Clinical implication of prolonged ECG monitoring for cryptogenic stroke

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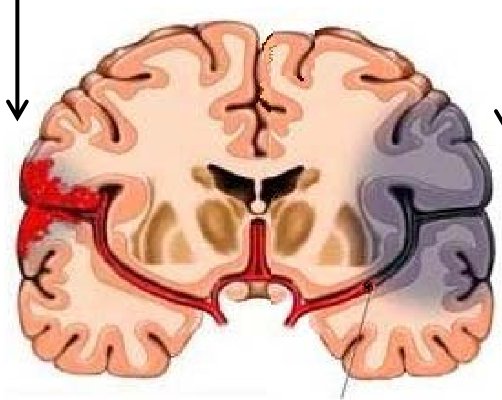
Contents

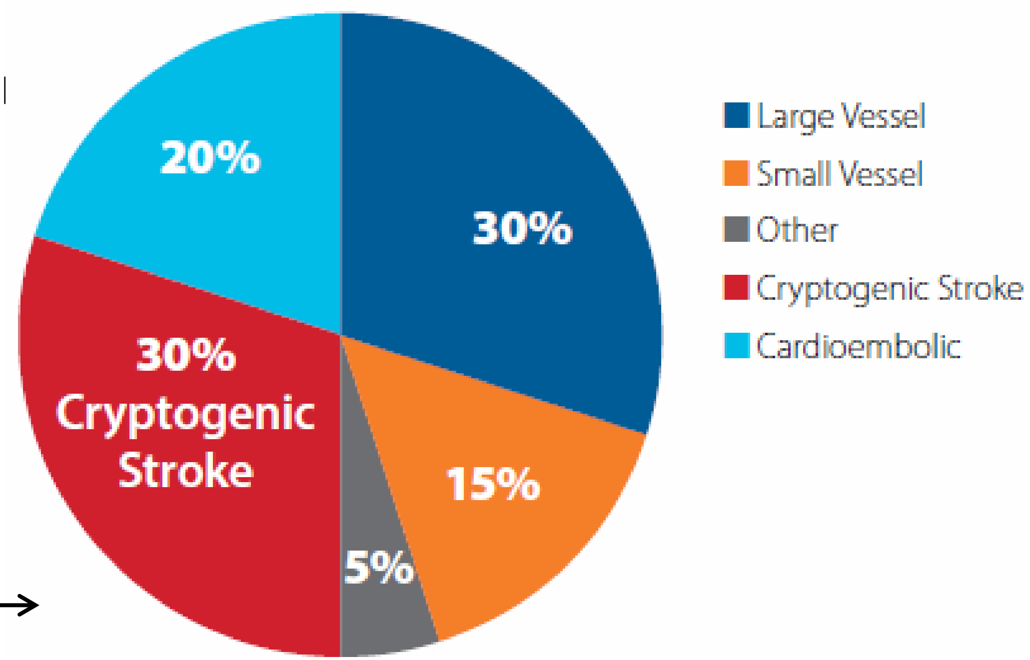
- Cryptogenic stroke (CS)
- Post stroke diagnostic pathway
- Long-term cardiac monitoring for CS
  - ECG
  - 24 hours Holter
  - Event-triggered recorder ~30 days
  - Mobile cardiac telemetry (MCT)
  - Implantable loop recorder
- Detection of occult AF with AI

Stroke Etiology

Vessel Rupture
or
Haemorrhagic
(15%)

Artery Occlusion
or
Ischemic
(85%)





Cryptogenic (25-40%)
Unknown cause

Adams HP Jr et al, Stroke. 1993; 24; 35-41.

Cryptogenic stroke

- TOAST defines cryptogenic stroke (stroke of undetermined etiology) as brain infarction that is not attributable to a definite cardio-embolism, large artery atherosclerosis, or small artery disease despite extensive vascular, cardiac, and serologic evaluation.
- Causative Classification System (CCS) require brain imaging, imaging of cerebral vessels, and evaluation of heart function. This classification system divides cryptogenic stroke into "cryptogenic embolism" and "other cryptogenic".

TOAST. Trial of Org 10172 in Acute Stroke Treatment. Stroke. 1993;24:35-41.
The Causative Classification of Stroke system. Neurology. 2010;75:1277-1284.

Diagnostic Evaluation of Ischemic Stroke to Determine Stroke Mechanism

Diagnostic Test	Suggested Algorithm
Brain imaging	Brain MRI in patients with cryptogenic stroke
	Brain CT when stroke mechanism is known
Vascular imaging	Intracranial and extracranial vascular imaging on all patients with ischemic stroke
	MRA with fat-suppressed images when clinical suspicion for cervical artery dissection
Cardiac imaging	TTE on all patients with ischemic stroke to look for evidence of cardiac disease (evidence of prior myocardial infarction warranting ischemic cardiac evaluation or systolic heart failure)
	TEE with bubble study on patients <50 y old to look for cardiac shunts/cardiac tumors if TEE was nonrevealing
Cardiac monitoring	Thirty-day noninvasive cardiac monitoring on patients with cryptogenic stroke and ≥40 y
	Implantable cardiac monitor if 30-day monitor does not reveal AF or flutter
Hypercoagulable testing	Serum hypercoagulable workup in patients with no or minimal risk factors
Screening for malignancy	Age appropriate screening
	CT chest/abdomen/pelvis when systemic symptoms suggestive of cancer are present such as unexplained weight loss or unexplained fever

AF indicates atrial fibrillation; CT, computed tomography; MRA, magnetic resonance angiography; MRI, magnetic resonance imaging; TEE, transesophageal echocardiography; and TTE, transthoracic echocardiography.

Circ Res. 2017;120:527-540

Diagnostic Evaluation and Therapeutic Implications in Ischemic Stroke

	Diagnostic Tests	Therapeutic Implications
Cardiac causes		
Paroxysmal occult AF	Noninvasive cardiac monitoring, and if no AF or flutter detected, then implantable cardiac monitoring	Anticoagulation therapy
Atrial cardiopathy	Serum NT-proBNP, echocardiography, ECG	Treatment with antiplatelet vs anticoagulation is unknown, but empirical treatment with anticoagulation may be reasonable
Atrial septal defect	Echocardiography (TEE superior to TTE)	Venous imaging if atrial septal defect detected
Atherosclerotic causes		
Aortic arch disease	Echocardiography (TEE superior to TTE)	Antiplatelet and statin therapy
Substenotic atherosclerosis	Vessel wall imaging, plaque MRI	Antiplatelet and statin therapy
Other causes		
Cancer	CT chest, abdomen, and pelvis	Antiplatelet vs. anticoagulation treatment of underlying cancer
Hypercoagulable state	Hypercoagulable work-up, including antiphospholipid antibodies	Anticoagulation therapy based on findings
Arterial dissection	MRA with fat-suppressed images	Antiplatelet therapy

AF indicates atrial fibrillation; CT, computed tomography; MRA, magnetic resonance angiography; MRI, magnetic resonance imaging; NT-proBNP, N-terminal pro-B-type natriuretic peptide; TEE, transesophageal echocardiography; and TTE, transthoracic echocardiography.

Circ Res. 2017;120:527-540

Post-stroke diagnostic FU in cryptogenic stroke

TEE to excluded
- Right to left shunt (PFO, ASD, etc)
- LA thrombi
- Valve vegetation
- Aortic arch atheroma
- Spontaneous echo contrast (SEC)
- Mitral stenosis
- Others

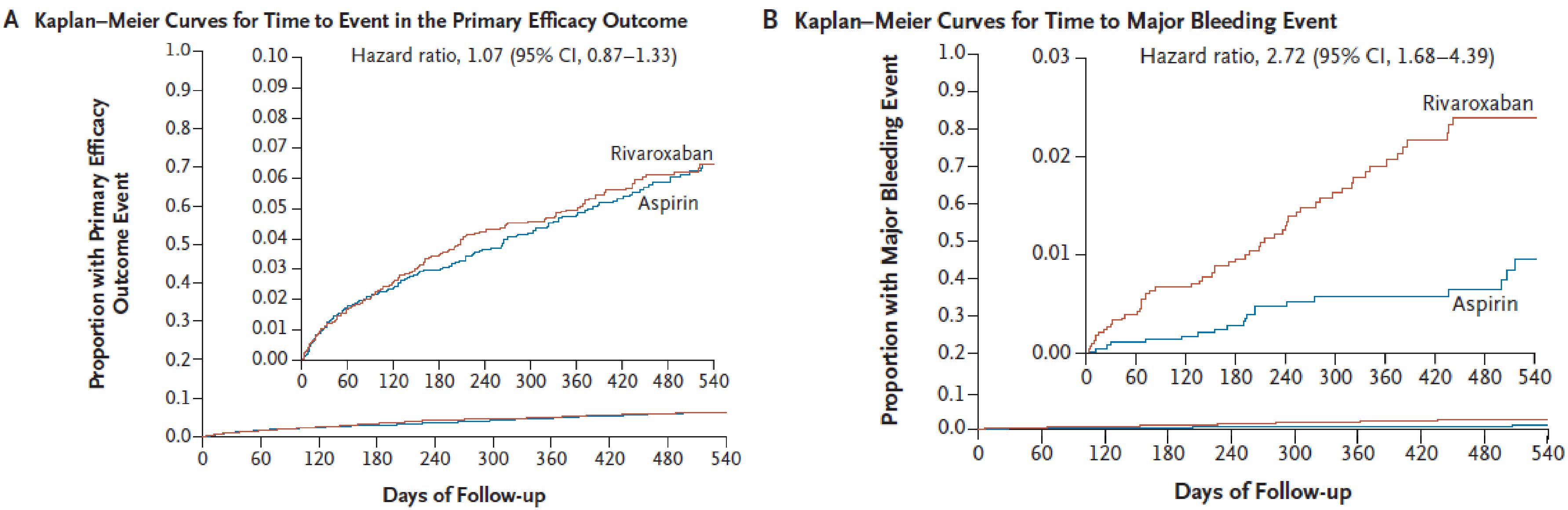
Holter monitor/prolong outpatient telemetry
- **Occult paroxysmal AF or AFL**

Intra-cranial arterial wall imaging
- Sub-stenotic plaque
- Dissection

Additional Lab testing
- CSF exam
- Immune response
- Hypercoagulability
- Others depending on clinical situation

Yaghi S, et al. Neurol Clin Pract. 2014;4:386-393

Rivaroxaban for Stroke Prevention after Embolic Stroke of Undetermined Source



No. at Risk (A)

	0	60	120	180	240	300	360	420	480	540
Rivaroxaban	3609	3211	2854	2525	2156	1874	1584	1306	1046	786
Aspirin	3604	3205	2858	2531	2166	1880	1579	1319	1036	779

No. at Risk (B)

	0	60	120	180	240	300	360	420	480	540
Rivaroxaban	3609	3249	2906	2582	2206	1911	1615	1342	1071	807
Aspirin	3604	3254	2918	2597	2231	1939	1637	1371	1083	822

CONCLUSIONS

Rivaroxaban was not superior to aspirin with regard to the prevention of recurrent stroke after an initial embolic stroke of undetermined source and was associated with a higher risk of bleeding. (Funded by Bayer and Janssen Research and Development; NAVIGATE ESUS ClinicalTrials.gov number, NCT02313909.)

N Engl J Med 2018;378:2191-201

Risk of stroke in patients with AF

Well-established data indicate that AF is associated with a **5-fold increase** in the risk for ischemic stroke[1]

5x

2x

Ischemic stroke associated with AF is **nearly twice as likely** to be fatal as non-AF stroke[2]

In patients with AF, oral anticoagulants **decrease** the risk for stroke by 64% compared with placebo[3]

64%

1. Wolf PA, et al. Arch Intern Med 1987;147:1561-1564.
2. Lin HJ, et al. Stroke. 1996; 27:1760-1764.
3. Stroke Prevention in Atrial Fibrillation Investigators. Circulation 1991;84:527-539.

AHA/ASA 2018 Guidelines for the Early Management of Patients with Acute Ischemic Stroke

Stroke

AHA/ASA GUIDELINE

2018 Guidelines for the Early Management of Patients With Acute Ischemic Stroke: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association

William J. Powers, Alejandro A. Rabinstein, Teri Ackerson, Opeolu M. Adeoye, Nicholas C. Bambakidis, Kyra Becker, José Biller, Michael Brown, Bart M. Demaerschalk, Brian Hoh, Edward C. Jauch, Chelsea S. Kidwell, Thabele M. Leslie-Mazwi, Bruce Ovbiagele, Phillip A. Scott, Kevin N. Sheth, Andrew M. Southerland, Deborah V. Summers, David L. Tirschwell,
on behalf of the American Heart Association Stroke Council

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DOI https://doi.org/10.1161/STR.0000000000000158
Stroke. 2018;STR.0000000000000158
Originally published January 24, 2018

6.3. Cardiac Evaluation	COR	LOE	New, Revised, or Unchanged
1. Cardiac monitoring is recommended to screen for atrial fibrillation and other potentially serious cardiac arrhythmias that would necessitate emergency cardiac interventions. Cardiac monitoring should be performed for at least the first 24 hours.	I	B-NR	Recommendation and Class unchanged from 2013 AIS Guidelines. LOE amended to conform with ACC/AHA 2015 Recommendation Classification System.
2. The clinical benefit of prolonged cardiac monitoring to detect atrial fibrillation after AIS is uncertain.	IIb	B-R	New recommendation.
3. In some patients with AIS, prolonged cardiac monitoring to provide additional information to plan subsequent secondary preventive treatment may be reasonable, although the effect on outcomes is uncertain.	IIb	C-EO	New recommendation.

Occult paroxysmal AF

- Detection of AF is important in the evaluation of patients with otherwise cryptogenic stroke to identify those who might benefit from anticoagulation

- Paroxysmal AF is often asymptomatic, and may not be detected with short-term monitoring

- Technologies available for extended cardiac monitoring include continuous telemetry, ambulatory electrocardiography, serial ECG's, trans-telephonic ECG monitoring, and implantable cardiac monitors

Bang OY, et al. Stroke 2014;45:1186-1194.
Yaghi S et al. Neurol Clin Pract 2014;4:386-393.

Why short-term monitoring isn't enough

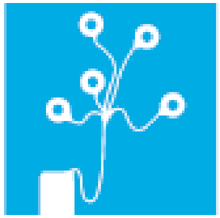
At least 1/3 OF AF PATIENTS ARE **ASYMPTOMATIC**

84 days MEDIAN **TIME TO AF DETECTION** IN CRYPTOGENIC STROKE PATIENTS

- **Conventional Monitoring**

Limitations

- Many cryptogenic stroke patients with AF may remain undiagnosed
- Interference with rehabilitation and daily activities
- Wide range of patient compliance



Holter Monitor	Event Recorder	Mobile Cardiac Telemetry
24–48 hours of monitoring	Up to 30 days of monitoring	Up to 30 days of monitoring
External loop recorder	Event-triggered loop recorder	External loop recorder
Saves all cardiac rhythm data	Saves events only	Saves all cardiac rhythm data
	62% patient compliance[14]	53–90% patient compliance*[15-18]

*Dependent on type of MCT

Which patients will benefit from prolonged ECG monitoring?

- Predictor of AF after CS
  - Atrial size >45mm, the presence of APCs
  - Prolonged PR interval, advanced age
  - Total atrial conduction time (by doppler echo) using PA-TDI interval
  - iPAB score (PHx of arrhythmia, AAD drug use, atrial dilation, elevated BNP)
  - High CHA2DS2-VASc scores
  - Cerebral infarction with typical topographic features such as cortical location or multiple vascular territories

How long?

- The evidence regarding the monitoring time to be employed in patients with CS for detecting AF is still inconclusive.
- 2017 ISHNE-HRS proposes a careful evaluation of each patient prior to device use based on cost-efficacy, patient's acceptance, and compliance.
- 30 days of ECG monitoring after a CS appears to be a feasible choice in clinical practice.

Montalvo M, et al. Open Cardiovasc Med J. 2016;10:89–93

How to detect?

Type of monitoring	Setting	Invasive vs. noninvasive	Duration	Rate of detection of atrial fibrillation, % [20,21,23,27,28]
Admission ECG	Inpatient	Noninvasive	N/A	2.7
Inpatient continuous telemetry	Inpatient	Noninvasive	3-5 d	5.5-7.6
Holter monitor	Outpatient	Noninvasive	24 h	3.2-4.8
			48 h	6.4
			7 d	12.5
Mobile continuous outpatient telemetry	Outpatient	Noninvasive	21-30 d	16-25
Implantable loop recorders	Outpatient	Invasive	6 mo	9
			36 mo	30

Yaghi S, et al. Neurol Clin Pract. 2014;4:386-393

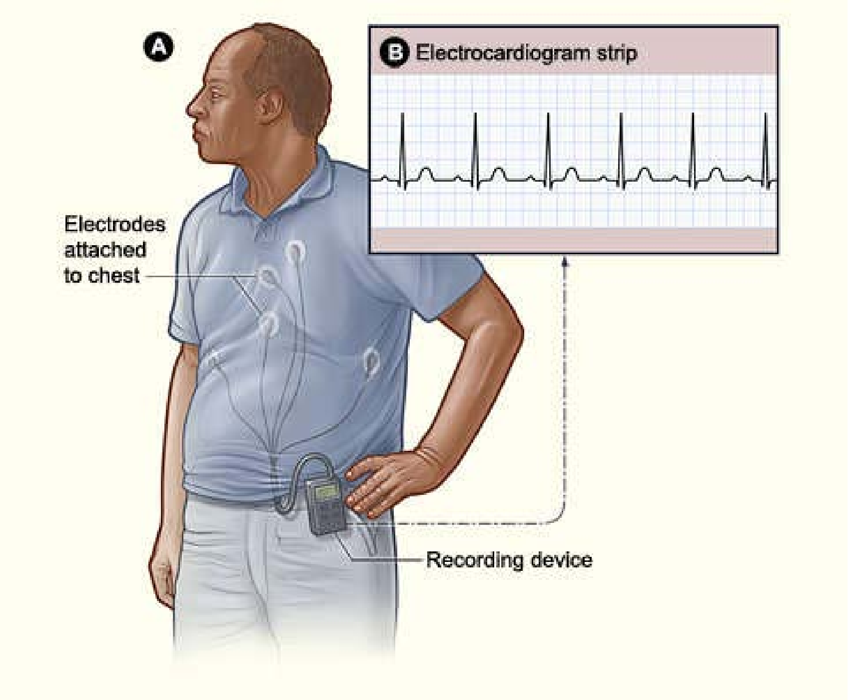
Modalities and technology of ambulatory ECG recording

Definitions	Modalities of recording	Duration	Type of electrodes	Number. of leads	Clinical indications
Holter monitors	Continuous single and multi-lead external recorders without wireless data transmission	a) 24–168 h (1–7 days) b) 7–21 days	a) Adhesive disposable wired electrodes b) Wireless embedded electrodes in vests or belts	a) 3 to 12 leads b) 1–3 leads	-Rhythm monitoring -Arrhythmic burden -Risk stratification and substrate characterization
Patch ECG monitors	Continuous single or two lead external recorders without and with wireless data transmission	Up to 14 days	Adhesive patches with built-in recording systems	1 or 2 leads	-Rhythm monitoring -Arrhythmic burden
External loop recorders (ELR)	Intermittent external patient- or event-activated (auto-triggered) recorders	4–8 weeks	Adhesive disposable wired electrodes	1 or 2 leads	-Rhythm monitoring *(symptomatic and asymptomatic arrhythmias)*
External event recorders	Intermittent external patient- or auto-trigger activated post-event recorders	Up to 30 s (*multiple recordings, recently also available as smartphone based systems*)	Build-in electrodes to be applied directly on the chest (or held by both hands)	1 lead	-Rhythm monitoring (*only symptomatic arrhythmias, or event screening*)
Mobile cardiac outpatient telemetry (MCOT)t	External real-time continuous cardiac tele-monitoring systems	Real-time streaming to call centers	a) Wireless electrodes embedded in a patch, necklace pendant or a chest belt carrier b) Adhesive disposable wired electrodes	a) 1 lead b) 1–3 leads	-Rhythm monitoring -Arrhythmic burden
Implantable loop recorders (ILR)	Intermittent implantable or insertable patient- or auto-trigger activated post-event recorders	Up to 3 years	Build-in electrodes	1 lead	-Rhythm monitoring *(symptomatic and asymptomatic arrhythmias)*

E.T. Locati. Journal of Electrocardiology 2017;50:828–832.

Holter monitor

- Portable external monitor that monitor the cardiac rhythm for 24-48 hours
- Saves all data
- Cumbersome to wear during rehabillitation
- Relatively short period of data



https://commons.wikimedia.org/wiki/File:Holter_monitor_NIH.jpg

External loop recorder, Event monitors

- Worn on the body for 14 days and more (usually 30 days)
- Often requires activation to record an event
- May require awareness of patients to push event button or change batteries
- Saves events only

Mobile cardiac technology

- A monitor worn on the skin that automatically detects, records and transmits abnormal heart rhythms for up to 30 days
- Lasts 7-14 days then changed for a total 30 day recording
- Saves all events
- Waterproof

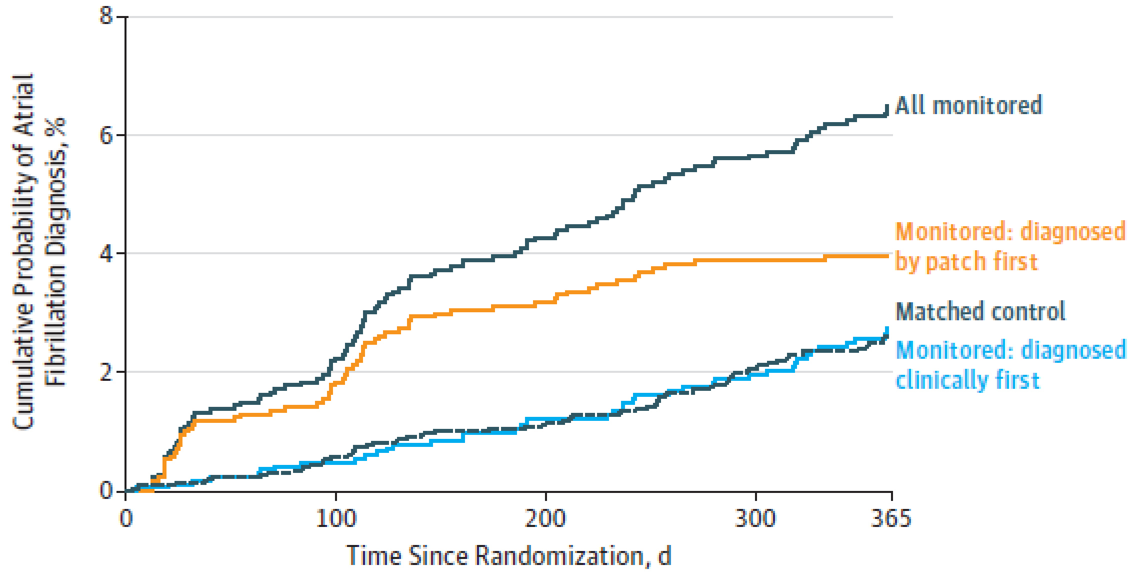
JAMA | Original Investigation

Effect of a Home-Based Wearable Continuous ECG Monitoring Patch on Detection of Undiagnosed Atrial Fibrillation

The mSToPS Randomized Clinical Trial

Steven R. Steinhubl, MD; Jill Waalen, MD, MPH; Alison M. Edwards, MStat; Lauren M. Ariniello, BS; Rajesh R. Mehta, RPh, MS; Gail S. Ebner, BS; Chureen Carter, PharmD, MS; Katie Baca-Motes, MBA; Elise Felicione, MPH, MBA; Troy Sarich, PhD; Eric J. Topol, MD

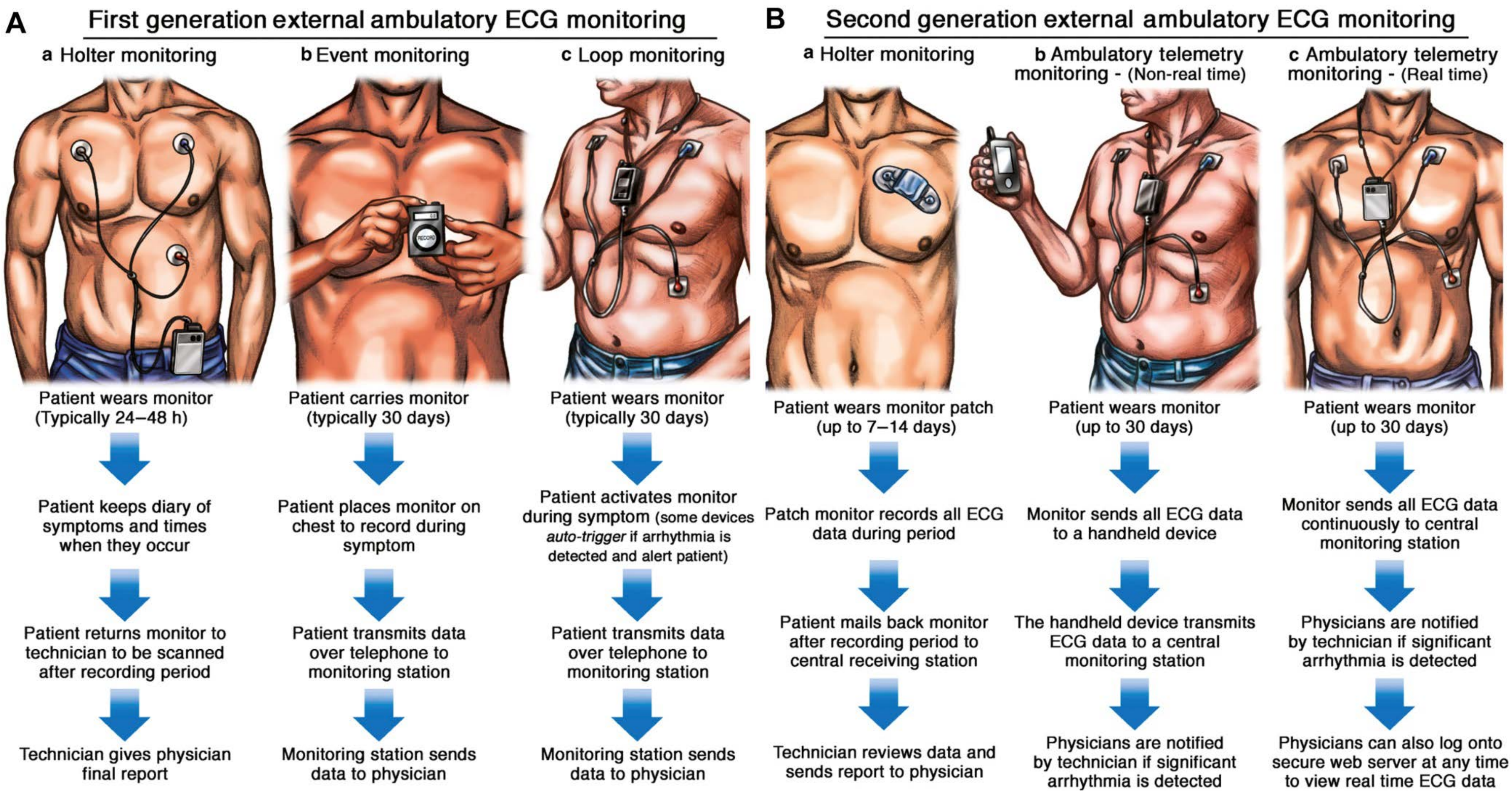
Figure 2. Cumulative Rate of First Diagnosis of Atrial Fibrillation in the Actively Monitored and Observational Cohorts



No. at risk					
All monitored	1738	1681	1555	1469	1446
Monitored: diagnosed by patch first	1738	1681	1555	1469	1446
Monitored: diagnosed clinically first	1738	1681	1555	1469	1446
Matched control	3476	3348	3028	2832	2762

Steven R. Steinhubl, et al. *JAMA*. 2018;320(2):146-155.

Types of AECG monitors currently available in clinical practice



2017 ISHNE-HRS expert consensus statement on ambulatory ECG and external monitoring/telemetry. Ann Noninvasive Electrocardiol. 2017;22:e12447

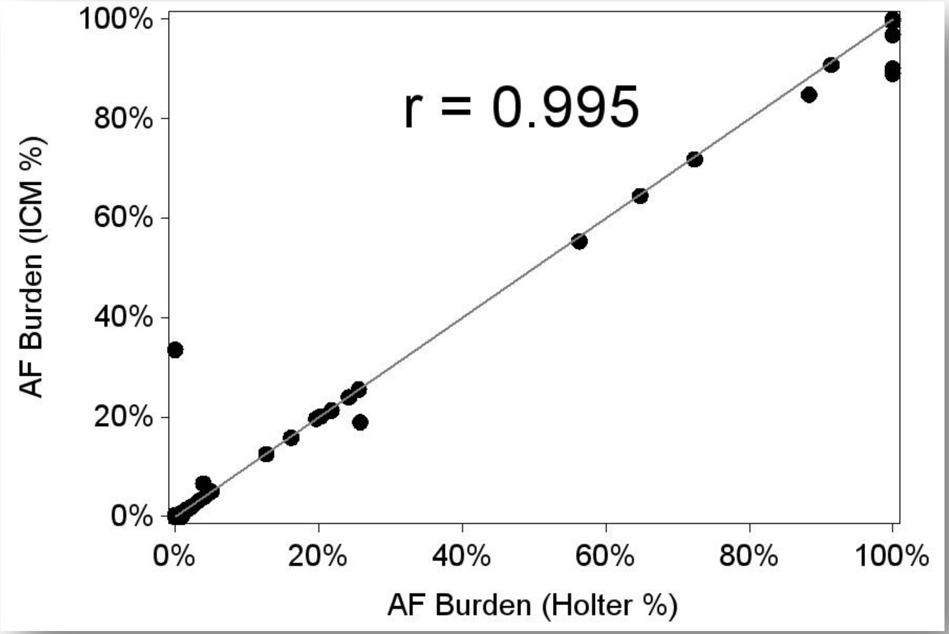
AF detection with external cardiac monitoring in cryptogenic stroke

Citation	Number of Patients	AF Definition	Monitoring Duration	AF Detection Yield	Monitoring Type
Tayal et al[32]	56	<30 s	21 days	18%	MCOT
		>30 s		5%	
Elijovich et al[33]	20	N/A	30 days	20%	Event Monitor
Gaillard et al[34]	98	32 s	30 days	9%	Transtelephonic monitoring
Bhatt et al[31]	62	30 s	28 days	24%	MCOT
Flint et al[35]	236	≤30 s	30 days	4%	MCOT
		>30 s		7%	
Kamel et al[36]	20	30 s	21 days	0%	MCOT
Miller et al[37]	156	<30 s	30 days	12%	MCOT
		≥30 s		5%	
EMBRACE[30]	572	30 s	30 days	16.1%	Event Monitor
			24 h	3.2%	Holter
		2.5 min	30 days	9.9%	Event Monitor
			24 h	2.5%	Holter

AF indicates atrial fibrillation; CS, cryptogenic stroke; MCOT, mobile cardiac outpatient telemetry; N/A, not availabl

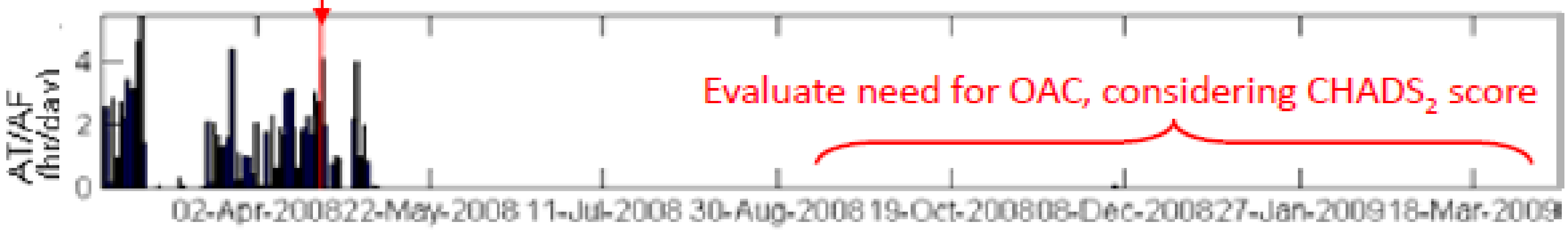
Heart Rhythm Monitoring Strategies for Cryptogenic Stroke:
2015 Diagnostics and Monitoring Stroke Focus Group Report
J Am Heart Assoc. 2016;5:e002944 doi: 10.1161/JAHA.115.002944

Implantable loop recorder



*In patients with known, % of AF or non-AF detected appropriately

- **ILR accurately detects AF 99.4%* of the time**
- **Designed to enable timely AF diagnosis and management**
  - Up to 3 years of continuous cardiac monitoring with ILR
  - Proven AF detection algorithm
  - Safe for use in MRI setting same day at 1.5 and 3.0 Tesla*

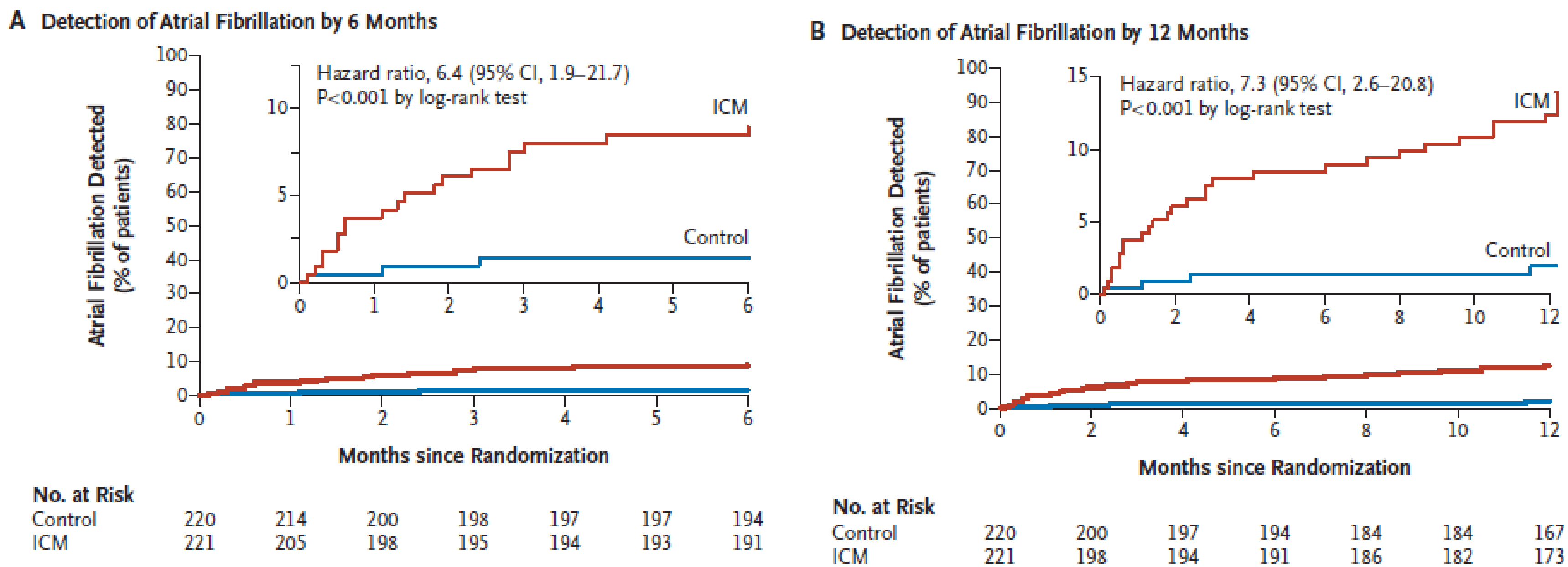


The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

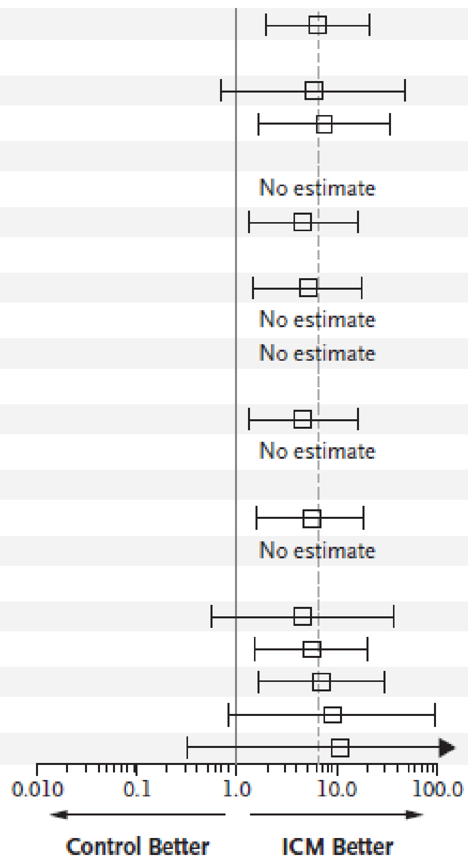
Cryptogenic Stroke and Underlying Atrial Fibrillation

Tommaso Sanna, M.D., Hans-Christoph Diener, M.D., Ph.D.,
Rod S. Passman, M.D., M.S.C.E., Vincenzo Di Lazzaro, M.D.,
Richard A. Bernstein, M.D., Ph.D., Carlos A. Morillo, M.D.,
Marilyn Mollman Rymer, M.D., Vincent Thijs, M.D., Ph.D.,
Tyson Rogers, M.S., Frank Beckers, Ph.D., Kate Lindborg, Ph.D.,
and Johannes Brachmann, M.D., for the CRYSTAL AF Investigators*



ILR is clearly better, but....for all?

Subgroup	No. of Patients (%)	Atrial Fibrillation Detected by 6 Mo (% of patients) ICM	Control	Hazard Ratio (95% CI)	P Value for Interaction
Overall	441 (100.0)	8.9	1.4		
Age					0.85
≤65 yr	276 (62.6)	4.4	0.8		
>65 yr	165 (37.4)	17.0	2.5		
Sex					0.99
Female	161 (36.5)	6.7	0.0	No estimate	
Male	280 (63.5)	10.1	2.3		
Race or ethnic group					1.00
White	385 (87.3)	8.0	1.6		
Other	29 (6.6)	9.1	0.0	No estimate	
Not available	27 (6.1)	20.0	0.0	No estimate	
Patent foramen ovale					0.99
No	343 (77.8)	8.0	1.8		
Yes	98 (22.2)	11.8	0.0	No estimate	
Index event					0.99
Stroke	401 (90.9)	8.3	1.6		
TIA	40 (9.1)	15.0	0.0	No estimate	
$CHADS_2$ score					0.73
2	150 (34.0)	3.0	0.0		
3	183 (41.5)	7.8	2.2		
4	84 (19.0)	15.4	3.2		
5	23 (5.2)	33.3	0.0		
6	1 (0.2)	0.0	NA		



CRYSTAL AF study, N Engl J Med 2014;370:2478-86.

Safety and benefit of ILR

- Infection :1.4%
- ILR remained inserted in 97% in at 1 year
- Number needed to implant to detect 1st episode of AF 14 for 6 months, 4 for 36 months.

CRYSTAL AF study, N Engl J Med 2014;370:2478-86.

Advantages and Disadvantages of Available Monitoring Technologies

	Advantages	Disadvantages
24-H Holter	Inexpensive	Miss of most PAF External leads – patient discomfort
Extended Holter	Inexpensive	Depending on duration – miss AF External leads – patient discomfort Poor patient compliance
Patch monitor	Continuous intermediate-term monitoring Minimally obtrusive for an external device Well tolerated	Relatively more expensive Depending on duration – miss AF Extended monitoring require ≥ 1 patch
Mobile cardiac telemetry	Continuous intermediate-term monitoring Rapid response to clinical events (AF)	Relatively more expensive Long-term monitoring incurs costs Rely on external leads – patient discomfort
Implantable loop recorder	No external device and wires Excellent patient compliance Long-term continuous monitoring (3 yrs) Rapid response to clinical events (AF)	Most expensive (ILR and procedure) Need for minor invasive procedure Need to define Long-term pathway for data analysis & management Long-term monitoring incurs costs

Heart Rhythm Monitoring Strategies for Cryptogenic Stroke:
2015 Diagnostics and Monitoring Stroke Focus Group Report
J Am Heart Assoc. 2016;5:e002944 doi: 10.1161/JAHA.115.002944

Cost

Expected Volumes of Long-Term Ambulatory ECG Tests Under the Current State

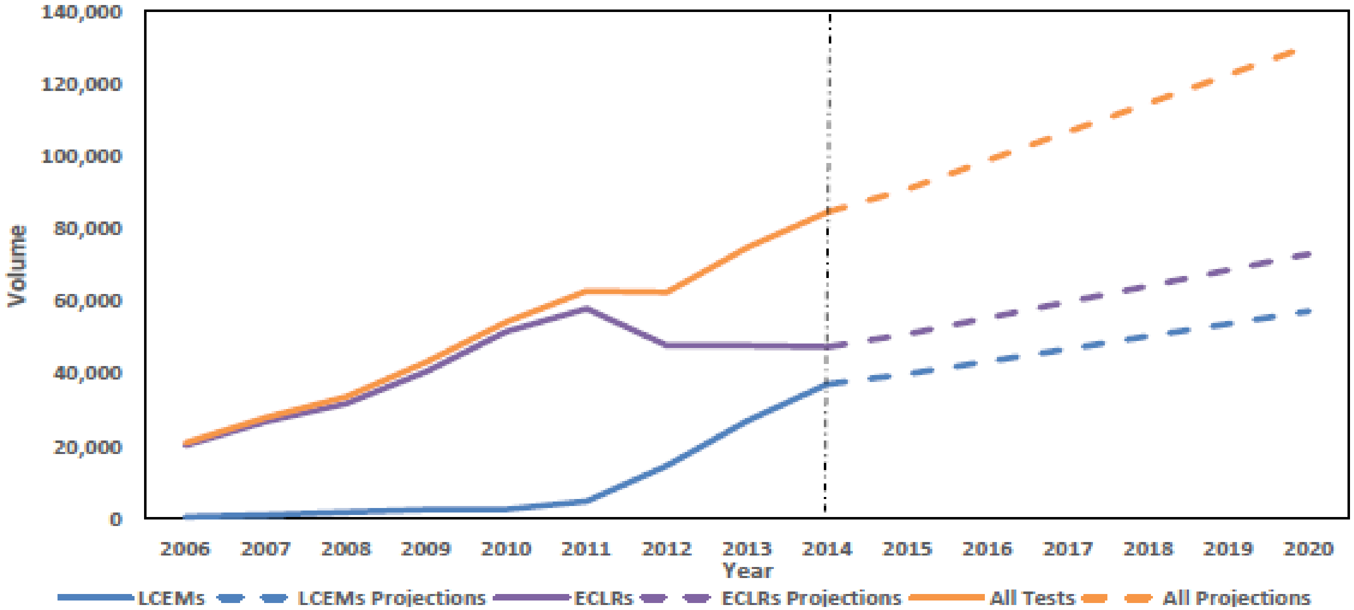
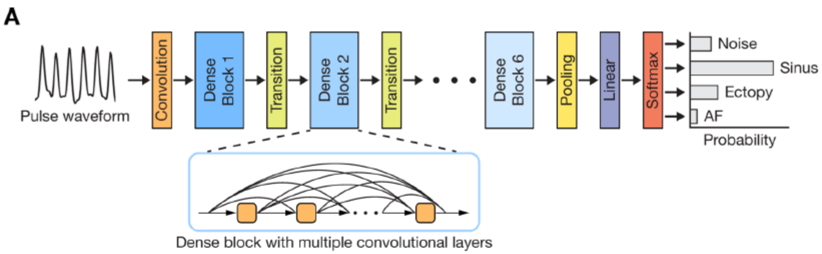


Table 12: Results of Base Case Analysis, Total Costs and Net Budget Impact of an Increasing Uptake Rate for Long-Term Continuous ECG Monitors vs. Constant Current State

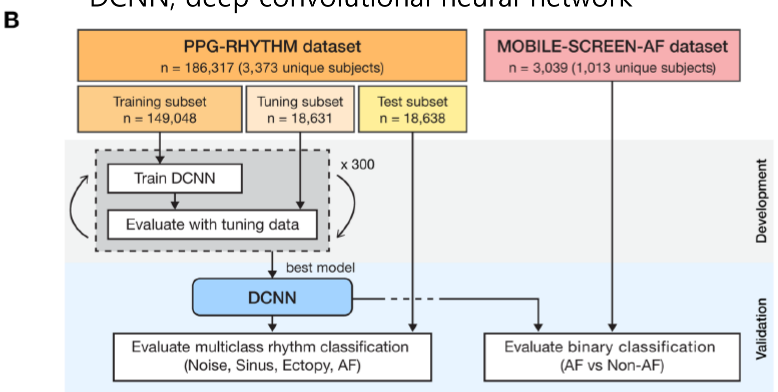
	$ million[a]				
Year	**2016**	**2017**	**2018**	**2019**	**2020**
Current state: constant proportions of ECLR tests (56%) and LCEM tests (44%)	29.10	31.42	33.74	36.05	38.37
Increase in LCEM tests along 2011–2014 linear trend	29.23	31.61	33.99	36.36	38.74
Net budget impact	0.13	0.19	0.25	0.31	0.37

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.
[a] All costs are 2016 Canadian dollars.

Detection of occult AF with AI



DCNN; deep convolutional neural network



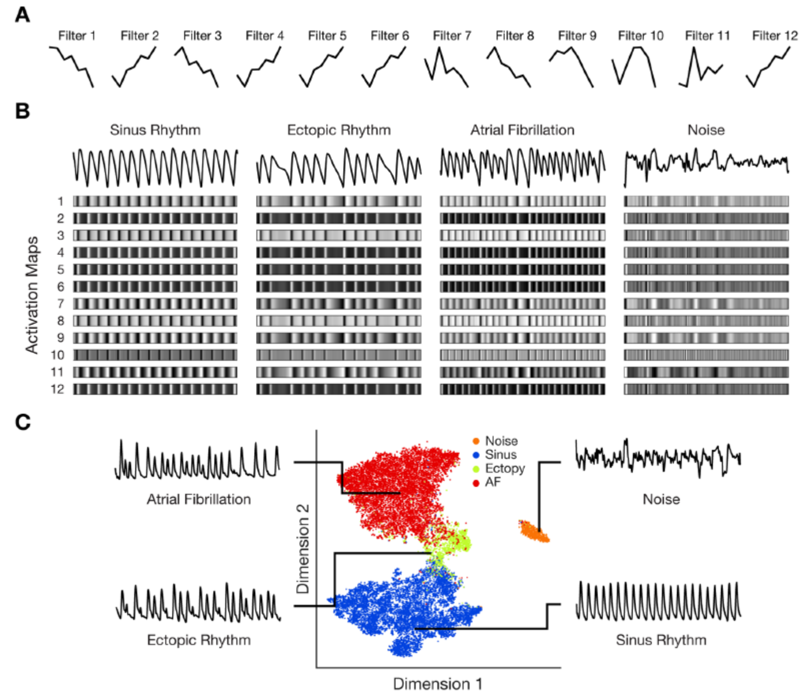


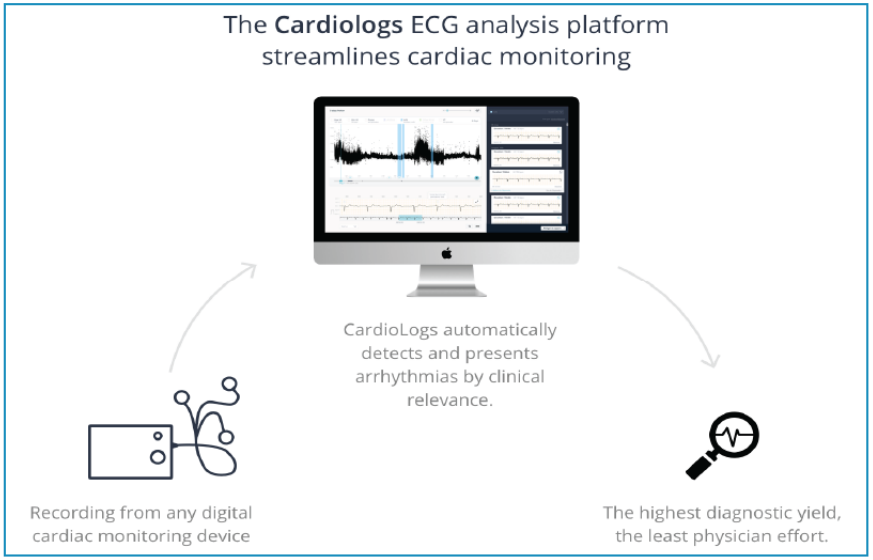
Table 3 DCNN performance for detection of AF versus several state-of-the-art AF detectors on the MOBILE-SCREEN-AF (clinical validation) data set

	Single measurement, % (95% CI)				Triplicate measurements, % (95% CI)			
Method	Sensitivity	Specificity	PPV	NPV	Sensitivity	Specificity	PPV	NPV
CoSEn[6]	88.1 (79.2 to 94.1)	81.9 (80.5 to 83.3)	12.2 (11.0 to 13.4)	99.6 (99.3 to 99.8)	**100.0** (87.7 to 100)	84.7 (82.3 to 86.9)	15.6 (13.8 to 17.7)	**100.0** (99.4 to 100)
Poincaré plot[9]	92.9 (85.1 to 97.3)	82.8 (81.4 to 84.2)	13.3 (12.2 to 14.5)	99.8 (99.5 to 99.9)	**100.0** (87.7 to 100)	85.8 (83.5 to 87.9)	16.7 (14.6 to 18.9)	**100.0** (99.4 to 100)
nRMSSD + ShEn[7]	84.5 (75.0 to 91.5)	88.4 (87.2 to 89.5)	17.1 (15.3 to 19.1)	99.5 (99.2 to 99.7)	92.9 (76.5 to 99.1)	91.0 (89.0 to 92.7)	22.6 (18.9 to 26.8)	99.8 (99.2 to 99.9)
nRMSSD + SD1/SD2[8]	90.5 (82.1 to 95.8)	88.9 (87.7 to 90.0)	18.8 (17.0 to 20.8)	99.7 (99.4 to 99.8)	96.4 (81.7 to 99.9)	92.2 (90.3 to 93.8)	26.0 (21.9 to 30.5)	99.9 (99.3 to 100)
CoV[5]	**96.4** (89.9 to 99.3)	88.5 (87.3 to 89.6)	19.2 (17.6 to 21.0)	**99.9** (99.7 to 100)	**100.0** (87.7 to 100)	91.1 (89.1 to 92.8)	24.1 (20.7 to 28.0)	**100.0** (99.4 to 100)
Ensemble	90.5 (82.1 to 95.8)	90.3 (89.2 to 91.3)	20.9 (18.9 to 23.2)	99.7 (99.4 to 99.9)	**100.0** (87.7 to 100)	92.5 (90.7 to 94.1)	27.5 (23.3 to 32.0)	**100.0** (99.4 to 100)
SVM[10]	90.5 (82.1 to 95.8)	96.1 (95.3 to 96.8)	39.6 (35.1 to 44.2)	99.7 (99.5 to 99.9)	92.9 (76.5 to 99.1)	97.7 (96.5 to 98.5)	53.1 (42.7 to 63.2)	99.8 (99.2 to 100)
DCNN	95.2 (88.3 to 98.7)	**99.0** (98.6 to 99.3)	**72.7** (65.1 to 79.3)	**99.9** (99.7 to 100)	**100.0** (87.7 to 100)	**99.6** (99.0 to 99.9)	**87.5** (72.5 to 94.9)	**100.0** (99.4 to 100)

AF, atrial fibrillation; CoSEn, coefficient of sample entropy; CoV, coefficient of variation; DCNN, deep convolutional neural network; NPV, negative predictive value; nRMSSD, normalised root mean square of successive differences; PPV, positive predictive value; SD1/SD2, Poincaré plot geometry; ShEn, Shannon entropy; SVM, support vector machine. The highest score among all detectors is indicated in bold.

Poh M-Z et al. Heart 2018;104:1921–1928

AI based ECG analysis



Deep Neural Networks Improve Atrial Fibrillation Detection in Holter-*First Results*

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Background Atrial Fibrillation (AF) is the most common human arrhythmia. High prevalence in the aged population (0.5% for 50-59 to 9% for 80-89) and increased risks of hospitalization, strokes, and death call for early detection using long-term ambulatory Electrocardiogram (Holter ECG). Previous works concluded that algorithms using RR interval durations as input yield a good sensitivity (Se) while being robust to noise. However, such algorithms are characterized by poor specificity (Sp) and positive predictive values (PPV); no previous algorithm which uses shape information, such as atrial fibrillatory pattern...

	SE*	PPV**
State-of-the-art	96.3	58.7
Cardiologs AI	97.0	91.0

* Sensitivity: Proportion of positivize cases truly identified.
** Positive Predictive Value: Proportion of true positive cases in cases detected.

Is it really better? Not yet

A deep neural network learning algorithm outperforms a conventional algorithm for emergency department electrocardiogram interpretation

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Table 8a
ECGs with all Groups correctly identified (no overcalls and no undercalls)
Comparison of algorithms in Cases in which the initial expert interpretations were congruent (did not need tie-breaking). $N = 914/1473$ total (62.1%).

	Cardiologs®		Veritas®		P
	Number	%, 95% CI	Number	%, 95% CI	
All ECGs	779/914	85.2% (82.8–87.4)	645/914	70.6% (67.5–73.4)	<0.0001
ECGs with ≥1 abnormality	400/504	79.4% (75.6–82.7)	353/504	70.0% (65.9–73.9)	0.0007
ECGs with ≥1 Major abnormality	249/293	85.0% (80.4–88.6)	216/293	73.7% (68.4–78.4)	0.0008
ECGs with ≥1 Emergency	17/21	81.0% (60.0–92.3)	15/21	71.4% (50.0–86.2)	0.4687

Table 8b
Sensitivity for abnormal groups.

	Cardiologs®		Veritas®		P
	Number	%, 95% CI	Number	%, 95% CI	
All abnormalities	448/533	84.1% (80.7–86.9)	420/533	78.8% (75.1–82.1)	0.0001
Major abnormalities	297/322	92.2% (88.8–94.7)	283/322	87.9% (83.9–91.0)	0.0043
Emergency abnormalities	20/23	87.0% (67.9–95.5)	17/23	73.9% (53.5–87.5)	0.375

Table 8c
Positive predictive value (true positives by the algorithm divided by all positives for that algorithm).

	Cardiologs®		Veritas®		P
	Number	%, 95% CI	Number	%, 95% CI	
All abnormalities	448/527	85.0% (81.7–87.8)	420/671	62.6% (58.9–66.2)	< 0.0001
Major abnormalities	297/347	85.6% (81.5–88.9)	283/439	64.5% (59.9–68.8)	< 0.0001
Emergency abnormalities	20/28	71.4% (52.9–84.7)	17/33	51.5% (35.2–67.5)	0.1126

Journal of Electrocardiology 52 (2019) 88–95

Proposed ECG monitoring algorithm for Cryptogenic stroke

- Repeat of 12 lead EKG
- At least 24 hours of telemetry monitoring
- 2-4 weeks of continuous cardiac telemetry
- Cryptogenic stroke with high probability of PAF: consider prolonged (1-3 years) outpatient loop recording

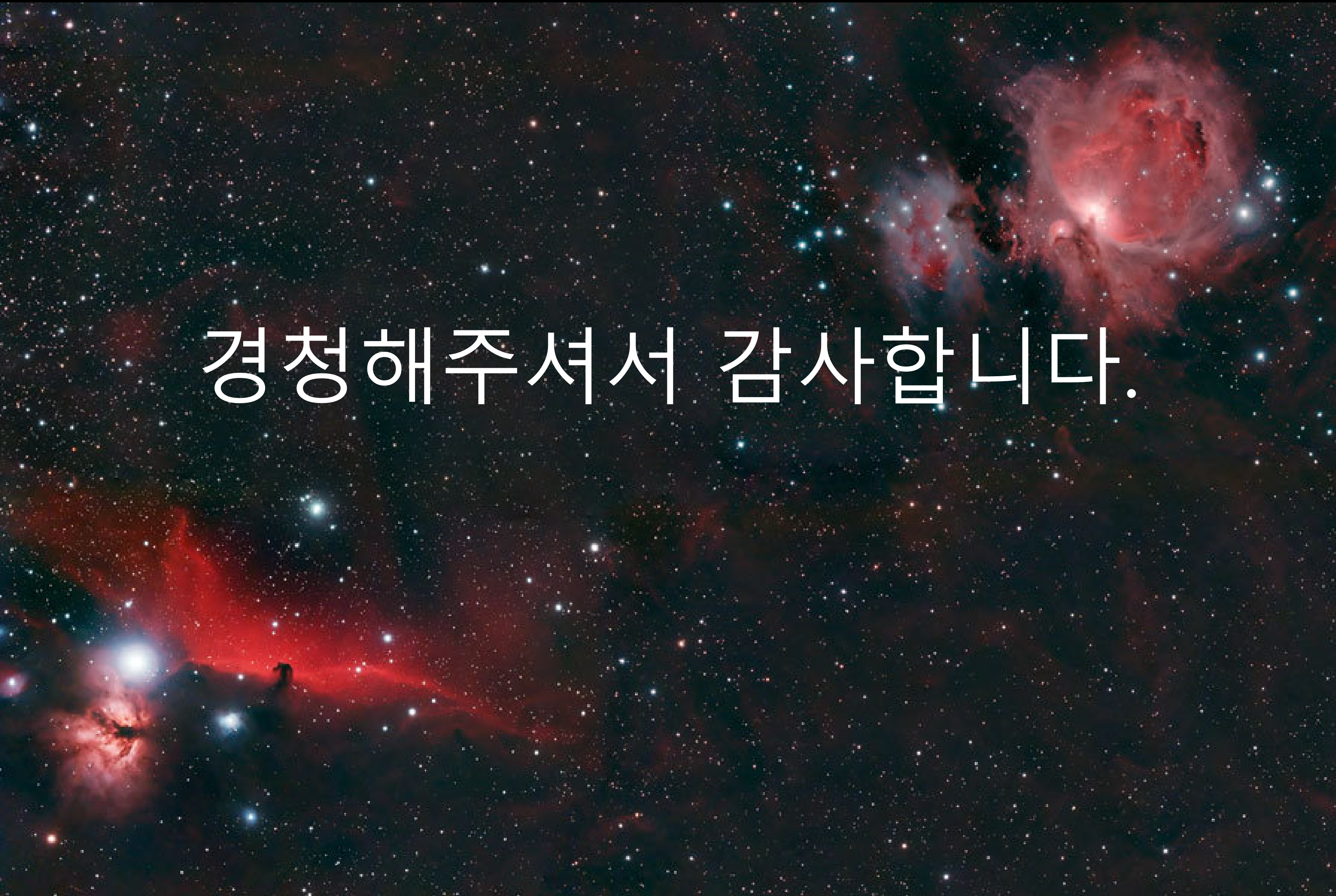
Saver, J. et al. NEJM, 2016 374:2065-74.

Summary

- Cryptogenic stroke is a diagnosis of exclusion
- Long-term monitoring studies of patients with otherwise cryptogenic stroke find that between one-fifth and one-third have paroxysmal AF and are at risk for cardio-embolic stroke.
- Cryptogenic stroke patients without documented atrial fibrillation may have other mechanisms for stroke

Prolong ECG monitoring for cryptogenic stroke

- Important Considerations
  - Length of monitoring desired
  - Ability of the patient to trigger event monitor, change batteries, keep monitor on
  - Feedback system (real time, mail in, reports generated by vendor)
  - Medical institution/vendor relationships
  - Relationships between Provider and Cardiologist
  - Patient agreeable to procedure to insert loop recorder
  - Patient selection: Would you anticoagulated this patient if you found AF?
  - Cost


경청해주셔서 감사합니다.