Opportunistic Screening for Atrial Fibrillation With Continuous ECG Monitoring in the Emergency Department

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Study objectives: To determine the prevalence of undiagnosed atrial fibrillation detectable through continuous ECG monitoring in adult emergency department (ED) patients, and to estimate the stroke risk of ED patients discharged with undiagnosed atrial fibrillation.

Methods: Retrospective cohort study of 65,244 unique consecutive adult patients who received continuous ECG monitoring in an academic ED from August 23, 2020, to January 16, 2024. Primary outcome was the proportion of patients with at least 30 seconds of atrial fibrillation on continuous monitoring who were discharged without documented atrial fibrillation diagnosis or anticoagulation. Secondary outcomes included atrial fibrillation burden, proportion of cases suitable for anticoagulation based on CHA_2DS_2-VASc score, and incidence of ischemic stroke through August 31, 2024, by atrial fibrillation status on discharge (no atrial fibrillation, known atrial fibrillation, and undiagnosed atrial fibrillation). We compared demographic and insurance characteristics of patients with undiagnosed versus known atrial fibrillation. We estimated Cox proportional hazard models for ischemic stroke after ED visit, stratified by atrial fibrillation status and adjusting for CHA_2DS_2-VASc score.

Results: Of 65,244 monitored patients, 1,945 (3.0%) were discharged with undiagnosed atrial fibrillation, with 1,385 (71.2%) meeting criteria for anticoagulation. Compared to patients with known atrial fibrillation, patients with undiagnosed atrial fibrillation were younger (median age 72 [interquartile range, 50 to 84] versus 79 [interquartile range, 69 to 87] years), more likely to be women (49.6% versus 43.7%), on Medicaid (16.9% versus 7.0%), lack a primary care provider (22.5% versus 12.4%), and identify as Black (7.0% versus 3.7%) or Hispanic/Latino (17.1% versus 9.5%). Patients with undiagnosed atrial fibrillation had 2.6 ischemic strokes per 100 person-years of follow-up, with an adjusted hazard ratio for stroke of 3.00 (95% confidence interval, 2.39 to 3.76) compared to patients without atrial fibrillation on monitor, and 1.32 (95% confidence interval, 1.02 to 1.71) compared to patients with known atrial fibrillation.

Conclusion: Analysis of continuous ECG monitoring in the ED identified undiagnosed atrial fibrillation in 3% of patients, predominantly from underserved populations, and at high risk of stroke. Opportunistic screening in the ED could facilitate earlier diagnosis and anticoagulation to prevent stroke. [Ann Emerg Med. 2025;■:1-10.]

Please see page XX for the Editor's Capsule Summary of this article.

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SEE EDITORIAL, P. XXX.

INTRODUCTION

Background

Ischemic stroke is a leading cause of morbidity and mortality worldwide, with atrial fibrillation implicated in at least 12% of cases.[1] This figure is likely underestimated due to the underdiagnosis of atrial fibrillation, which is often paroxysmal and asymptomatic.[2] Traditional 12-lead ECGs detect atrial fibrillation only when present during the brief recording period, typically 10 seconds. Although wearable or implanted devices can improve atrial fibrillation detection, their implementation is limited by cost and accessibility, exacerbating disparities in diagnosis and outcomes.[3-5]

Importance

Early atrial fibrillation detection enables stroke prevention in high-risk patients through timely anticoagulation.[6] Current guidelines recommend

Editor's Capsule Summary

What is already known on this topic

Detecting atrial fibrillation and starting anticoagulation reduces stroke risk.

What question this study addressed

What is the prevalence of atrial fibrillation detected incidentally on continuous ECG monitoring among emergency department (ED) patients without documented prior atrial fibrillation?

What this study adds to our knowledge

In a retrospective study of people seen in one ED, atrial fibrillation detection occurred in 3% of those incidentally monitored and "atrial fibrillation-naïve." They were discharged without anticoagulation and higher stroke incidence compared to patients without atrial fibrillation detected.

How this is relevant to clinical practice

Continuous ED ECG monitoring can improve detection and hopefully treatment of those with paroxysmal atrial fibrillation.

anticoagulation based on CHA_2DS_2-VASc scores: ≥ 2 in men and ≥ 3 in women, with consideration for lower scores.[6] Efforts to improve detection and management of atrial fibrillation through screening have been reported predominantly in primary care populations, with variable diagnostic yield.[7] The emergency department (ED) often serves as the initial point of atrial fibrillation diagnosis when patients present with rapid ventricular response or hemodynamic instability.[8] However, because ED patients, unlike primary care populations, often receive continuous ECG monitoring, atrial fibrillation may be incidentally detected when patients present with unrelated complaints but exhibit atrial fibrillation on continuous monitoring. Opportunistic screening in the ED through routine bedside monitoring may facilitate earlier detection and management of atrial fibrillation in a diverse population including patients with limited access to primary and specialty care.[9] Screening in the ED also enables confirmatory testing, risk stratification, and treatment initiation at the point of detection.

Goals of This Investigation

This study aimed to determine the prevalence of undiagnosed atrial fibrillation detectable through continuous ECG monitoring in adult ED patients, characterize the demographics and stroke risk of patients with undiagnosed atrial fibrillation, and estimate the proportion likely to benefit from anticoagulation.

METHODS

Study Design and Population

This was a retrospective cohort study at a single academic ED at a tertiary referral center and teaching hospital, with approximately 80,000 adult ED visits annually. The study population comprised all adult patients who received continuous ECG monitoring during ED visits between August 23, 2020, and January 16, 2024. Assignment to a monitored bed at the study hospital is determined by the charge nurse, based on estimated patient acuity, comorbidities, chief complaint, and bed availability. Primary analysis was at the patient level: for patients with any atrial fibrillation detected, we included the first visit with atrial fibrillation. For patients with no atrial fibrillation detected in the study period, we included their first ED visit during the study period. Two secondary analyses (validation of continuous ECG algorithm and atrial fibrillation burden over successive visits) included all available data (not restricted to a single visit per patient). The study followed the Strengthening the Reporting of Observational Studies in Epidemiology reporting guideline.

Data Collection and Atrial Fibrillation Detection

For each ED visit, data extraction included continuous ECG waveforms and rhythm labels from Philips IntelliVue bedside monitors, stored in an on-premises data warehouse. The Philips ST/AR algorithm has been validated in several public and proprietary cardiologist-annotated ECG databases, with reported 92% to 100% sensitivity, 86% to 97% positive predictive value, and 98% specificity for atrial fibrillation detection.[10-12] We performed additional validation of the algorithm on our ED data, detailed in section "Validation of Continuous ECG Algorithm."

We used 30 seconds as the minimum detection threshold to match consensus electrophysiologic definitions for detection of an atrial fibrillation episode.[13] In a secondary analysis, we use a longer 6-minute duration threshold, which has been studied in continuously monitored populations as a predictor of ischemic stroke.[14] The Philips algorithm used at the study hospital detects atrial fibrillation based on variation in RR interval, PR interval, and P-wave morphology for consecutive beats, and therefore does not classify atrial flutter. For each atrial fibrillation-positive visit, we calculated the total atrial fibrillation duration and atrial fibrillation burden (percentage of monitoring time in atrial fibrillation).

For all patients, we extracted all 12-lead ECGs and cardiologist-reviewed interpretations from the study hospital's Philips ECG database (distinct from the continuous monitoring data warehouse). We obtained all coded diagnoses and diagnosis dates, and all home medications and prescription dates, from the Stanford Medicine Research Data Repository, a clinical data warehouse containing data from the Epic electronic health record at Stanford Health Care, and from auxiliary hospital applications such as the radiology Picture Archiving and Communications System. This database includes diagnoses and prescriptions from all ED, inpatient, and outpatient encounters. We obtained all-cause out-of-hospital mortality records from the California Department of Public Health vital statistics database. We obtained all data available through August 31, 2024, with no date restriction for inclusion of prior records.

Identification of Undiagnosed Atrial Fibrillation

We aimed to classify patients by atrial fibrillation status on discharge. Known atrial fibrillation was defined by one or more criteria met by the time of discharge (from the ED, or from the inpatient service for patients admitted from the ED): (1) atrial fibrillation or atrial flutter diagnostic codes (International Classification of Diseases [ICD-10] codes I48.0–I48.4, I48.91–I48.92), (2) prescription of anticoagulation (direct factor Xa inhibitors, coumarin-type anticoagulants, thrombin inhibitors, and heparin and related preparations), or (3) cardiologist-interpreted 12-lead ECG showing atrial fibrillation.

For patients meeting none of these criteria, we performed manual chart review using global record search (including non-study site hospital records through Health Information Exchange) to identify known atrial fibrillation cases not reflected in coded diagnoses or 12-lead ECG interpretations (Figure 1). We aimed to observe best practices for chart review.[15] Reviewers were blinded to study hypotheses at the time of chart review, and trained to use the global record search feature of the study site's Epic electronic health record, which accesses all notes from both the study hospital and from other (but not all) academic, community, and safety net hospitals in California. Reviewers searched for "atrial fibrillation" and "afib," retrieving any notes referencing these terms prior to the index ED visit, and recorded whether any prior notes including the terms corresponded to a known diagnosis (eg, "history of atrial fibrillation" or "telemetry showing paroxysmal atrial fibrillation" were recorded as a prior atrial fibrillation diagnosis, but "family history of afib" or "no known history of atrial fibrillation" were not). For atrial fibrillation references constituting a known diagnosis, reviewers recorded the date associated with the first diagnosis or mention of atrial fibrillation. Each reviewer was directly supervised by an emergency physician during their first 5 chart reviews. Ambiguous results were resolved by a supervising emergency physician.

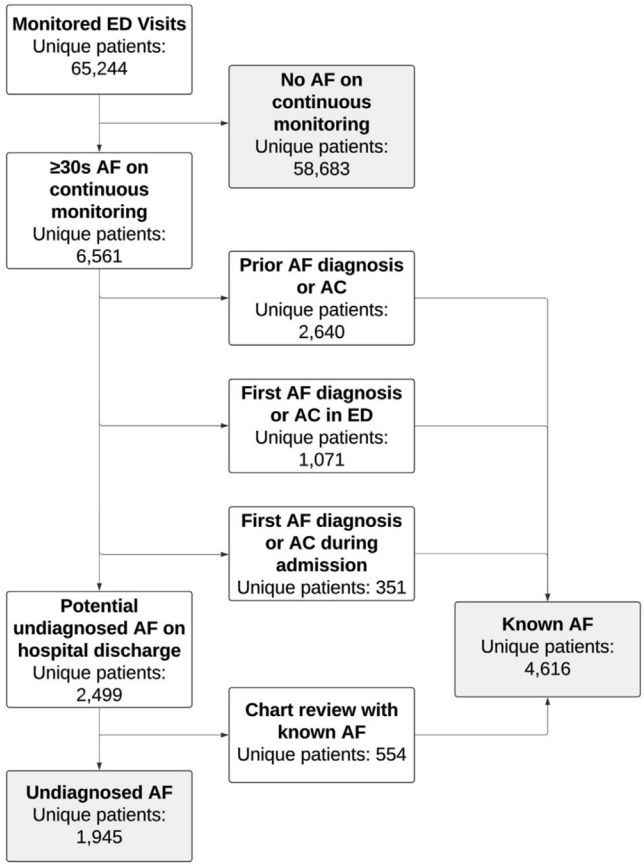

Figure 1. Identification of undiagnosed atrial fibrillation. Atrial fibrillation cases were considered undiagnosed if they met all 5 criteria: (1) at least 30 consecutive seconds of atrial fibrillation on continuous monitoring, (2) no prior or same-visit atrial fibrillation/flutter diagnosis codes, (3) no prior or same-visit 12-lead ECG showing atrial fibrillation, (4) no prior or same-visit anticoagulation (AC), and (5) no evidence of atrial fibrillation diagnosis in external records through Health Information Exchange. "AF diagnosis" in this figure includes both atrial fibrillation diagnosis codes and atrial fibrillation rhythm on cardiologist-reviewed 12-lead ECGs. *AF*, atrial fibrillation.

Notably, patients who received a new diagnosis of atrial fibrillation during the index ED visit or resulting admission were excluded from our definition of "undiagnosed atrial fibrillation," such that patients we identified as having undiagnosed atrial fibrillation were undiagnosed when they left the hospital (whether from the ED, or after admission).

Stroke Risk Assessment

CHA_2DS_2-VASc scores were automatically calculated based on age, sex, and coded prior diagnoses in the

electronic health record by the end of the encounter: congestive heart failure (ICD-10 codes I50, I09.81, I11.0, I13.0, I13.2); hypertension (I10–I15); diabetes mellitus (E08-E14); stroke, transient ischemic attack, or arterial thromboembolism (I60-I64, I74, G45); and vascular disease, including prior myocardial infarction (I21, I22, I25.2), coronary artery disease (I25, Z95.1, Z95.5), peripheral artery disease (I70.2, I70.3-I70.7, I70.92, I73.9, Z95.820), and aortic atherosclerosis (I70). Following current guidelines,[6] patients were stratified into 2 groups based on stroke risk: strong anticoagulation candidates (men with scores $\geq$2 or women with scores $\geq$3) and possible candidates (men with scores $\geq$1 and women with scores $\geq$2).

Outcome Measures

The primary outcome was the prevalence of undiagnosed atrial fibrillation, defined as atrial fibrillation on continuous ED monitoring in patients without prior diagnosis or anticoagulation, and without new atrial fibrillation diagnosis or anticoagulation at any time during the index visit, including hospital admission for patients admitted from the ED (Figure 1). Secondary outcomes included atrial fibrillation burden and duration of longest episode, proportion of cases suitable for anticoagulation based on CHA_2DS_2-VASc score, and incidence of ischemic stroke (new ICD-10 code I63 after the ED visit).

We followed all patients through August 31, 2024. We describe stroke incidence as strokes per 100 person-years of follow-up, and used Cox proportional hazards models to estimate stroke incidence, accounting for variable follow-up periods and adjusting for CHA_2DS_2-VASc score. We used electronic health record-linked state death records (all-cause in- and out-of-hospital mortality) to censor models.

Among the subset of patients with undiagnosed atrial fibrillation and at least 24 months of follow-up data, we calculated the proportion receiving an atrial fibrillation diagnosis or anticoagulation prescription during follow-up (ICD-10 codes and medication categories described above), and the duration in days from ED visit to diagnosis or anticoagulation.

Statistical Analysis

Descriptive statistics summarized patient characteristics. Proportions were compared using the two-sided χ^2 test. Medians were compared with the Wilcoxon rank-sum test. Cox proportional hazards models estimated hazard ratios for ischemic stroke by atrial fibrillation status at the time of discharge from the index visit, adjusting for CHA_2DS_2-VASc scores, and censoring at the end of the follow-up period (August 31, 2024), or patient death. All tests used a significance threshold of $P < .05$.

To characterize the proportion of visits with atrial fibrillation detected as a function of monitoring duration, we fit exponential, logistic, and polynomial functions to the observed data (proportion of patients with atrial fibrillation detected versus minutes of ECG monitoring), and visualized against the observed data the function with lowest Akaike information criterion (AIC). We calculated the duration of monitoring needed to detect 90% of observed atrial fibrillation cases, stratified by newly detected (undiagnosed) versus known atrial fibrillation.

All primary analyses are at the patient level (one monitored visit per patient). In a secondary analysis, we include multiple monitored visits per patient, and calculate the median atrial fibrillation burden by visit number: first, second, third, and fourth or more. We assess the trend in atrial fibrillation burden across successive visits with the nonparametric Jonckheere-Terpstra test.

Validation of Continuous ECG Algorithm

We performed additional validation of the continuous ECG rhythm classifications, using cardiology-reviewed 12-lead ECG interpretations as the gold standard. Specifically, we analyzed all 12-lead ECGs obtained on ED patients simultaneously receiving continuous ECG monitoring (irrespective of prior atrial fibrillation diagnosis), and compared rhythm labels from the continuous ECG segment (produced by ST/AR) with those from the simultaneous, cardiologist-reviewed 12-lead ECG (taking the latter as gold standard). This analysis included all simultaneous pairs of continuous ECG segments and cardiology-reviewed 12-lead ECGs, and was not restricted to a single visit per patient. Twelve-lead ECGs labeled atrial fibrillation belonged either to the "known atrial fibrillation" group (this being one of the criteria for assignment to "known atrial fibrillation") or were not included in primary analyses (if not from a patient's first eligible visit in the study period). The validation analysis had no bearing on the classification of patients in the primary analyses. We calculated test characteristics (sensitivity, specificity, positive predictive value, negative predictive value) for detection of atrial fibrillation from continuous ECG, and 95% confidence intervals (CIs) using Wilson's method.

Ethical Considerations

The study was approved by the Stanford University Institutional Review Board with a waiver of informed consent for retrospective research.

Table. Baseline characteristics of monitored patients, by atrial fibrillation status.

Characteristic	Patients, No. (%)		
	No Atrial Fibrillation On Monitor (n=58,683)	Known Atrial Fibrillation (n=4,616)	Undiagnosed Atrial Fibrillation (n=1,945)
Age, y, median (IQR)	55 (38-71)	79 (69-87)	72 (50-84)
Sex			
Women	31,125 (53.0)	2,018 (43.7)	965 (49.6)
Men	27,530 (46.9)	2,596 (56.2)	976 (50.2)
Race and ethnicity			
Asian	11,227 (19.1)	724 (15.7)	317 (16.3)
Black	2,929 (5.0)	170 (3.7)	136 (7.0)
Hispanic (any race)	14,744 (25.1)	438 (9.5)	333 (17.1)
White	25,302 (43.1)	2,979 (64.5)	1,000 (51.4)
Other*	22,154 (37.8)	913 (19.8)	628 (32.3)
Insurance status			
Private/other	29,835 (50.8)	1,498 (32.5)	742 (38.1)
Medicaid	13,617 (23.2)	323 (7.0)	328 (16.9)
Medicare	15,231 (26.0)	2,795 (60.6)	875 (45.0)
No PCP	16,120 (27.5)	571 (12.4)	438 (22.5)
Medical history‡			
Atrial fibrillation/flutter	2,033 (3.5)	3,018 (65.4)	0 (0.0)
CHF	2,485 (4.2)	1,272 (27.6)	157 (8.1)
Hypertension	10,349 (17.6)	1,864 (40.4)	530 (27.2)
Diabetes mellitus	5,131 (8.7)	709 (15.4)	257 (13.2)
Stroke/TIA/thromboembolism	3,213 (5.5)	759 (16.4)	285 (14.7)
Vascular disease	4,742 (8.1)	1,070 (23.2)	280 (14.4)
Prior anticoagulation‡	1,269 (2.2)	980 (21.2)	0 (0.0)
Prior 12-lead ECG with atrial fibrillation‡	911 (1.6)	3,189 (69.1)	0 (0.0)
CHA_2DS_2-VASc			
≥2 (M)/≥3 (F)	18,126 (30.9)	3,773 (81.7)	1,134 (58.3)
≥1 (M)/≥2 (F)	27,712 (47.2)	4,282 (92.8)	1,385 (71.2)
Triage HR, beats per minute, median (IQR)	85 (74-99)	89 (74-109)	82 (69-96)
Monitoring duration, minute, median (IQR)	186 (109-286)	279 (191-395)	269 (170-390)
Atrial fibrillation burden, % (IQR)	0 (0-0)	54.5 (9.1-89)	2.5 (0.7-14.9)
Same-encounter 12-lead ECG	43,999 (75.0)	4,250 (92.1)	1,532 (78.8)
ED disposition			
Discharge	29,090 (49.6)	858 (18.6)	588 (30.2)
Inpatient	17,461 (29.8)	2,492 (54.0)	810 (41.6)
Observation	8,737 (14.9)	785 (17)	344 (17.7)
ICU	2,155 (3.7)	386 (8.4)	158 (8.1)
ED LOS, hour, median (IQR)	5.7 (4.2-7.7)	6.5 (5.0-8.6)	6.8 (5.0-9.4)

CHF, Congestive heart failure; *ED*, emergency department; *HR*, heart rate; *ICU*, intensive care unit; *LOS*, length of stay; *PCP*, primary care physician; *TIA*, transient ischemic attack.
*Other includes American Indian or Alaska Native, Native Hawaiian or Other Pacific Islander, and race/ethnicity recorded as "other."
‡Evaluated at hospital discharge.

RESULTS

Of 65,244 unique patients, 6,561 (10.1%) had atrial fibrillation detected on continuous ECG monitoring. Compared with simultaneous cardiologist-reviewed 12-lead ECGs, continuous ECG labels were very specific (99.2%) and moderately sensitive (85.0%) for detection of atrial fibrillation (Table E1, available at http://www.annemergmed.com).

Of patients with atrial fibrillation detected on continuous ED monitoring, 3,194 (48.7%) had evidence of prior atrial fibrillation diagnosis (coded diagnosis, 12-

lead ECG with atrial fibrillation, or chart review indicating known atrial fibrillation) or anticoagulation. A total of 1,071 (16.3%) received a first atrial fibrillation diagnosis or anticoagulation prescription during the ED visit, and 351 (5.3%) during hospital admission from the ED. A total of 1,945 (29.6%) were discharged from the ED or hospital without evidence of atrial fibrillation diagnosis, 12-lead ECG showing atrial fibrillation, or anticoagulation (Figure 1, Table). These "undiagnosed atrial fibrillation" cases constitute 3.0% of the monitored ED cohort (4.7% of patients aged 65 years and older; 1.9% of patients aged less than 65 years). Undiagnosed atrial fibrillation cases differed significantly from known atrial fibrillation cases across demographic and clinical characteristics. Compared to known atrial fibrillation cases, patients with undiagnosed atrial fibrillation were younger (median age 72 [interquartile range (IQR), 50 to 84] versus 79 [IQR, 69 to 87] years), more often women (49.6% versus 43.7%), more often insured by Medicaid (16.9% versus 7.0%), more likely to lack a primary care provider (22.5% versus 12.4%), and to identify as Black (7.0% versus 3.7%) or Hispanic/Latino (17.1% versus 9.5%; all differences significant at $P < .001$). Patients with undiagnosed atrial fibrillation were also more likely to be discharged home from the ED than patients with known atrial fibrillation (30.2% versus 18.6%). Most undiagnosed atrial fibrillation cases (58.3%) met strong anticoagulation criteria, with an additional 12.9% meeting possible criteria.

Undiagnosed atrial fibrillation cases had much lower atrial fibrillation burdens (median 2.5%, IQR 0.7% to 14.9%) compared to patients with known atrial fibrillation (median burden 54.5%, IQR 9.1 to 89.0% $P < .001$). A total of 1,532 (78.8%) of patients with undiagnosed atrial fibrillation had a 12-lead ECG performed during the visit. Atrial fibrillation detection increased with duration of monitoring, with a longer duration of monitoring required to detect undiagnosed atrial fibrillation compared to known atrial fibrillation cases (Figure 2).

A total of 930 ischemic strokes occurred over 135,482 person-years of follow-up, with a median of 238 days (IQR 60 to 544 days) after ED visit (Table E2, available at http://www.annemergmed.com). Stroke incidence was significantly higher among patients with undiagnosed atrial fibrillation (2.6 per 100 person-years) compared to patients without atrial fibrillation on monitor (0.5 per 100 person-years), with a CHA_2DS_2-VASc-adjusted hazard ratio 3.00 (95% CI 2.39 to 3.76), and unadjusted hazard ratio of 4.75 (95% CI 3.80 to 5.94) (Figure 3). Compared to patients with known atrial fibrillation (2.4 strokes per 100 person-years), patients with undiagnosed atrial fibrillation had similar unadjusted stroke incidence (hazard ratio 1.08 [95% CI 0.84 to 1.38]) but higher CHA_2DS_2-VASc-adjusted risk (adjusted hazard ratio 1.32 [95% CI 1.02 to 1.71]).

Among 914 patients with undiagnosed atrial fibrillation and at least 24 months of follow-up data, only 174 (19.0%) received an atrial fibrillation diagnosis or anticoagulation prescription during follow-up, a median of 244 days (IQR 67 to 551 days) after their ED visit.

In secondary analyses, a 6-minute (rather than 30-second) detection threshold for atrial fibrillation reduced detection of undiagnosed atrial fibrillation from 3.0% to 1.0% of monitored patients (632). This subset had much higher median atrial fibrillation burden (25.2%, IQR 11.2% to 55.3%) than the group identified with a 30-second threshold (2.5%, IQR 0.7% to 14.9%), but only marginally higher stroke incidence (2.9 versus 2.6 strokes per 100 person-years, Table E3, available at http://www.annemergmed.com). Secondary analysis of patients with multiple monitored visits showed that atrial fibrillation burden increased significantly over successive ED presentations ($P < .001$; Figure E1, available at http://www.annemergmed.com).

LIMITATIONS

Our study has limitations. First, as a single-center study, our findings may not generalize to all ED populations. Detection rates will vary with the characteristics of the ED population, and with the criteria used to assign patients to continuous monitoring. Monitored patients are likely to have higher acuity and greater risk of arrhythmia compared to the general ED population.

Second, despite comprehensive record review including external clinical records, we may have underestimated prior atrial fibrillation diagnoses and anticoagulation. Indeed, even among patients with known atrial fibrillation, most had no record of anticoagulation, though this is consistent with prior results.[16] Likewise, CHA_2DS_2-VASc scores, incident strokes, and anticoagulation will have been underestimated for patients with relevant diagnoses and prescriptions not recorded in the electronic health record. We used only the CHA_2DS_2-VASc score to assess potential suitability for anticoagulation, and did not assess the proportion of patients with contraindications to anticoagulation. Because we exclude from "undiagnosed atrial fibrillation" cases patients with any prior prescription of anticoagulation, some patients with anticoagulation prescribed for reasons other than arrhythmia may have been excluded from the undiagnosed atrial fibrillation group. Our classification framework was designed to be maximally specific for new atrial fibrillation; that is, to err on the side of underestimating new cases.

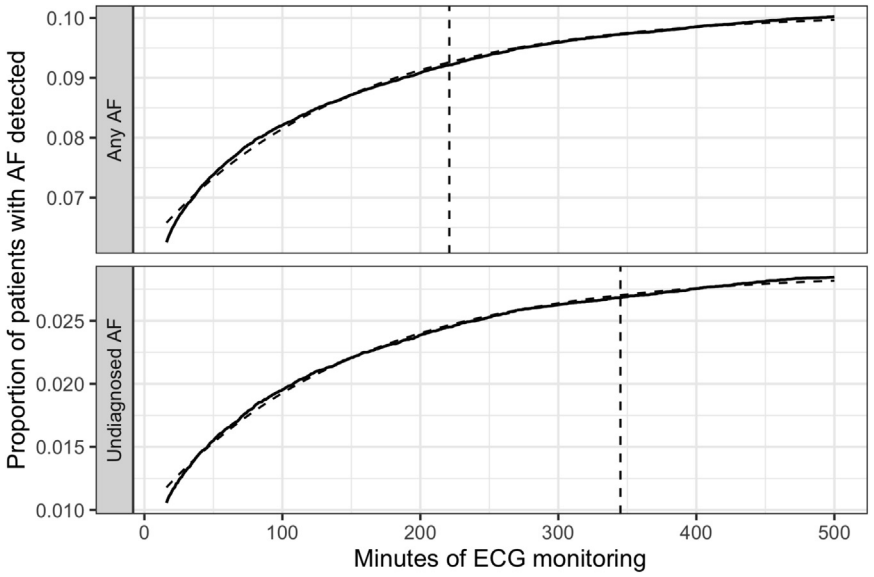

Figure 2. Proportion of visits with atrial fibrillation detected, by duration of monitoring. The proportion of total (top panel) and undiagnosed (bottom panel) atrial fibrillation cases on continuous monitoring increases as a saturating exponential function. Solid curves are the proportions of monitored visits with detected atrial fibrillation, by duration of continuous ECG monitoring. Dashed curves are the best-fitting negative exponential functions. Dashed vertical lines give the duration of monitoring needed to detect 90% of observed cases: 221 minutes for any atrial fibrillation, and 345 minutes for undiagnosed atrial fibrillation cases.

Third, algorithmic identification of atrial fibrillation from continuous ECG is imperfect. In our data set, comparing continuous ECG rhythm labels to simultaneous, cardiologist-reviewed 12-lead ECGs, we find very high specificity (99.2%) and negative predictive value (98.6%) for detection of atrial fibrillation from continuous ECG, but comparatively lower sensitivity (85.0%) and positive predictive value (90.7%). In a novel screening application, however, in which identification of putative undiagnosed atrial fibrillation may drive nontrivial management decisions, we believe that avoidance of false positives (ie, high specificity) is most important. Inclusion of nonspecific "irregular heart rate" or "supraventricular rhythm" labels would increase sensitivity to 96.7%, at the cost of lower specificity (84.8%).

Finally, current guidelines do not specify a minimum atrial fibrillation burden for anticoagulation.[6] We used 30 seconds as the minimum detection threshold to match consensus electrophysiologic definitions for detection of an atrial fibrillation episode.[13] In secondary analyses, we use a longer 6-minute duration threshold, which has been studied in continuously monitored populations as a predictor of ischemic stroke.[14] Although undiagnosed atrial fibrillation cases showed lower atrial fibrillation burdens than known cases, their high stroke risk and observed pattern of increasing burden over time suggest that any newly detected atrial fibrillation warrants further evaluation.

DISCUSSION

In this large retrospective study of ED patients, continuous ECG monitoring identified undiagnosed atrial fibrillation in 3% of patients. Most ED patients in whom we identified undiagnosed atrial fibrillation met criteria for anticoagulation, yet few received atrial fibrillation diagnosis or treatment. Their elevated incidence of subsequent ischemic stroke highlights missed opportunities for stroke prevention. Undiagnosed atrial fibrillation cases were disproportionately from underserved populations, suggesting that ED-based screening could reduce known disparities in atrial fibrillation diagnosis and stroke prevention.[5]

To our knowledge, this is the first study using continuous ECG monitoring in the ED for detection of atrial fibrillation. Continuous bedside monitoring has been studied for detection of atrial fibrillation in critical care populations (5% to 46% depending on population) and in stroke units, though neither population is comparable to the general monitored ED population.[11,17] Atrial fibrillation in critical illness is often transient and related to acute physiologic derangements (only 8.1% of the ED patients with undiagnosed atrial fibrillation required intensive care), and detection of atrial fibrillation after stroke is poorly comparable to an ED population of which only 14.7% had any history of stroke, transient ischemic attack, or thromboembolism.[17]

Compared to atrial fibrillation screening in primary care populations, predominantly with 10-second ECGs, we

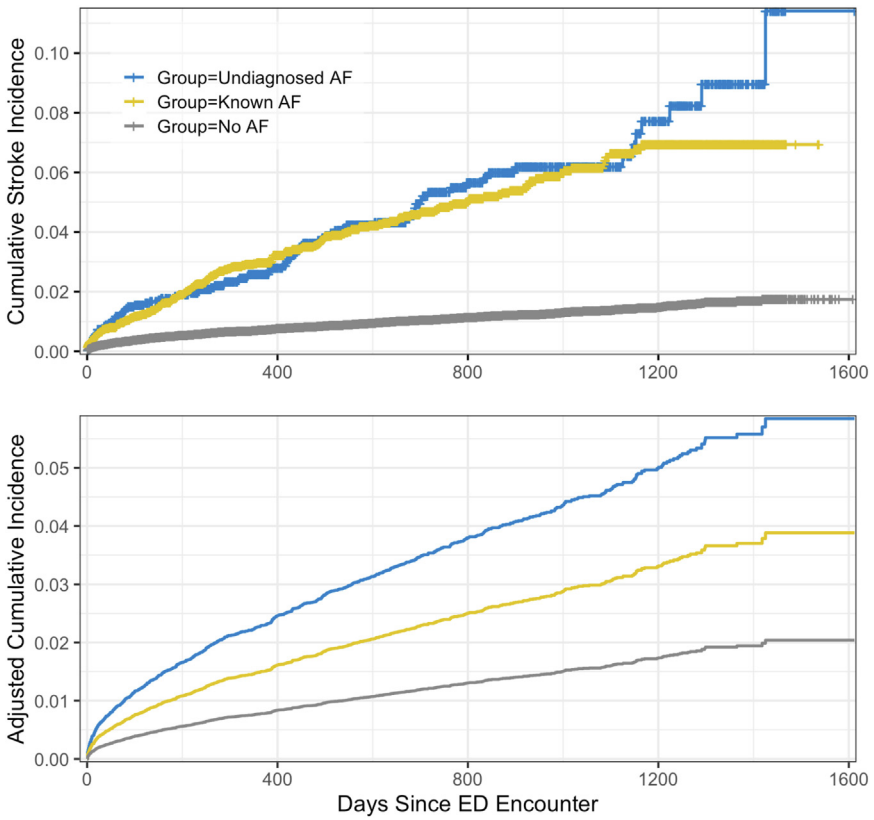

Figure 3. Incidence of ischemic stroke after ED visit. Top panel shows the cumulative incidence of ischemic stroke after ED visit, by atrial fibrillation status at the time of discharge. Bottom panel shows cumulative stroke incidence adjusted for CHA_2DS_2-VASc score, using a Cox proportional hazard model regressing censored time to stroke on atrial fibrillation status and CHA_2DS_2-VASc score. Adjusted incidence values (bottom panel) are lower than the actual incidence (top panel) because the adjusted model calculates incidence curves at the mean cohort-wide CHA_2DS_2-VASc score.

detect more than 3 times as many new cases (4.7% versus 1.4% for patients aged 65 and older, 1.9% versus 0.4% for patients under age 65).[7] Indeed, 78.8% of patients with undiagnosed atrial fibrillation in our study received a 12-lead ECG during their visit, showing rhythms other than atrial fibrillation.

Our results for detection of undiagnosed atrial fibrillation are closer to those reported with more prolonged continuous monitoring. One study of patients aged 65 years and older with hypertension and pacemakers but no known atrial fibrillation, using 14-day pacemaker-derived ECG recordings, found that 3% had undiagnosed atrial fibrillation, with 2.2 strokes per person-year.[18] This study used a 6-minute detection threshold over 14 days of monitoring, compared to our threshold of 30 seconds over a median monitoring period of 4.5 hours (we report results with a 6-minute threshold in Table E3).

These comparisons suggest that ED screening through routinely collected continuous ECG may have a yield for detection of high stroke risk atrial fibrillation far superior to spot-screening strategies, and comparable to more prolonged continuous monitoring. Indeed, the functional relationship between detection rate and monitoring duration (Figure 2) suggests that ED monitoring, in actual use, approaches the asymptote of detection. Continuous ECG monitoring can detect many paroxysmal atrial fibrillation cases missed by standard 12-lead ECGs: in this study, most patients with atrial fibrillation on continuous monitoring showed no evidence of atrial fibrillation on 12-lead ECGs obtained during the same visit. At the study hospital, atrial fibrillation alarms are not routinely used at the central monitoring station. Any patients in whom atrial fibrillation was detected from monitoring, leading to a confirmatory 12-lead ECG showing atrial fibrillation, a diagnosis of atrial fibrillation, or a prescription of anticoagulation, were excluded from the "undiagnosed atrial fibrillation" group and classified as "known atrial fibrillation."

The very high specificity (99.2%) of our atrial fibrillation detection method compared to simultaneous cardiologist-reviewed 12-lead ECGs suggests that ED screening may be more clinically useful than screening with

consumer wearable devices, which produce many false positive detections.[2,3,19] Moreover, ED patients will often already have received the laboratory tests recommended in new atrial fibrillation, and can be referred for echocardiogram as needed.[2] The high incidence of ischemic stroke in our cohort compared to other screening populations, coupled with low rates of subsequent diagnosis and anticoagulation, indicates a high risk population with large unmet needs.[20] ED screening enables immediate risk stratification and treatment initiation, irrespective of patient resources. With an estimated 25 patients needing anticoagulation to prevent one ischemic stroke, screening our cohort's 1,134 high-risk patients could have prevented approximately 45 strokes.[21]

The diagnostic potential of routine continuous ECG monitoring is unrealized. The optimal workflow for its use in opportunistic screening will depend on the system in which it is implemented, and individual providers will vary in their predilection to initiate management of an incidentally detected condition.[22] We propose that future studies prospectively evaluate whether an automated screening strategy could improve diagnostic equity and stroke prevention while leveraging existing ED infrastructure.

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Author contributions: DK conceived the study and supervised the research. DK, BTJ, EB, EM, AN, AP, and YW analyzed the data and reviewed patient records. EB, DK, and BTJ performed statistical analysis. EB, DK, CR, and CP drafted the manuscript, and all authors contributed substantially to its revision. DK takes responsibility for the manuscript as a whole.

Data sharing statement: Deidentified patient data including continuous ECG waveforms, data dictionary, and no analytic code are available as of March 2025 at https://physionet.org/content/mc-med/1.0.0/ (for offline use) and https://docs.ngsci.org/datasets/mcmed-stanford-multi/ (for online use) to researchers who register for PhysioNet or Nightingale Open Science platform and sign the relevant data use agreement.

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