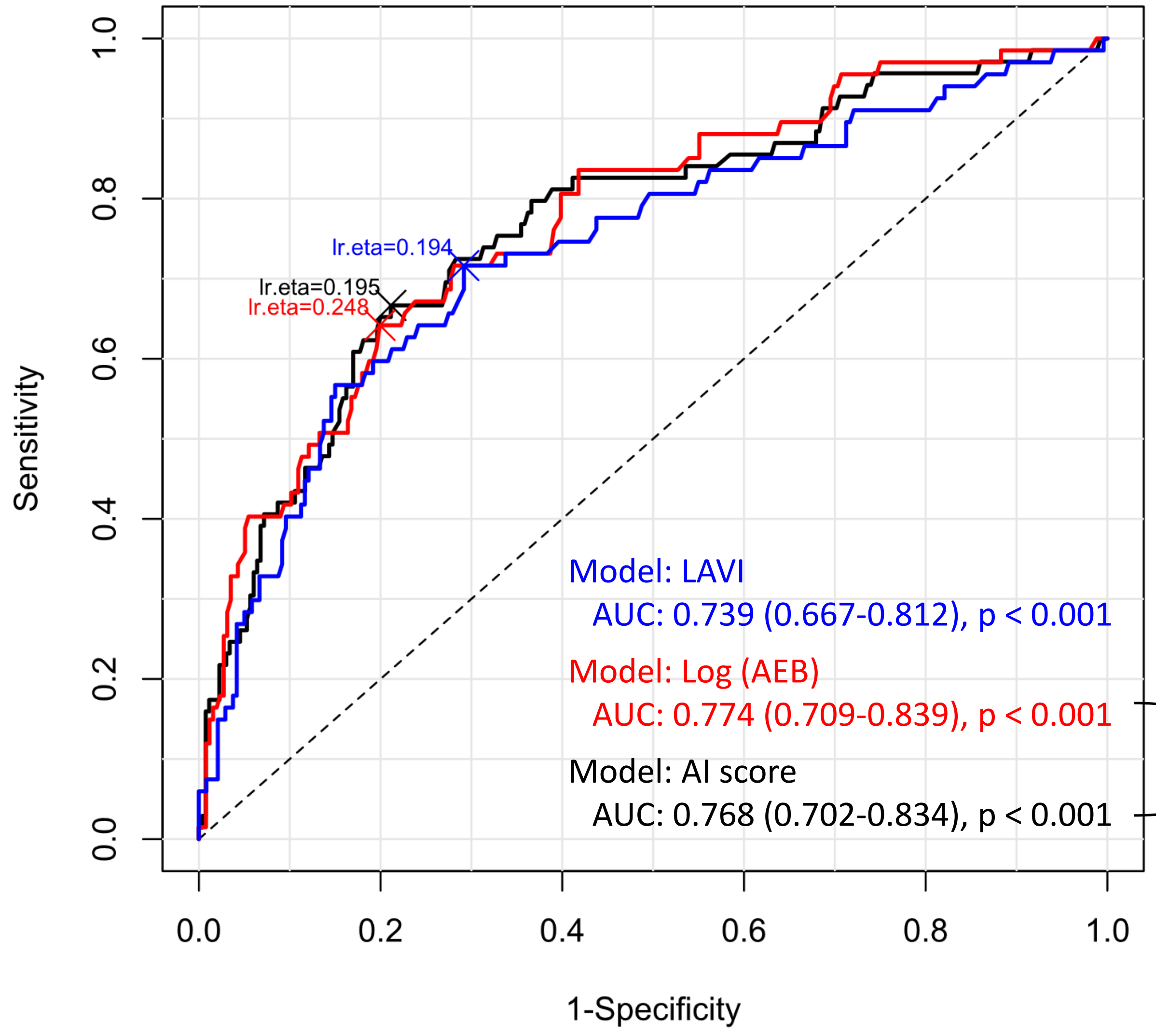
Results -- Baseline Characteristics

	No AF detection n=274	AF (≥5 min) detection n=71	P value
Age	62.7 ± 12.8	70.1 ± 9.6	<0.001
Female	96 (35.0%)	22 (31.0%)	0.616
Height, cm	164.0 ± 9.1	162.9 ± 9.3	0.35
Weight, kg	65.6 ± 11.2	67.5 ± 12.6	0.204
BMI, kg/m^2	24.3 ± 3.1	25.3 ± 3.5	0.016
Past History			
Heart failure	2 (0.7%)	6 (8.5%)	0.001
HTN	142 (51.8%)	44 (62.0%)	0.163
DM type 2	60 (21.9%)	22 (31.0%)	0.148
HCMP	1 (0.4%)	3 (4.2%)	0.029
Myocardial infarction	1 (0.4%)	1 (1.4%)	0.372
CHA_2DS_2VASc	3.9 ± 1.4	4.6 ± 1.4	<0.001
PR interval on ECG, ms	170.3 ± 27.9	180.3 ± 35.9	0.032
Holter monitoring			
Number of APCs	20.0 [6; 67]	162 [33; 486]	<0.001
Burden of atrial ectopy, %	0.0 [0.0; 0.1]	0.2 [0.0; 0.7]	<0.001
Echocardiography			
LVEF, %	62.8 ± 5.1	61.8 ± 5.7	0.165
LAVI, ml/m^2	32.7 ± 9.6	44.1 ± 16.7	<0.001
PFO	76 (27.7%)	17 (23.9%)	0.623
Discharge medication			
Aspirin	206 (75.2%)	42 (59.2%)	0.011
Clopidogrel	151 (55.1%)	28 (39.4%)	0.026
OAC	19 (6.9%)	17 (23.9%)	<0.001
Statin	236 (86.1%)	59 (83.1%)	0.647

Values are expressed as n(%), mean ± standard deviation or median [;interquartile range]

Results

ROC curve analysis for AF ≥ 5 min detection



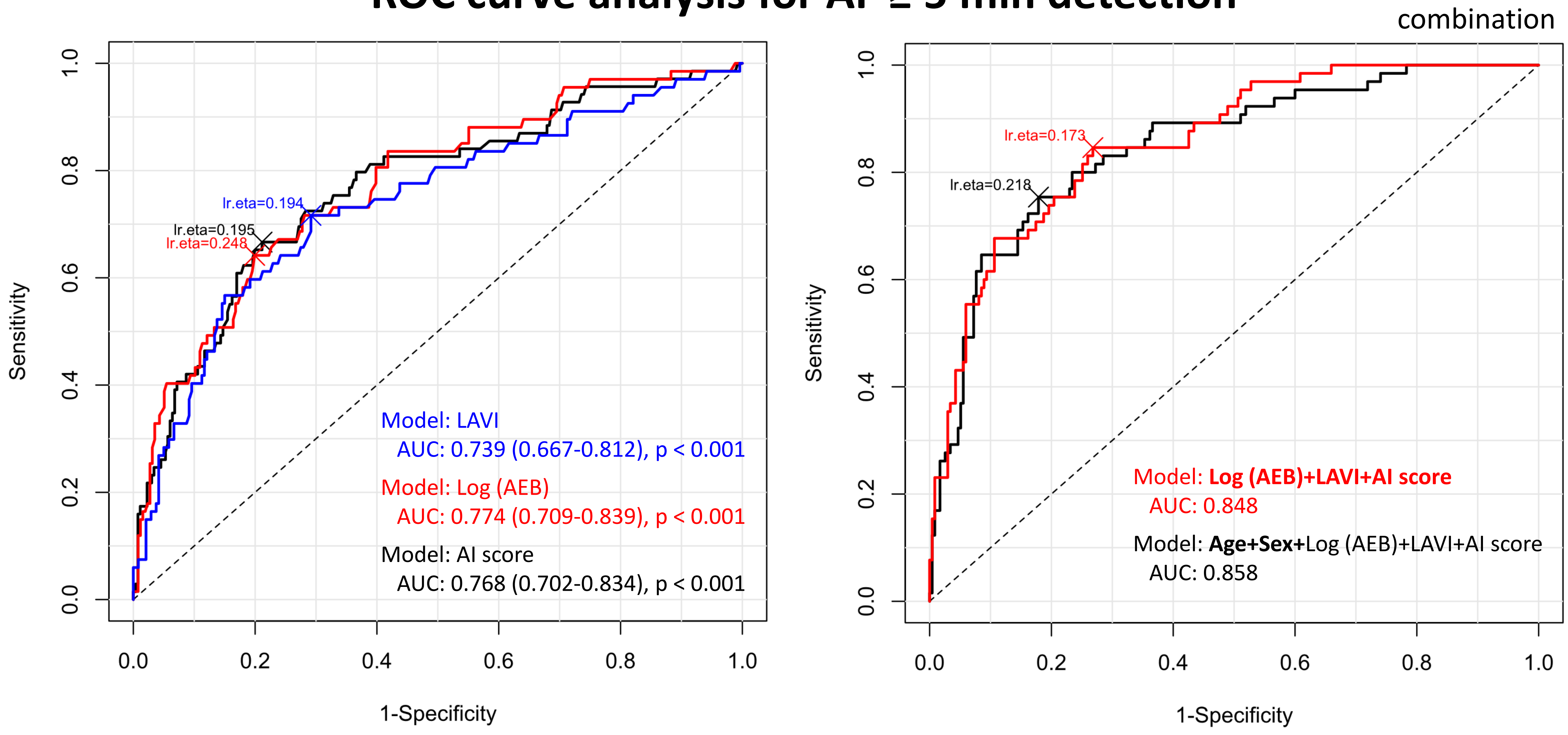
DeLong's test for two correlated ROC curves
Log (AEB) vs. AI score
p= 0.821

* 3 prediction models: LAVI, Log (AEB), AI score
  → To predict paroxysmal A-fib

LAVI, Left atrial volume index; AEB, Atrial ectopic burden

Results

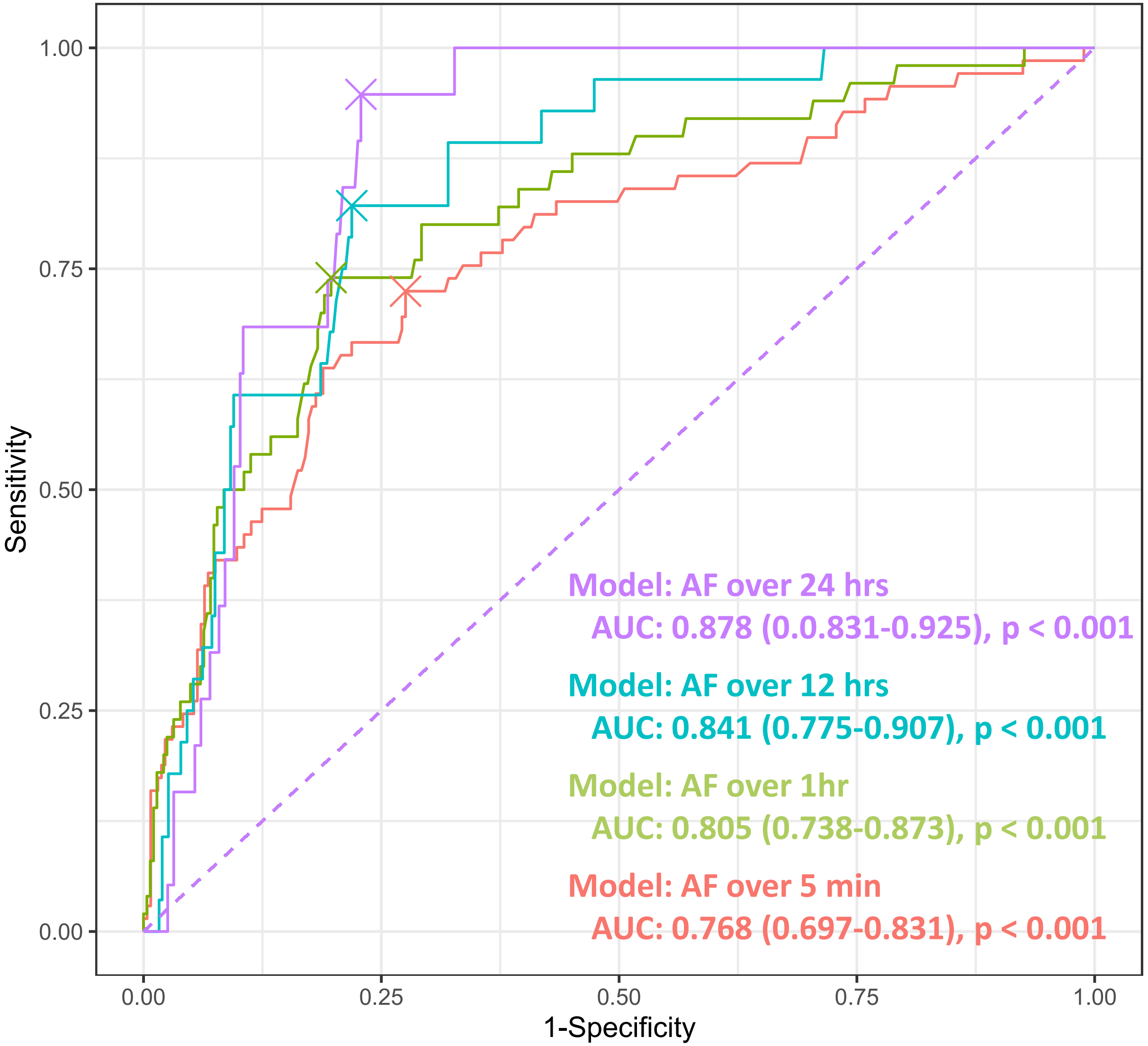
ROC curve analysis for AF ≥ 5 min detection



Parameters: LAVI, Left atrial volume index; AEB, Atrial ectopic burden

Results

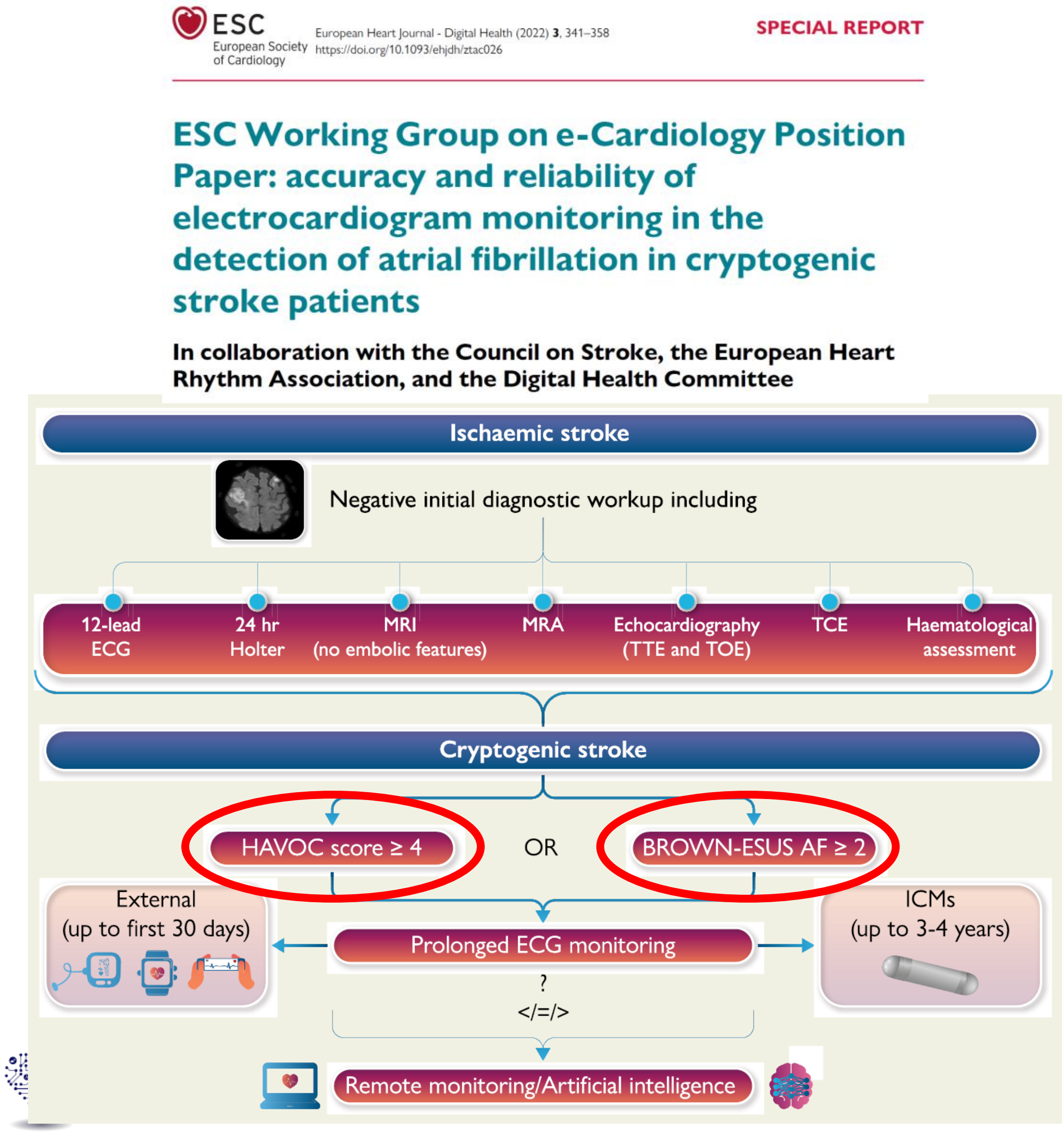
Performance of AI score for AF detection according to AF duration

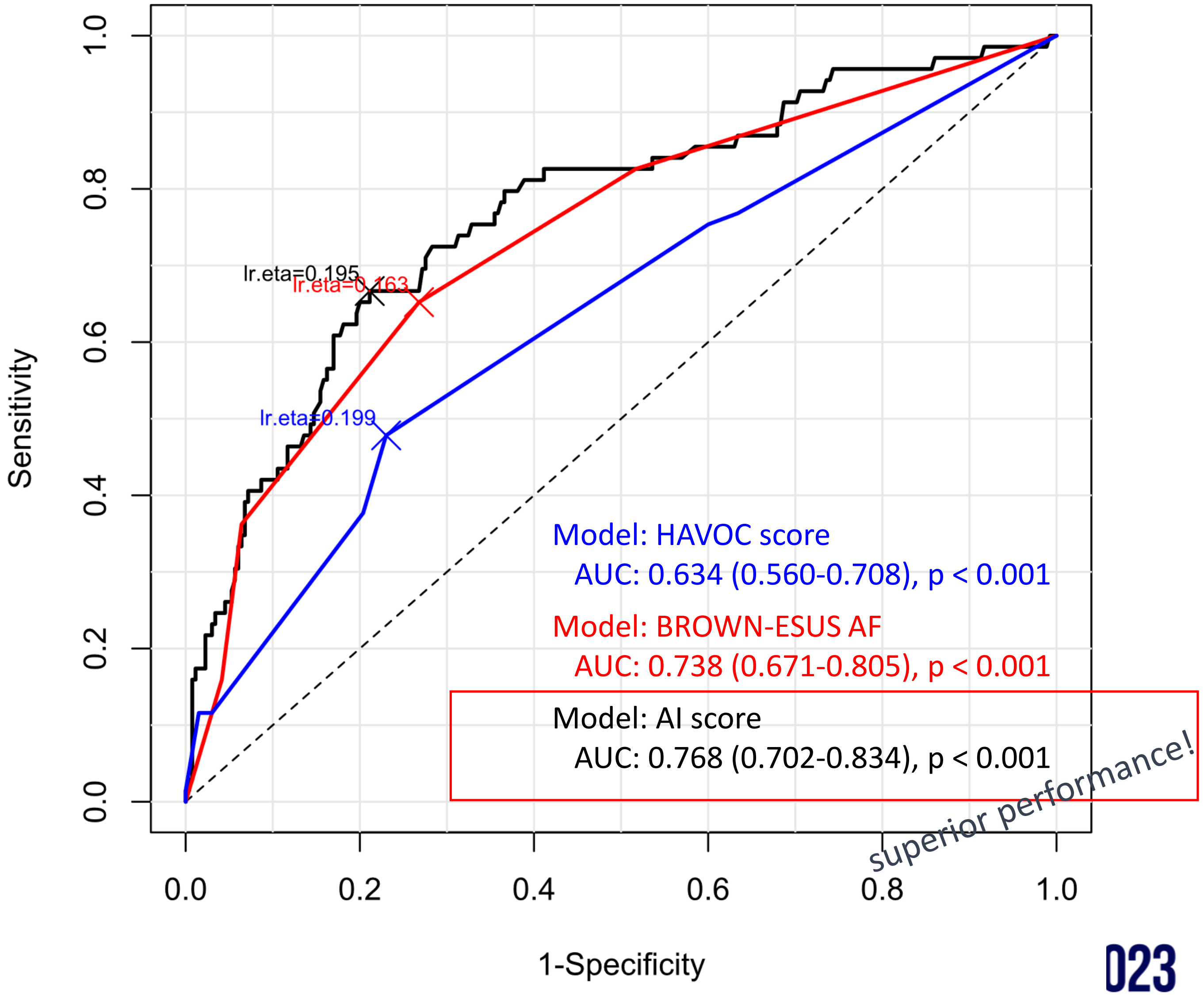


AF Duration ↑
& AUC value ↑
& Model performance ↑

Results

Comparison with conventional AF prediction scores in ESUS





Conclusion

- The AI accurately identified paroxysmal AF using 12-leads sinus rhythm ECG in patients with embolic stroke of undetermined source (ESUS).
- The AI outperformed clinical risk factors including LA enlargement and conventional AF prediction models in patients with ESUS.
- When atrial ectopic burden and left atrial volume index were added to the prediction model, it showed increased diagnostic performance.
- The AI ECG model may serve as a promising, cost-effective, and time-efficient tool for the screening of paroxysmal AF.

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Thank you for your attention!

Jina Choi, M.D.

Junior Fellow

jinachoi.cardio@gmail.com

Seoul National University Bundang Hospital

Korean Heart Rhythm Society

COI Disclosure

Jina Choi

The authors have no financial conflicts of interest to disclose concerning the presentation

Table 2. Predictive performance for detection of the AF according to models

	AUC	Sensitivity	Specificity	PPV	NPV	F1 score
LAVI	0.739	0.716	0.708	0.101	0.593	0.177
AI score	0.768	0.667	0.789	0.099	0.549	0.172
Log_AEB	0.774	0.642	0.801	0.105	0.543	0.180
AI score with LAVI and Log_AEB	0.848	0.754	0.821	0.077	0.462	0.140
AI score with LAVI, Log_AEB, Age, and Sex	0.858	0.846	0.732	0.055	0.534	0.103

AEB, atrial ectopic burden; AUC, area under the curve; LAVI, left atrial volume index; NPV, negative predictive value; PPV, positive predictive value.

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