# AI-ECG Guided Screening for Low Ejection Fraction (EAGLE)

## A Randomized Clinical Trial

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#AHA20

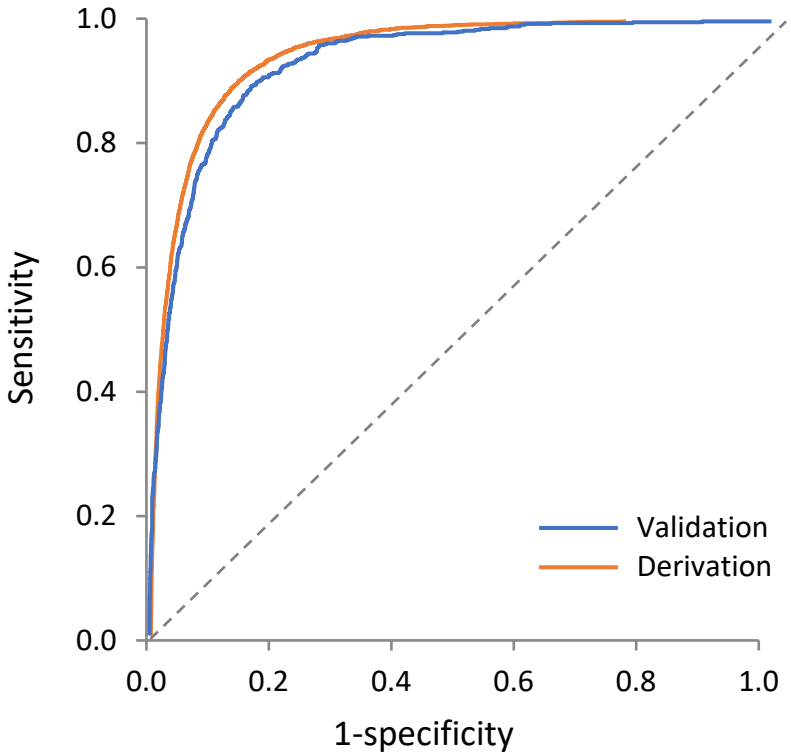
American Heart Association.
Scientific Sessions

# Disclosures

The study was funded by the Mayo Clinic Robert D. and Patricia E. Kern Center for the Science of Health Care Delivery.

Mayo Clinic has licensed the low EF AI-ECG algorithm to Eko, a maker of digital stethoscopes with embedded ECG electrodes. At no point will Mayo Clinic benefit financially from the use of the AI-ECG for the care of patients at Mayo Clinic. Other trial investigators (not PAN or XXY) may receive financial benefit from this agreement for use outside Mayo Clinic.

# Detection of low ejection fraction by *ECG*

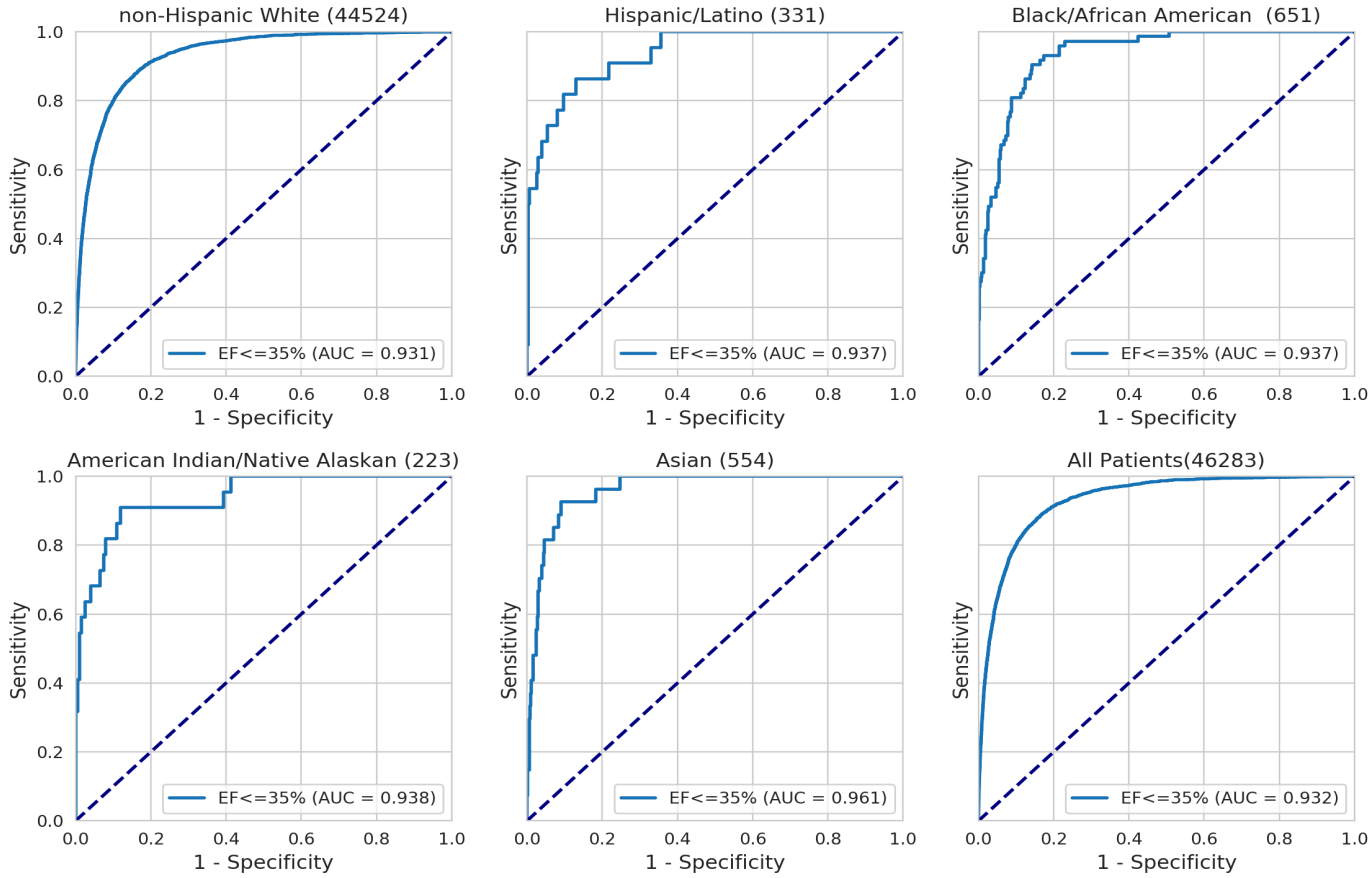



Area under curve = **0.93**

**Validated**
In other populations

Nat Med 2019

# Consistent model performance across racial group

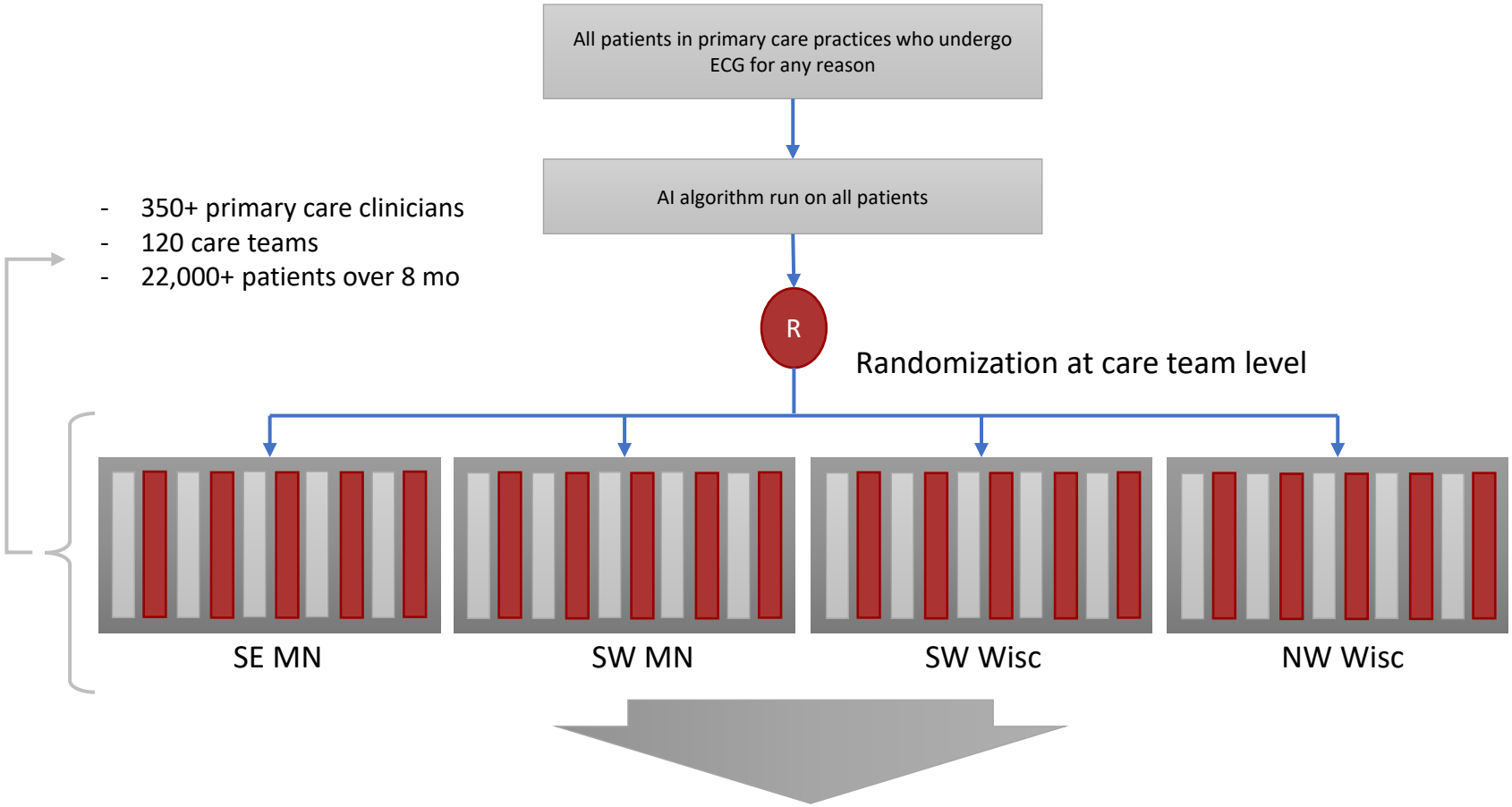


# Translation to practice?



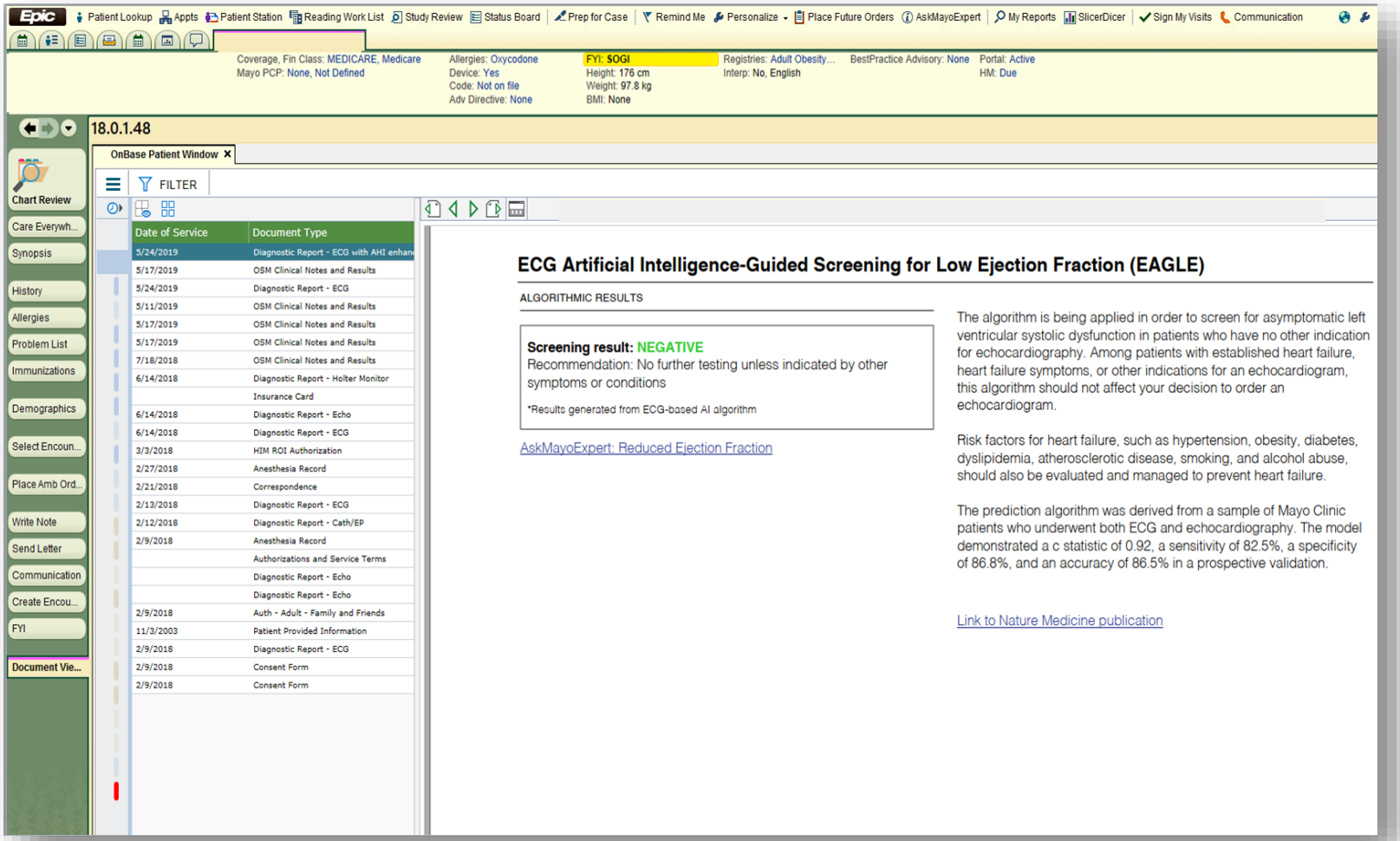
…“delivering the potential of AI will require testing interventions in RCTs and reporting these results in a standardized and transparent fashion,” *Nature Medicine* Editorial Board

# Cluster-randomized, pragmatic design

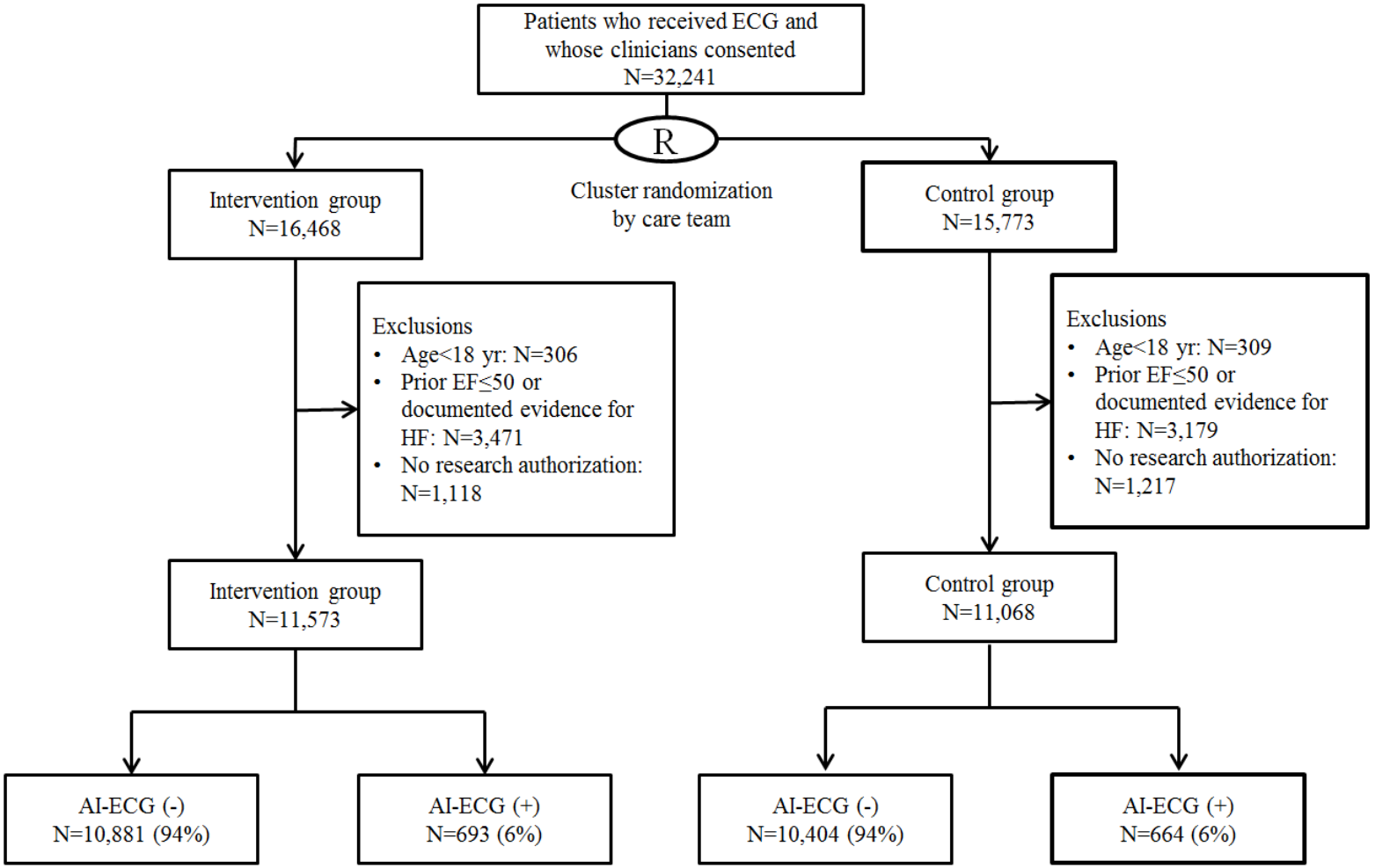



**Outcomes: 1. New low EF diagnosis, 2. Treatment patterns, 3. Qualitative assessment**

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
Chart Review
Care Everywh...
Synopsis
History
Allergies
Problem List
Immunizations
Demographics
Select Encoun...
Place Amb Ord...
Write Note
Send Letter
Communication
Create Encou...
FYI
Document Vie...
Date of Service
Document Type
5/24/2019 Diagnostic Report - ECG with AHI enhan
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



# Baseline Characteristics

| Characteristic | Control (N=11,068) | Intervention (N=11,573) |
|---|---|---|
| **Age, y, mean (SD)** | 60.5 (17.6) | 60.5 (17.5) |
| **18-64** | 5934 (53.6%) | 6256 (54.1%) |
| **65-74** | 2630 (23.8%) | 2764 (23.9%) |
| **≥75** | 2504 (22.6%) | 2553 (22.1%) |
| **Female, N(%)** | 6123 (55.3%) | 6080 (52.5%) |
| **Rural, N (%)** | 5019 (45.4%) | 6323 (54.6%) |
| **Medical History, N(%)** | | |
| **Hypertension** | 6177 (55.8%) | 6491 (56.1%) |
| **Diabetes** | 2221 (20.1%) | 2347 (20.3%) |
| **MI** | 717 (6.5%) | 770 (6.7%) |
| **PAD** | 444 (4.0%) | 411 (3.6%) |
| **Stroke or TIA** | 381 (3.4%) | 409 (3.5%) |
| **Prior AF** | 919 (8.3%) | 991 (8.6%) |
| **New AF on Index ECG** | 248 (2.2%) | 246 (2.1%) |
| **Valvular Heart Disease** | 152 (1.4%) | 129 (1.1%) |
| **CKD** | 1209 (10.9%) | 1373 (11.9%) |
| **Prior Echocardiogram** | 1896 (17.1%) | 1903 (16.4%) |
| **Location of ECG ordered** | | |
| **Outpatient Clinic** | 5969 (53.9%) | 6043 (52.2%) |
| **Emergency Room** | 4056 (36.6%) | 4411 (38.1%) |
| **Hospital** | 1043 (9.4%) | 1119 (9.7%) |

# ECGs were ordered for a variety of indications

| Indication for ECG | N (%) |
|---|---|
| Chest pain | 3,014 (13.3%) |
| Baseline screening | 2,467 (10.9%) |
| Pre-operative study | 1,510 (6.7%) |
| Shortness of breath/dyspnea | 840 (3.7%) |
| Dizziness | 328 (1.4%) |
| Other Diagnosis | 2,789 (12.3%) |
| Unknown | 11,693 (51.6%) |

# Primary findings

- 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)

- 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)

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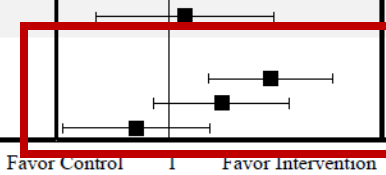
# Subgroup Analyses

| Subgroup | Control | | | Intervention | | | Odds Ratio (95% CI) | P for interaction |
|---|---|---|---|---|---|---|---|---|
| | No. of patients | No. of events | % events | No. of patients | No. of events | % events | | |
| **Overall** | 11068 | 178 | 1.6% | 11573 | 244 | 2.1% | 1.32 ( 1.08 , 1.61 ) | |
| **Age** | | | | | | | | 0.66 |
| 18-64 yr | 5934 | 64 | 1.1% | 6256 | 82 | 1.3% | 1.22 ( 0.88 , 1.69 ) | |
| 65-74 yr | 2630 | 50 | 1.9% | 2764 | 66 | 2.4% | 1.26 ( 0.87 , 1.84 ) | |
| ≥75 yr | 2504 | 64 | 2.6% | 2553 | 96 | 3.8% | 1.49 ( 1.08 , 2.05 ) | |
| **Sex** | | | | | | | | 0.11 |
| Female | 6123 | 49 | 0.8% | 6080 | 79 | 1.3% | 1.63 ( 1.14 , 2.33 ) | |
| Male | 4945 | 129 | 2.6% | 5493 | 165 | 3.0% | 1.16 ( 0.92 , 1.46 ) | |
| **Rural** | | | | | | | | 0.89 |
| No | 6048 | 89 | 1.5% | 5249 | 98 | 1.9% | 1.27 ( 0.95 , 1.70 ) | |
| Yes | 5019 | 89 | 1.8% | 6323 | 146 | 2.3% | 1.31 ( 1.00 , 1.71 ) | |
| **Hypertension** | | | | | | | | 0.22 |
| No | 4891 | 62 | 1.3% | 5082 | 71 | 1.4% | 1.10 ( 0.78 , 1.55 ) | |
| Yes | 6177 | 116 | 1.9% | 6491 | 173 | 2.7% | 1.43 ( 1.12 , 1.84 ) | |
| **Diabetes** | | | | | | | | 0.88 |
| No | 8847 | 127 | 1.4% | 9226 | 172 | 1.9% | 1.30 ( 1.04 , 1.64 ) | |
| Yes | 2221 | 51 | 2.3% | 2347 | 72 | 3.1% | 1.34 ( 0.92 , 1.96 ) | |
| **AF** | | | | | | | | 0.49 |
| No | 9901 | 128 | 1.3% | 10336 | 168 | 1.6% | 1.25 ( 0.98 , 1.60) | |
| Prior AF | 919 | 23 | 2.5% | 991 | 43 | 4.3% | 1.77 ( 1.06 , 2.96 ) | |
| New AF on index ECG | 248 | 27 | 10.9% | 246 | 33 | 13.4% | 1.24 ( 0.68 , 2.23 ) | |
| **MI or PAD** | | | | | | | | 0.49 |
| No | 9985 | 124 | 1.2% | 10484 | 180 | 1.7% | 1.37 ( 1.05 , 1.79 ) | |
| Yes | 1083 | 54 | 5.0% | 1089 | 64 | 5.9% | 1.19 ( 0.82 , 1.73 ) | |
| **CKD** | | | | | | | | 0.96 |
| No | 9859 | 143 | 1.5% | 10200 | 193 | 1.9% | 1.31 ( 1.05 , 1.63 ) | |
| Yes | 1209 | 35 | 2.9% | 1373 | 51 | 3.7% | 1.29 ( 0.84 , 2.00 ) | |
| **Prior echo** | | | | | | | | 0.38 |
| No | 9172 | 144 | 1.6% | 9670 | 207 | 2.1% | 1.36 ( 1.08 , 1.71 ) | |
| Yes | 1896 | 34 | 1.8% | 1903 | 37 | 1.9% | 1.09 ( 0.68 , 1.74 ) | |
| **ECG Location** | | | | | | | | 0.02 |
| Outpatient Clinic | 5969 | 57 | 1.0% | 6043 | 98 | 1.6% | 1.71 ( 1.23 , 2.37 ) | |
| Emergency Department | 4056 | 66 | 1.6% | 4411 | 96 | 2.2% | 1.32 ( 0.92 , 1.88 ) | |
| Hospital | 1043 | 55 | 5.3% | 1119 | 50 | 4.5% | 0.84 ( 0.57 , 1.24 ) | |



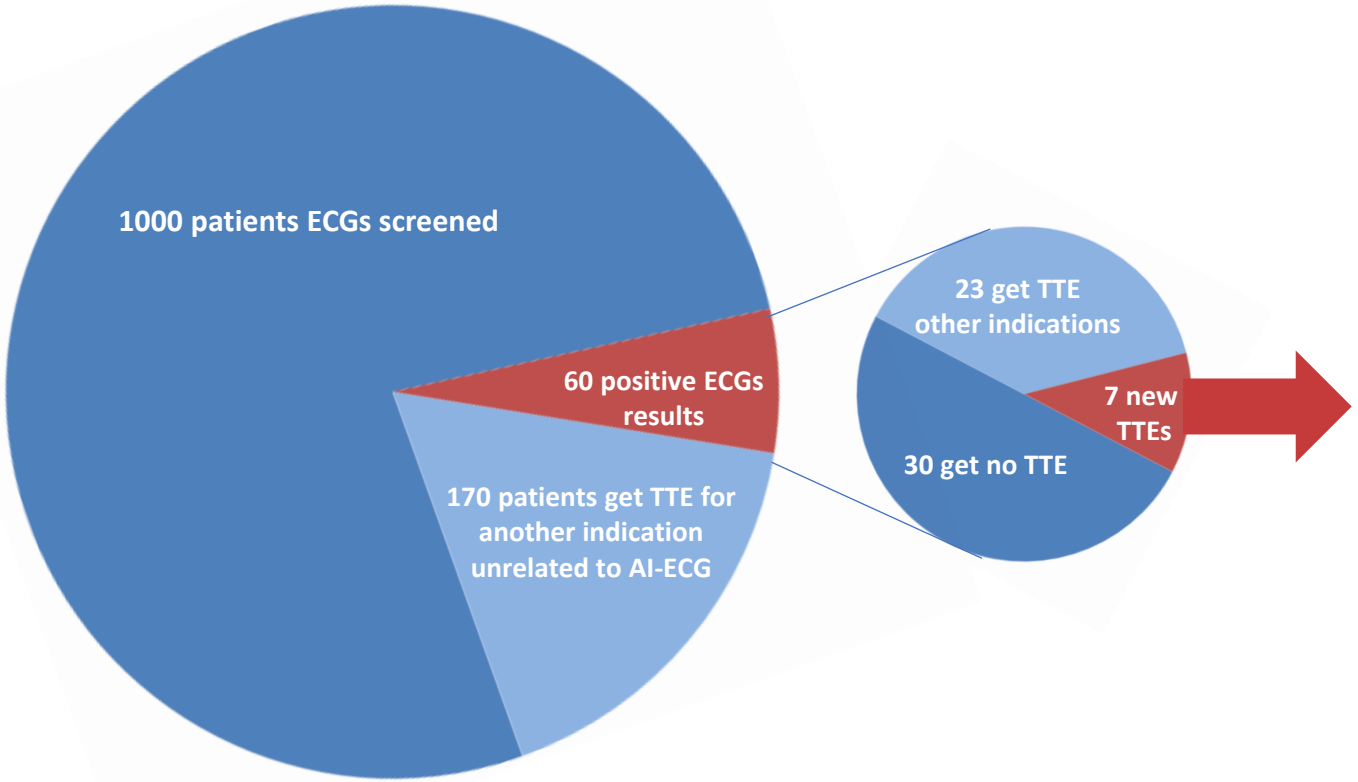
# Treatment for low EF

| | Control (N=70) | Intervention (N=102) | P value |
|---|---|---|---|
| **New Prescription, N (%)** | | | |
| ACEi/ARB or Beta Blockers | 52 (74.3%) | 74 (72.5%) | 0.800 |
| ACEi/ARB | 37 (52.9%) | 44 (43.1%) | 0.210 |
| ACEi | 27 (38.6%) | 39 (38.2%) | 0.964 |
| ARB | 14 (20.0%) | 7 (6.9%) | 0.010 |
| Beta Blockers | 38 (54.3%) | 65 (63.7%) | 0.215 |
| **Baseline or New Prescription, N(%)** | | | |
| ACEi/ARB or Beta Blockers | 65 (92.9%) | 99 (97.1%) | 0.199 |
| ACEi/ARB | 53 (75.7%) | 83 (81.4%) | 0.370 |
| ACEi | 44 (62.9%) | 68 (66.7%) | 0.607 |
| ARB | 19 (27.1%) | 26 (25.5%) | 0.809 |
| Beta Blockers | 62 (88.6%) | 95 (93.1%) | 0.297 |

# Other incidental echo findings

| | Negative ECG N=(3643) | "False Positive" ECG N=(365) |
|---|---|---|
| **All other findings** | 315 (8.6%) | 56 (15.3%) |
| **Valve Heart Disease (≥moderate)** | 287 (7.9%) | 55 (15.1%) |
| **Aortic Regurgitation** | 44 (1.2%) | 8 (2.2%) |
| **Mitral Regurgitation** | 60 (1.6%) | 12 (3.3%) |
| **Tricuspid Regurgitation** | 123 (3.4%) | 27 (7.4%) |
| **Aortic Stenosis** | 85 (2.3%) | 16 (4.4%) |
| **Mitral Stenosis** | 3 (0.1%) | 0 (0.0%) |
| **Bicuspid Aortic Valve** | 15 (0.4%) | 2 (0.5%) |
| **Atrial Septal Defect** | 18 (0.5%) | 0 (0.0%) |
| **Ventricular Septal Defect** | 11 (0.3%) | 0 (0.0%) |
| **Hypertrophic Cardiomyopathy** | 3 (0.1%) | 1 (0.3%) |

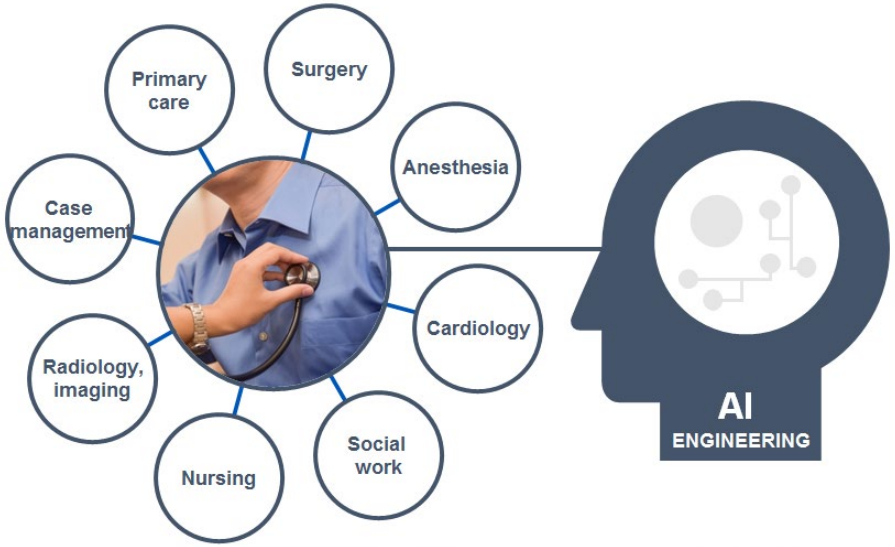
# Overall diagnostic yield




**Screening yields 5 new low EF diagnoses/1000 over usual care (21 with intervention versus 16 in usual care)**

# Conclusion

- AI-ECG can be integrated into routine primary care practices through EHR
- AI-ECG integration increased the diagnosis of previously unrecognized low EF
- Since ECGs are already routinely performed for a variety of purposes, the algorithm could be applied to existing health records to facilitate early low EF diagnosis
- Must now focus on how to make sure that these interventions are minimally disruptive and that they add value to the clinical interaction



# *Thank You.*