

Journal of Heart and Cardiovascular Medicine

Review Article

Evaluation of ambulatory ECG monitoring as a Prognostic Tool in atrial fibrillation

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Received: 23 October 2025; Accepted: 20 January 2026; Published: 13 April 2026.

Citation of this article: Yamamoto K, Yoshida R, Nakamura H (2026) Evaluation of ambulatory ECG monitoring as a Prognostic Tool in atrial fibrillation. J Heart Cardiovasc Med, 9(1): 01-07. DOI: [10.5281/zenodo.22814698](https://doi.org/10.5281/zenodo.22814698)

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Abstract

Background: Atrial fibrillation is often paroxysmal and asymptomatic, so brief, symptom-triggered electrocardiography misses its true burden; ambulatory monitoring from Holter recordings to implantable loop recorders and wearables has revealed atrial fibrillation as a continuous, quantifiable burden rather than a binary diagnosis.

Objective: This review synthesizes evidence on ambulatory ECG monitoring as a prognostic tool in atrial fibrillation, covering detection performance across monitoring modalities, the relationship between device-measured burden and stroke or mortality risk, and trial evidence guiding anticoagulation in subclinical disease.

Methods: We synthesized randomized trials, prospective device-diagnostic registries, and guideline statements addressing monitoring modalities, arrhythmia burden, subclinical atrial fibrillation, and post-stroke and population screening applications.

Findings: Detection yield rises with monitoring duration and continuity across Holter, patch, and loop recorder comparisons; device-detected burden and episode duration predict stroke and mortality in graded fashion; and anticoagulation trials in subclinical atrial fibrillation show a net but narrower benefit than in clinical disease, with meaningful bleeding cost.

Conclusions: Ambulatory ECG monitoring is now a genuine prognostic instrument in atrial fibrillation, with burden functioning as a continuous risk variable guiding individualized anticoagulation decisions, though thresholds for the population identified through wearable screening remain incompletely validated.

Keywords: atrial fibrillation; ambulatory ECG monitoring; arrhythmia burden; subclinical atrial fibrillation; stroke prevention

1. Introduction

Atrial fibrillation is the most common sustained cardiac arrhythmia in clinical practice and a major independent driver of ischemic stroke, heart failure, cognitive decline, and death. For decades it was diagnosed almost exclusively by a symptomatic episode on a standard electrocardiogram or a single 24-hour Holter recording, an approach that performs poorly for the paroxysmal, often asymptomatic episodes that account for much of clinically important disease. Implantable loop recorders, insertable cardiac monitors, cardiac implantable electronic devices with atrial sensing, and consumer-grade wearables have transformed atrial fibrillation from a binary diagnosis into a quantifiable, continuously monitored burden. Two landmark trials made this transformation unavoidable: CRYSTAL-AF showed that an insertable cardiac monitor detected atrial fibrillation in 8.9% of cryptogenic stroke patients within six months, versus 1.4% with conventional follow-up [1], and the companion EMBRACE trial found that 30-day ambulatory event monitoring after cryptogenic stroke more than tripled detection versus a repeat 24-hour Holter [2].

Ambulatory ECG monitoring spans a spectrum from 24-48-hour Holter recordings, through 7-14-day adhesive patches and mobile telemetry, to implantable loop recorders capable of years of surveillance, and now smartphone-paired wearables deployed at population scale. Each modality trades sensitivity against invasiveness, cost, and burden, and each has generated evidence linking detected arrhythmia burden to cardiovascular risk. This review synthesizes that evidence: how monitoring-derived burden and duration stratify stroke and mortality risk, how that evidence has reshaped anticoagulation decisions for subclinical disease, and where the field is heading.

2. Detection modalities across the monitoring spectrum

Holter monitoring is the most available and least

expensive modality, but its yield for paroxysmal atrial fibrillation is limited by short duration. A direct comparison of 24-hour Holter against a 14-day adhesive patch found the patch detected arrhythmia events, including atrial fibrillation, at more than triple the Holter rate, with better patient adherence [3], illustrating that yield scales with duration of wear more than with recording sophistication.

Table 1: Ambulatory ECG monitoring modalities and their reported atrial fibrillation detection characteristics [3,4,10,37].			
Modality	Typical duration	Key evidence	Detection characteristic
24-48 h Holter	1-2 days	Reference comparator	Lowest yield for paroxysmal disease
Adhesive patch monitor	7-14 days	[3,4]	More than triple Holter detection rate
Self-applied ECG patch (mSToPS)	Up to 4 months	[10]	More than doubled 4-month diagnosis rate vs usual care
Insertable cardiac monitor	Up to 3 years	[37]	High cumulative detection in high-risk screening population

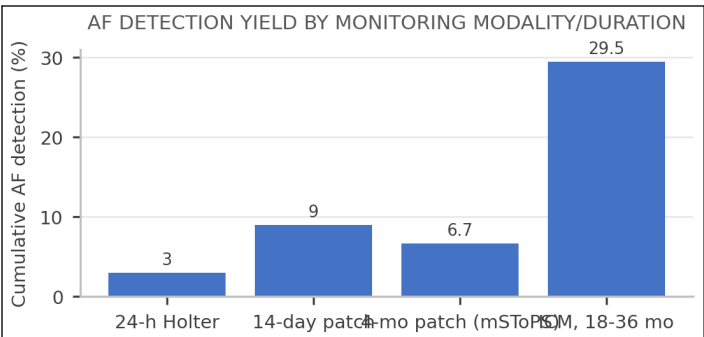


Figure 1: Atrial fibrillation detection yield by ambulatory monitoring modality and duration, comparing 24-hour Holter, 14-day adhesive patch, and long-term insertable cardiac monitor follow-up, showing detection continuing to accrue well beyond conventional short-duration monitoring windows [3,6,7].

Leadless adhesive patch monitors extended wear time while improving tolerance. A validation study of a leadless monitor found high sensitivity and specificity for atrial fibrillation across 14 days, with substantially better completion rates than historical Holter cohorts [4]. Mobile telemetry and event-triggered systems added real-time transmission, allowing episodes to be adjudicated during monitoring rather than only in retrospective review,

relevant when guiding urgent anticoagulation after cryptogenic stroke [5].

Implantable loop recorders provide continuous, unattended surveillance for up to three years. Long-term CRYSTAL-AF follow-up showed detection continuing to accrue throughout three years, with many episodes identified only after the first six months, indicating shorter windows underestimate true prevalence [6]. Diederichsen and colleagues extended this to a broader at-risk population, finding loop-recorder surveillance detected atrial fibrillation at several-fold the rate of intermittent monitoring [7].

Cardiac implantable electronic devices with atrial sensing provide near-continuous surveillance in patients who already carry them. Glotzer and colleagues showed in the MOST substudy that pacemaker-detected atrial high-rate episodes independently predicted death and stroke [8], and the TRENDS registry related daily device-recorded burden directly to thromboembolic risk in a dose-dependent fashion [9].

3. Wearable and consumer-grade monitoring technologies

Ambulatory monitoring has moved from clinical devices into consumer electronics, expanding the screened population. The mSToPS trial found that a self-applied ECG patch more than doubled new atrial fibrillation diagnosis at four months versus usual care, with monitored patients more likely to initiate anticoagulation [10]. The Apple Heart Study applied smartwatch photoplethysmography across more than 400,000 participants and confirmed atrial fibrillation in a substantial proportion of those with an irregular-pulse notification who completed patch confirmation, though yield varied with age [11].

The Fitbit Heart Study replicated this at large scale, again finding meaningful positive predictive value for confirmed atrial fibrillation, underscoring that confirmatory

monitoring rather than the wearable signal alone establishes the diagnosis [12]. These platforms differ from clinical-grade ambulatory ECG in signal source and opportunistic rather than prescribed wear, and their scale raises questions about managing low-burden, incidentally detected disease.

4. Arrhythmia burden as a continuous prognostic variable

Continuous monitoring has reframed atrial fibrillation from a binary diagnosis into a continuous burden with graded prognostic implications. Chen and colleagues argued in an American Heart Association statement that burden, the cumulative time in arrhythmia, carries prognostic information a diagnostic label does not [13]. Charitos and colleagues showed that clinical classifications as paroxysmal, persistent, or permanent correlate poorly with device-measured persistence [14].

This burden-outcome relationship recurs across cohorts. Go and colleagues found higher measured burden associated with graded increases in stroke risk after adjustment for clinical risk factors [15]. Piccini and colleagues, using a case-crossover design, found both the presence and recent escalation of burden independently predicted death [16]. Boriani and colleagues, pooling more than 10,000 SOS AF patients, confirmed device-detected atrial fibrillation, even when silent, carried elevated stroke risk [17].

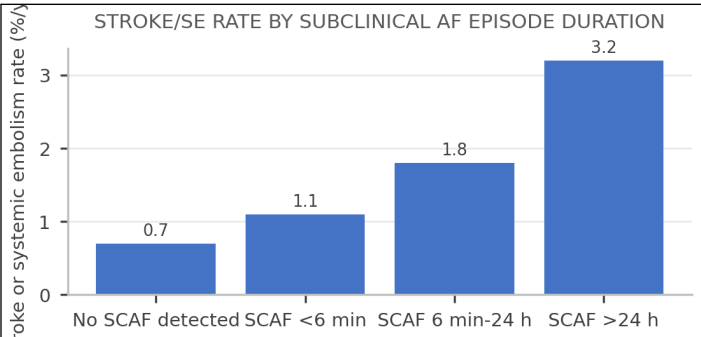


Figure 2: Ischemic stroke or systemic embolism rate by device-detected subclinical atrial fibrillation episode duration, rising from a low baseline with brief atrial high-rate episodes to a markedly higher rate with episodes exceeding 24 hours, illustrating burden as a graded rather than binary risk factor [18,21,19].

Duration thresholds matter directly. Van Gelder and colleagues, in ASSERT, found episode duration graded stroke risk, with episodes exceeding roughly 24 hours carrying meaningfully higher risk than shorter ones, though brief episodes were not risk-free [18]. Swiryn and colleagues found even brief device-detected episodes, short of common trial thresholds, carried measurably elevated stroke rates, suggesting no single cutoff cleanly separates risk [19]. Ziegler and colleagues found patients with higher cumulative burden had significantly worse long-term outcomes than those with lower or absent burden [20].

5. Subclinical atrial fibrillation, stroke risk, and anticoagulation trials

Healey and colleagues established the prognostic significance of subclinical atrial fibrillation in ASSERT: device-detected episodes over six minutes carried significantly increased stroke or embolism risk, comparable to though somewhat lower than clinical atrial fibrillation, an association that held after adjustment for CHA2DS2-VASc risk factors [21] [22]. This motivated two randomized anticoagulation trials.

ARTESiA randomized subclinical atrial fibrillation lasting six minutes to 24 hours to apixaban or aspirin, building on ASSERT and TRENDS burden-outcome data [23], and found apixaban significantly reduced stroke or systemic embolism versus aspirin at the cost of more major

bleeding [24]. The parallel NOAH-AFNET 6 trial randomized patients with atrial high-rate episodes to edoxaban or placebo and found a nonsignificant stroke reduction offset by significantly more major or clinically relevant bleeding, suggesting net benefit in subclinical disease is real but narrower than in clinical atrial fibrillation and depends on burden and bleeding risk [25].

Table 2: Randomized trials of oral anticoagulation in device-detected subclinical atrial fibrillation [23,24,25].

Trial	Population	Comparison	Principal finding
ARTESiA [24]	Device-detected SCAF, 6 min-24 h	Apixaban vs aspirin	Reduced stroke/systemic embolism; higher major bleeding
NOAH-AFNET 6 [25]	Atrial high-rate episodes	Edoxaban vs placebo	Nonsignificant stroke reduction; increased major/CRNM bleeding
ARTESiA design [23]	Device-detected SCAF	Trial rationale	Built directly on ASSERT and TRENDS burden-risk data

The 2016 and 2020 European Society of Cardiology guidelines addressed subclinical atrial fibrillation explicitly, recommending individualized risk assessment incorporating episode duration and clinical risk scores rather than a uniform threshold [26] [27]. Israel and colleagues showed that atrial fibrillation recurrence after apparently successful rhythm control was common and often asymptomatic, reinforcing that monitoring findings, not symptoms, should guide ongoing anticoagulation decisions [28].

6. Post-stroke monitoring and cryptogenic stroke

Cryptogenic stroke is a principal setting for ambulatory monitoring, since detecting unrecognized atrial fibrillation changes secondary prevention from antiplatelet to anticoagulant therapy. Beyond CRYSTAL-AF and EMBRACE [1] [2], the Find-AF-RANDOMISED trial showed enhanced, prolonged Holter monitoring after acute ischemic stroke detected significantly more atrial fibrillation than

standard care, extending the rationale beyond narrowly cryptogenic stroke [29]. A meta-analysis by Kishore and colleagues found detection yield after stroke or transient ischemic attack rose consistently with monitoring duration and intensity [30].

The cognitive consequences of undetected atrial fibrillation add further weight to monitoring in this population: Diener and colleagues summarized evidence that atrial fibrillation is independently associated with accelerated cognitive decline and dementia, mediated by both overt strokes and covert cerebral infarcts, extending the stakes of missed diagnosis beyond a single index event [31].

7. Population screening and monitoring-based detection programs

Ambulatory monitoring has also been deployed for population screening, since much prevalent atrial fibrillation remains undiagnosed. The AF-SCREEN collaboration concluded that opportunistic and systematic screening in patients over 65, using single-lead ECG or photoplethysmography with confirmatory ECG, likely offers a favorable yield-to-cost balance [32]. STROKESTOP, a large population screening trial using handheld single-lead ECG, found meaningful yield of previously undiagnosed disease and, on extended follow-up, reduced stroke, embolism, and death among those invited to screening [33].

Results are not uniformly positive: VITAL-AF, a primary-care cluster-randomized trial, found only a modest, not universally significant increase in new diagnosis versus usual care, showing yield depends on population risk and downstream pathways [34]. Fitzmaurice and colleagues similarly found systematic screening detected more disease than opportunistic screening, but the increment was modest [35]. A cost-effectiveness analysis by Welton and colleagues concluded systematic single-lead ECG screening was likely cost-effective in patients 65 and older, though

sensitive to downstream anticoagulation uptake [36]. REVEAL AF, using an insertable monitor in a high-risk screening population, found a strikingly high 18-month detection rate exceeding intermittent modalities, reinforcing that continuous monitoring detects more true disease than any intermittent strategy [37].

8. Discussion

This literature supports several converging conclusions. First, detection yield rises consistently with monitoring duration and continuity across Holter, patch, and loop-recorder comparisons [3] [4] [6] [7]. Second, atrial fibrillation burden behaves as a continuous rather than binary prognostic variable, with cumulative time, episode duration, and trajectory each carrying graded associations with stroke and mortality across markedly different cohorts [8] [9] [15] [16] [17] [18] [20] [13]. Third, the randomized anticoagulation trials in subclinical atrial fibrillation, ARTESiA and NOAH-AFNET 6, have converted this observational relationship into actionable, though incompletely resolved, treatment guidance: anticoagulation reduces stroke risk but at a real bleeding cost, and neither trial defines a clean burden threshold for withholding treatment [24] [25].

Consumer wearables have amplified detection capacity but outpaced the evidence base for managing the low-burden disease they now frequently uncover [10] [11] [12]. Much burden-outcome evidence was generated in device-detected populations with different comorbidity profiles than the younger individuals receiving smartwatch notifications, and extrapolating implantable-device thresholds to this population is not yet well validated; guideline bodies have responded by recommending individualized rather than uniform thresholds [26] [27].

Open questions remain: optimal monitoring duration and modality by indication is unstandardized and cost-effectiveness varies by population risk [36] [30]; burden thresholds from implantable cohorts may not

generalize to wearable-detected disease; and the cognitive and quality-of-life consequences of a subclinical diagnosis deserve further study given the established atrial fibrillation-cognition link [31].

9. Conclusion

Ambulatory ECG monitoring has evolved from a diagnostic tool into an established prognostic instrument in atrial fibrillation, with a consistent evidence base showing that both presence and quantitative burden of device-detected arrhythmia predict stroke, mortality, and other adverse outcomes. Randomized anticoagulation trials have converted decades of observational burden-risk data into evidence-based guidance, even as gaps remain around burden thresholds, optimal monitoring strategy, and management of the population identified through wearable screening. As monitoring technology extends its duration and population reach, the central task is translating an increasingly granular, continuous measure of burden into individualized, risk-proportionate management rather than treating every detected episode as equivalent.

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