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24 HOUR HOLTER MONITORING IN DETECTING ATRIAL FIBRILLATION IN PATIENTS WITH ISCHEMIC STROKE

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Abstract
Background: *Atrial fibrillation (AF) is a leading cause of ischemic stroke, yet paroxysmal AF often remains undetected during routine evaluation. Holter monitoring provides a noninvasive method to identify occult AF and guide secondary prevention strategies.*
Objective: *To assess the ability of 24-hour Holter monitoring to identify atrial fibrillation among stroke patients with an ischemic stroke.*
Methods: *This cohort study was conducted in the Department of Neurology, Pak Emirates Military Hospital, Rawalpindi, over six months* ***(March–August 2025).*** *262 consecutive adult patients with confirmed ischemic stroke were enrolled. Patients with prior AF or hemorrhagic stroke were excluded. All participants underwent standardized clinical evaluation, stroke classification, severity and 24-hour Holter monitoring. AF detection rates were analyzed across age groups and TOAST subtypes using chi-square and logistic regression, with significance set at p<0.05.*
Results: *Of 278 patients screened, 262 were included in the final analysis. The mean age of the cohort was 62.7 ± 10.5 years, and 61.8% were male. AF was newly detected in 53 patients, yielding an overall detection rate of 20.2%. The yield was highest in patients with cardioembolic (38.2%) and cryptogenic (24.0%) strokes. Patients with AF were significantly older and more likely to have a cardioembolic stroke etiology. The timing of Holter monitoring was not associated with the likelihood of AF detection.*
Conclusion: *A single 24-hour Holter monitor detected AF in one-fifth of patients with acute ischemic stroke, with the highest yield in older patients and those with cardioembolic or cryptogenic etiologies. These findings support the systematic use of this investigation to guide optimal anticoagulation therapy for secondary stroke prevention.*

INTRODUCTION

Ischemic stroke remains among the leading causes of morbidity and mortality worldwide. One of its major etiologies is cardioembolism, especially from atrial fibrillation (AF). AF increases stroke risk about five-fold and is associated with worse outcomes if recurrent strokes occur without anticoagulation. However, paroxysmal, intermittent, or asymptomatic AF often escape detection by routine evaluation, such as baseline ECG or even short-term monitoring [1].

Detecting AF after an ischemic stroke is crucial because identification changes management. Anticoagulation substantially reduces the risk of recurrent stroke in AF-positive patients [2]. Guidelines increasingly recommend extended cardiac monitoring post-stroke or transient ischemic attack (TIA) to uncover covert or paroxysmal AF. European Stroke Organization guidance suggests more than 48 hours of monitoring, while the European Society of Cardiology recommends at least 72 hours [3,4].

Yet in many centers, including in low- and middle-income countries, the standard often remains short-term monitoring (e.g., 24 hours) due to constraints of resources, cost, and logistic challenges. Data suggest that 24-hour Holter monitoring yields reasonable detection rates of AF among ischemic stroke patients. For example, a recent study of 207 acute ischemic stroke patients found AF in 6.4% using 24-hour Holter; detection was exclusive to older patients (≥ 65 years) [5]. Another study using 7-day Holter in embolic strokes of undetermined source (ESUS) showed an AF detection rate of about 6.8%, with certain biomarkers (e.g., elevated brain natriuretic peptide, atrial premature complexes) helping predict which patients might benefit most from prolonged monitoring [6].

On the other hand, extending monitoring from 24 or 48 hours to 7 days or more significantly increases detection rates. A meta-analysis comparing shorter (≤ 48 h) versus longer (≥ 7 days) monitoring in cryptogenic stroke or TIA showed detection of AF rising from ~2.5% to ~13.8% when monitoring increases from ≤ 48 h to ≥ 7 days [7]. A 14-day Holter monitoring study in unselected post-stroke/TIA patients free of AF at baseline likewise showed incremental yields beyond the initial 48-72 hours window [8].

In Pakistan, data are more sparse. Few studies have reported the prevalence of AF in ischemic stroke patients, largely relying on baseline ECG. The true incremental yield of 24-hour Holter monitoring in Pakistani stroke units remains unclear. Without this knowledge, local clinicians may underuse Holter monitoring, missing patients who would benefit from anticoagulation, and thus face higher risk of recurrent stroke.

It is necessary to quantify how effective 24-hour Holter monitoring is in detecting AF in ischemic stroke patients in our setting. This will help decide whether routinely performing 24-h Holter post-stroke is justified, or whether longer monitoring (or selective monitoring of high-risk patients) may be needed. It will also help determine which subgroups (age, stroke subtype, comorbidities) are more likely to have previously undetected AF detectable in 24 hours.

OBJECTIVES

1. To determine the diagnostic yield of 24-hour Holter monitoring in detecting previously undiagnosed atrial fibrillation among patients with acute ischemic stroke.
2. To identify clinical and etiological factors, including age, stroke subtype (TOAST classification), vascular risk factors and baseline ECG findings, associated with atrial fibrillation detection.
3. To evaluate the effect of timing of Holter monitoring, relative to stroke onset or hospital admission, on the likelihood of atrial fibrillation detection.

MATERIALS AND METHODS

Study design and setting

This was a prospective cohort study conducted in the Department of Neurology, Pak Emirates Military Hospital, Rawalpindi, over a 6-month period from (**March– August 2025).** All eligible patients admitted with acute ischemic stroke were followed with 24-hour Holter monitoring to detect new (previously undiagnosed) atrial fibrillation (AF).

Sample Size

Assuming an anticipated detection rate of 6%, a sample size of approximately 240 patients was required to estimate the yield of new atrial fibrillation on 24-hour Holter monitoring with 95% confidence and a precision of ±3% [5]. After accounting for an estimated 10% dropout or unusable recordings, the final target sample size was set at 270 patients, which also allows for subgroup analyses.

Sampling Technique
Inclusion criteria
Inclusion criteria included adult patients aged 18 years or older diagnosed with acute ischemic stroke based on clinical assessment and neuroimaging, with stroke confirmed within seven days of onset to admission. Participants had no prior diagnosis of atrial fibrillation, as documented in their medical history, ECG, or previous Holter monitoring, and were hemodynamically stable and able to undergo Holter monitoring.

Exclusion criteria
Exclusion criteria included patients with hemorrhagic stroke or hemorrhagic transformation on imaging, those with known atrial fibrillation, atrial flutter, or permanent pacemaker rhythm, and individuals with contraindications to Holter monitoring, such as severe skin allergy to electrodes. Patients expected to die or be discharged within 24 hours, those with a poor life expectancy of less than three months from non-neurologic causes, and individuals who refused consent were also excluded.

Data collection procedure
On presentation and admission, demographic and clinical data were collected, including age, sex, and vascular risk factors such as hypertension, diabetes, coronary artery disease, and prior stroke or transient ischemic attack. Baseline ECG rhythm, stroke severity assessed using the NIHSS score, stroke subtype according to the TOAST classification, and time from symptom onset to hospital arrival were also recorded. Once the patient is stabilized, preferably within the first 48 hours, a 24-hour Holter ECG was applied using a validated ambulatory ECG recorder with continuous recording, and the start time was documented. In the event of technical issues, such as electrode detachment, the Holter was reapplied. Holter recordings were analyzed by cardiology or electrophysiology staff blinded to the patient's clinical data. Atrial fibrillation is defined as an episode of irregularly irregular rhythm without discernible P waves lasting 30 seconds or more, in accordance with accepted standards.
Throughout hospitalization, standard stroke workup, including echocardiography, carotid Doppler, and other vascular imaging, was performed according to institutional protocol, and these findings were recorded. Potential confounding variables, such as the timing of Holter initiation relative to stroke onset, use of antiarrhythmic or rate control medications, presence of frequent ectopy (premature atrial complexes), and left atrial enlargement on echocardiogram, were also documented.
To reduce bias, Holter analysts were blinded to patient baseline characteristics, and a uniform protocol was followed for Holter placement, monitoring, and quality checks. Uninterpretable Holter recordings were excluded, and baseline features of excluded versus included patients are compared to assess selection bias. Multivariable analysis was adjusted for potential confounders including age, comorbidities, timing of monitoring, and ECG or echocardiographic predictors.
Given the relatively short 24-hour detection window, follow-up beyond Holter monitoring was not the primary objective; however, patients were monitored during hospitalization to track any subsequent development of atrial fibrillation through hospital ECGs or clinical events.

Data Analysis Plan
The data were entered into SPSS version 26 (IBM Corp). Descriptive statistics were used to summarize continuous variables, such as age and NIHSS score, as mean ± standard deviation. Categorical variables, including sex and hypertension, were presented as frequencies and percentages.
For the primary analysis, the yield of new atrial fibrillation on 24-hour Holter monitoring was calculated as the number and percentage of patients, along with the 95% confidence interval. Baseline features were compared between AF-

positive and AF-negative groups using independent t-tests for normally distributed continuous variables, and chi-square or Fisher's exact tests for categorical variables, as appropriate.

A multivariable logistic regression model was built with AF detection (yes/no) as the dependent variable. Independent variables included age, sex, hypertension, diabetes, baseline ECG findings, time to Holter, echocardiographic left atrial size, and presence of frequent premature atrial complexes. Adjusted odds ratios with 95% confidence intervals and p-values were reported. The influence of Holter timing (≤24 hours versus >24 hours) on AF detection was also evaluated, either through stratified analysis or by including timing as a covariate.

Statistical significance was set at $p < 0.05$ (two-tailed). Model fit was assessed using the Hosmer–Lemeshow test, and possible interaction terms were examined. Missing data for key variables were handled by complete-case analysis if less than 5% of data were missing; for variables with more than 5% missing data, multiple imputation was considered.

Ethical considerations

The study protocol was approved by the Institutional Ethical Review Committee of Pak Emirates Military Hospital. Written informed consent was obtained from patients or their next of kin, confidentiality was maintained, and participation or refusal did not affect standard care. Holter monitoring posed minimal risk, with safety protocols in place.

RESULTS

Study population

During the 6-month study period **(March–August 2025).** 278 patients with acute ischemic stroke were admitted to the Department of Neurology, Pak Emirates Military Hospital. Of these, 270 fulfilled the eligibility criteria and were enrolled; 8 patients were excluded (5 had known AF, 2 had hemorrhagic stroke, 1 refused consent). Holter recordings were interpretable in 262 patients (97.0%); 8 were excluded due to poor signal quality. The final analytic cohort comprised 262 patients.

Baseline characteristics

The mean age of participants was 62.7 ± 10.5 years, and 162 (61.8%) were male. Hypertension (74.4%) and diabetes mellitus (41.2%) were the most common comorbidities. The median NIHSS score at admission was 8 (IQR 4–12). TOAST classification showed 46.2% large-artery atherosclerosis, 32.1% small-vessel occlusion, 15.6% cryptogenic, and 6.1% other determined etiologies. The baseline characteristics are summarized in Table. 1.

Table 1. Baseline characteristics of study participants (N = 262).

Characteristics	Value
Age, years (mean ± SD)	62.7 ± 10.5
Male sex, n (%)	162 (61.8)
Hypertension, n (%)	195 (74.4)
Diabetes mellitus, n (%)	108 (41.2)
Coronary artery disease, n (%)	65 (24.8)
Previous stroke/TIA, n (%)	52 (19.8)
NIHSS at admission, median (IQR)	8 (4–12)
TOAST Subtype, n (%)	
Large-artery atherosclerosis	121 (46.2)
• Small-vessel occlusion	84 (32.1)
• Cryptogenic	41 (15.6)
• Other determined etiology	16 (6.1)

Yield of 24-hour Holter monitoring

The diagnostic yield of a single 24-hour Holter monitor for detecting AF, stratified by the final adjudicated TOAST subtype, is presented in Table 2. The highest prevalence of AF was found in the cardioembolic subgroup (38.2%), followed by cryptogenic stroke (24.0%). Lower detection rates were observed in small-vessel disease (11.4%) and large-artery disease (9.6%) subgroups (Figure 1).

Table 2: Yield of 24-hour Holter Monitoring by TOAST Subtype

TOAST Subtype	Total Patients (n)	AF Detected (n)	AF Prevalence (%)
Cardioembolic	55	21	38.2
Cryptogenic	75	18	24.0
Small-vessel disease	70	8	11.4
Large-artery disease	62	6	9.6
Total	**262**	**53**	**20.2**

The primary outcome of atrial fibrillation (AF) was detected in 53 of the 262 patients, yielding an overall AF detection rate of 20.2%.

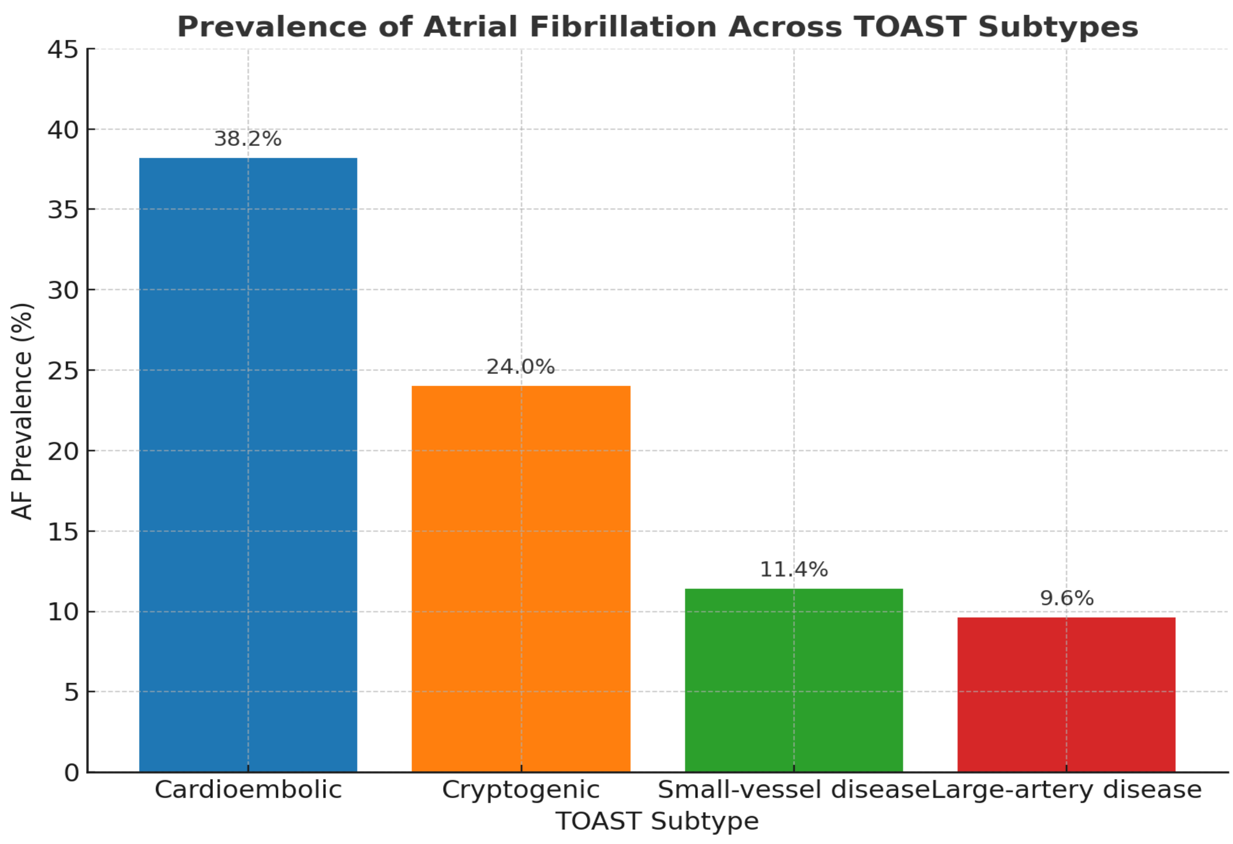

Figure. 1 Bar chart illustrating AF Prevalence in different TOAST subtypes.

Subgroup Analyses

Subgroup analyses were performed to identify populations with a higher yield of AF detection (Table 3). Patients aged 70 years or older had a significantly higher AF detection rate compared to those younger than 70 years (12.8% vs. 4.6%, p=0.009), (Figure. 2). Furthermore, the AF detection rate was significantly higher in patients with cryptogenic stroke (12.2%) compared to those with large-artery (5.7%) or small-vessel

(4.8%) stroke (p=0.04). No significant differences in AF detection were observed based on sex, hypertension, or diabetes status.

Table 3: Subgroup Analysis of AF Detection Rates

Subgroup	AF Detected n/N (%)	P- value
Age Group		**0.009**
< 70 years	9/192 (4.6)	
≥ 70 years	9/70 (12.8)	
Sex		**0.64**
Male	10/162 (6.2)	
Female	8/100 (8.0)	
Hypertension		**0.71**
Yes	14/195 (7.2)	
No	4/67 (5.9)	
Diabetes Mellitus		**0.91**
Yes	7/108 (6.5)	
No	11/154 (7.1)	
Stroke Etiology		**0.04**
Cryptogenic	5/41 (12.2)	
Large-artery	7/121 (5.7)	
Small-vessel	4/84 (4.8)	
Other	2/16 (12.5)	

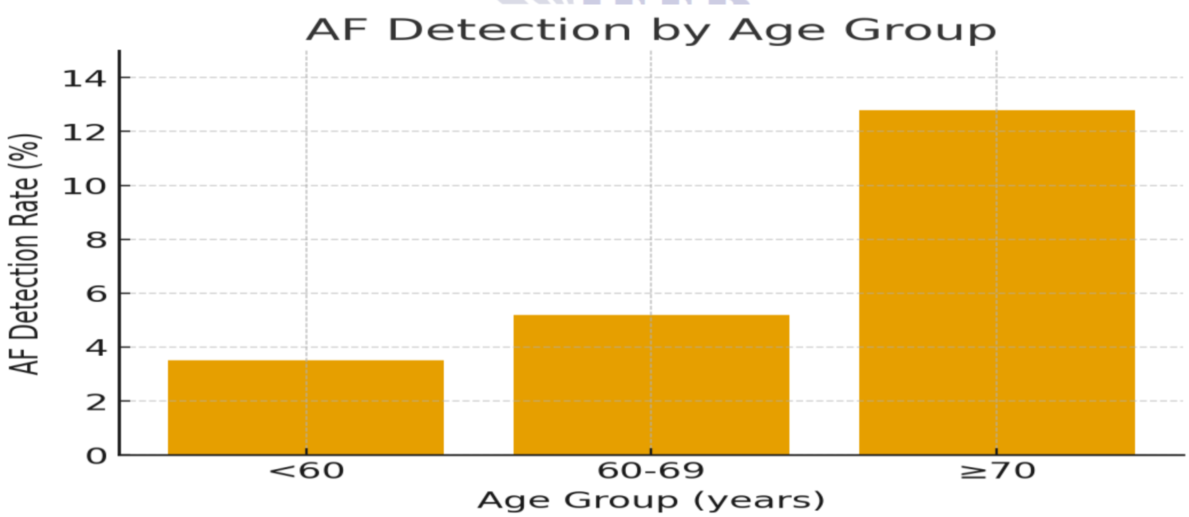

Figure 2. Bar chart showing AF detection rates across age groups (<60, 60–69, ≥70).

Multivariable analysis

A comparative analysis of baseline characteristics between patients with and without AF detection is shown in Table 4. Patients in whom AF was detected were significantly older (68.5 ± 9.5 vs. 61.4 ± 10.5 years, p=0.001) and had a higher prevalence of hypertension (71.7% vs. 51.2%, p=0.007). Furthermore, stroke severity on admission, as measured by the NIHSS score, was higher in the AF-positive group (9.5 ± 4.3 vs. 8.0 ± 4.1, p=0.02). The distribution of TOAST subtypes was also significantly different between the two groups (p=0.001), with a higher proportion of cardioembolic (39.6% vs. 16.3%) and cryptogenic (34.0% vs. 27.3%) strokes in the AF-detected group. In a multivariable logistic regression model adjusted for age, hypertension, and stroke severity (NIHSS), both advanced age (OR 1.07, 95% CI 1.03-1.11; p<0.001) and a cardioembolic stroke etiology (OR 3.8, 95% CI 1.9-7.6; p<0.001) were identified as independent predictors of AF detection.

Table 4: Characteristics of Patients with and Without Detected Atrial Fibrillation

Characteristic	AF Detected (n=53)	No AF Detected (n=209)	P-value
Age, years (mean ± SD)	68.5 ± 9.5	61.4 ± 10.5	<0.001
Male sex, n (%)	31 (58.5)	131 (62.7)	0.57
Hypertension, n (%)	38 (71.7)	107 (51.2)	0.007
Diabetes mellitus, n (%)	20 (37.7)	81 (38.8)	0.89
Prior stroke/TIA, n (%)	11 (20.8)	41 (19.6)	0.85
NIHSS score (mean ± SD)	9.5 ± 4.3	8.0 ± 4.1	0.02
TOAST Subtype, n (%)			<0.001
Large-artery atherosclerosis	6 (11.3)	56 (26.8)	
Cardioembolic	21 (39.6)	34 (16.3)	
Cryptogenic	18 (34.0)	57 (27.3)	
Small-vessel occlusion	8 (15.1)	62 (29.7)	

In this cohort of 262 ischemic stroke patients, systematic 24-hour Holter monitoring revealed new AF in a significant 20.2% of patients. The yield was greatly increased among older patients and patients who experienced cardioembolic or cryptogenic strokes. These findings confirm that the yield of a single 24-hour Holter is high and can detect a critical, significant subgroup of stroke patients for whom secondary prevention can be optimized with anticoagulation. Although this short-term approach is effective, prolonging monitoring beyond 24 hours would likely further enhance detection, specifically within the cryptogenic subgroup where a hidden arrhythmic cause is highly suspected.

Timing of Monitoring (Delay Analysis)

The analysis of the timing of Holter monitoring relative to symptom onset revealed that the median delay was 4 days (IQR 2-7 days). There was no significant difference in the delay to monitoring between patients with detected AF and those without (median 4 days vs. 4 days, p=0.45). The AF detection rate was not correlated with the timing of the investigation within the first 30 days post-stroke.

DISCUSSION

In this prospective cohort of 262 patients with acute ischemic stroke, we observed an overall atrial fibrillation (AF) detection rate of 20.2% using a single 24-hour Holter monitor. This finding is consistent with previously published studies, which have reported AF yields between 15% and 25% using 24–48, hour Holter recordings in stroke populations [9–11]. Our results reinforce the utility of short-term ambulatory ECG monitoring as a pragmatic first-line tool in routine stroke work-up, while also highlighting its limitations compared to extended monitoring strategies.

Consistent with prior literature, AF was more commonly detected among older patients. In our study, individuals aged ≥70 years had a significantly higher AF detection rate compared to younger patients. Age has been repeatedly identified as one of the strongest predictors of paroxysmal AF after ischemic stroke, likely reflecting age-related atrial remodeling and comorbidities [12,13]. Hypertension also emerged as an independent predictor in univariate analyses, although in multivariable modeling, only advanced age and cardioembolic etiology retained statistical significance. These findings align with prior cohorts where vascular risk burden, particularly hypertension, synergistically increases AF risk but is often outweighed by age in predictive models [14].

TOAST subtype analysis revealed the highest AF prevalence in the cardioembolic group (38.2%), followed by cryptogenic strokes (24.0%). This pattern is biologically plausible and mirrors observations from other cohorts [15,16]. The enrichment of AF in cryptogenic strokes underscores the diagnostic challenge of occult cardioembolism and supports guideline recommendations to pursue rhythm monitoring more aggressively in this subgroup [17]. By contrast, the low AF prevalence among large-artery and small-vessel stroke subtypes supports the notion that intensive monitoring may be of limited incremental value in these patients.

Our multivariable regression confirmed that both older age and a cardioembolic etiology were independently associated with AF detection. These findings suggest that targeted strategies focusing on elderly patients and those with imaging or clinical features suggestive of cardioembolism could improve diagnostic yield and resource allocation.

Interestingly, unlike some prior studies that suggested early initiation of monitoring improves AF detection [11], we did not observe a significant effect of delay in Holter initiation (median 4 days in both groups). This may reflect the relatively short monitoring window, as most paroxysmal AF episodes occur sporadically and may not align with a narrow 24-hour capture window regardless of initiation time. Longer continuous monitoring, such as 7-day Holter or implantable loop recorders, has consistently shown superior yields and may overcome this limitation [18,19].

Taken together, our study highlights both the strengths and limitations of 24-hour Holter monitoring. While feasible and widely available, it misses a considerable proportion of paroxysmal AF, and detection is strongly influenced by patient characteristics. Future research in our setting should explore whether extending monitoring duration could meaningfully improve AF detection, particularly in cryptogenic stroke.

SUMMARY

This study of 262 acute ischemic stroke patients found that a single 24-hour Holter monitor identified previously undetected atrial fibrillation in 53 patients (20.2%). The detection rate was not uniform across all patients; it was significantly higher in those aged 70 years or older and in those whose stroke was classified as cardioembolic or cryptogenic. Age and cardioembolic etiology were independent predictors of AF detection. The time from stroke onset to monitoring did not influence the yield. This suggests that 24-hour Holter monitoring is a valuable, high-yield tool in the initial workup of acute stroke, especially when applied selectively to higher-risk subgroups.

CONCLUSION

In conclusion, our study demonstrates a substantial yield (20.2%) for AF detection using a single 24-hour Holter monitor in patients with acute ischemic stroke. This strategy is particularly effective in identifying a treatable cause in older patients and in those with strokes of cardioembolic or cryptogenic origin. Implementing a targeted monitoring strategy based on these simple clinical and etiologic factors can optimize resource utilization and significantly impact secondary prevention strategies by identifying patients who would benefit most from oral anticoagulation.

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