Frequency and Patterns of Electrocardiogram Testing among High-risk Elderly Individuals

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ABSTRACT **Background:** Electrocardiogram (ECG) may detect atrial fibrillation (AF), but the true rate of ECG performance is unknown.

Objectives: To explore the performance rate of ECG testing in patient populations at high risk for AF in a real-world cohort and to explore the incidence of newly diagnosed AF.

Methods: This retrospective observational cohort study included de-identified data of members of Maccabi Health Services older than 65 years, excluding patients with prior AF and other cardiac diseases. Patients were followed between 1 January 2016 and 30 September 2020. The number of ECGs performed in an outpatient setting for each patient was reported.

Results: In total, 211,515 patients (59.8% female) were included. The mean age was 70.3 ± 6.6 years, with a mean CHA_2DS_2-VASc score of 2.6 ± 1.0. During the study period, over half of the patients (n=112,340; 53.1%) did not undergo any ECG tests, 51,644 patients (24.4%) had one ECG, 24,914 patients (11.8%) had two, while 22,617 patients (10.7%) had more than three. Of the patients referred for an ECG, 67,433 (81.1%) underwent ECG testing within 2 months following the referral. The median time from ECG referral to ECG testing was 5 days.

Conclusions: Most patients older than 65 years had no ECG tests within a 5-year period. However, when referred to an ECG test, most patients complied within a median of 5 days.

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KEY WORDS: atrial fibrillation (AF), electrocardiogram (ECG), oral anticoagulants (OAC), primary care, screening

Atrial fibrillation (AF), the most prevalent cardiac arrhythmia [1], is considered a major risk factor for cardiovascular diseases and accounts for one in five ischemic strokes [2]. AF prevalence is age-dependent, with a reported prevalence of 9–19.2% in a patient population 65 years of age or older [3,4]. Diagnosis of AF is of paramount prognostic importance. Beyond symptom control, diagnosed patients undergo stroke risk stratification and are prescribed oral anticoagulants (OAC) when indicated. This treatment is associated with improved outcomes [5]. AF diagnosis is based on rhythm documentation by an electrocardiogram (ECG) showing typical arrhythmia for at least 30 seconds [6]. The European Society of Cardiology (ESC) recommends routine heart rhythm assessment (i.e., pulse palpation) in all individuals older than 65 years, and a population-based screening program with prolonged non-invasive ECG for patients older than 75 years, or those older than 65 years at high risk [7]. ECG is a readily available test, ordered at the discretion of the healthcare provider (HCP), that may provide important cardiovascular data (e.g., cardiac ischemia, left ventricular hypertrophy, conduction abnormalities, and arrhythmias). ECG referral, for any reason, can also be utilized to diagnose asymptomatic AF, but data regarding the real-world performance of ECG tests ordered by the HCP and the incidence of AF diagnosis by ECG are lacking.

The aim of this study was to report the performance rate of ECG testing in a high-risk cohort of patients at an outpatient setting of the second largest healthcare provider is Israel and to explore the incidence of newly diagnosed AF in this population. Secondary objectives included describing indices associated with ECG performance and analyzing the differences in ECG referral.

PATIENTS AND METHODS

STUDY DESIGN AND DATA SOURCE

In this observational cohort study, we evaluated the rate of outpatient ECG testing in the elderly population in Israel. For this purpose, the Maccabi Healthcare Services (MHS, the second largest healthcare provider in Israel) electronic medical database, containing longitudinal data on a population of more than 2.7 million people, was utilized. Collected de-identified data on each participant included demographic data, diagnoses coded by physician visits, full pharmacy prescriptions, and purchase data. The MHS database also organizes data in automatically formulated registries (e.g., ischemic heart disease, peripheral vascular disease, and arrhythmia registries). These registries undergo automated updates, employing stringent algorithms for data management and categorization. The algorithms systematically aggregate information from multiple sources, including diagnoses codes, prescription records, hospital discharge data, and billing data. Diagnoses codes are based on the International Classification of Diseases 9th Revision, Clinical Modification (ICD-9-CM) coding systems, as well as internal MHS codes that correlate with standard ontologies. Medications were coded according to the Israeli coding system, with translation to the Anatomical Therapeutic Chemical coding system wherever available [8].

STUDY POPULATION

Participants were eligible for enrollment if they had turned 65 years old between 1 January 2016 and 30 September 2020. Exclusion criteria included previous diagnosis of AF based on at least one of the following criteria: entry to MHS AF registry prior to enrollment, at least two outpatient physician visits documented with AF diagnosis, hospital discharge note with AF diagnosis based on ICD-9 code, OAC prescription (≥ 3 dispensed prescriptions per patient) in a patient without a history of venous thromboembolism at approved doses for stroke prevention in AF within 6 months prior to study enrollment, a history of cardiac disease or cardiac surgery, membership in MHS for a duration of less than 1 year prior to study enrollment to ensure complete medical record, less than 3 months of follow-up.

All eligible participants were categorized into two main groups by age (age 65–74 and age ≥ 75 years). The groups were then sub-divided into four subgroups by frequency of ECG testing performed during follow-up period: no ECG, one ECG, two ECGs, and ≥ three ECGs. By the study entry date (the index date), all participants had to be 65 years of age, or they had to have reached this age during the study period. Based on this criterion, a participant could be counted in both age groups.

MAIN OUTCOME

The main outcome of this study was the number of ECG tests performed during follow-up. We utilized the available logs for ECG performance between the years 2016–2020 including ECG tests performed during HCP visits (both the primary care physician and cardiologists), MHS's emergency centers, and other MHS facilities. The number of ECGs per participant was collected and the annual rate of ECG per patient year was calculated. All data ECG referrals were collected based on electronic referral order after the index date. The end of the follow-up period was determined as the earliest of 31 December 2020, occurrence of AF, cardiac disease diagnosis, death, or MHS disenrollment.

PATIENT BASELINE CHARACTERISTICS

Baseline characteristics included demographics (e.g., sex and age), socioeconomic status (SES), smoking status (i.e., ever/never), CHA_2DS_2-VASc, and body mass index (BMI). SES is classified by the Central Bureau of Statistics in Israel, using a scale ranging from 1 (indicating the lowest status) to 10. This index is derived from multiple factors, such as household income, educational attainment, levels of crowding within the household, and ownership of vehicles [9]. The CHA_2DS_2-VASc score, which includes congestive heart failure, hypertension, age > 75 years, diabetes mellitus, stroke, vascular disease, age 65–74 years, sex category (female), is a validated score for stroke risk assessment recommended by ESC guidelines for this purpose [9].

Chronic co-morbidities were collected from MHS registries and included hypertension, diabetes mellitus, peripheral vascular disease, chronic kidney disease [10], and chronic obstructive pulmonary disease (COPD). Medications purchased at least once within 6 months prior to study entry included beta blockers (excluding sotalol), angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, aldosterone antagonists (spironolactone and eplerenone), diuretics, statins, ezetimibe, aspirin, clopidogrel, and OACs (apixaban, dabigatran, rivaroxaban, and warfarin).

STATISTICAL ANALYSES

Descriptive statistics are presented as number and percent for categorical variables and mean ± standard deviation for continuous variables. Comparisons of proportions and means across age groups or study groups were performed using chi-square test and Student's *t*-test or one-way ANO-

VA, respectively. A P-value < 0.05 was considered statistically significant. A multivariate logistic regression model was used to describe correlates of ECG testing. Age and sex were forced into the model and a backwards Wald method was used to explore the significance of all other covariates (P-value < 0.05 was used for inclusion and P-value < 0.1 for exclusion). Associations are expressed as odds ratios (ORs), with corresponding 95% confidence intervals (95%CI). The interquartile range (IQR) presents the first and third quartiles. Statistical analyses were performed using IBM Statistical Package for the Social Sciences statistics software, version 27 (SPSS, IBM Corp, Armonk, NY, USA).

ETHICS: APPROVAL AND DATA PROTECTION

The study was approved by MHS institutional review board (IRB number 0089-22-MHS). The study was performed in accordance with the Helsinki Declaration of 1964, and its later amendments. Due to its retrospective and de-identified nature, informed consent was waived. Data collection and analysis were performed by MHS. Raw data, including de-identified patient-level data, were available for MHS research personnel only.

RESULTS

A total of 297,546 MHS members aged ≥ 65 years were screened for inclusion in this study. A flowchart of study population selection is presented in Figure 1. After exclusions, a total of 211,515 participants were included in this study. The study's main cohort was comprised of 59.8% females, with a mean age of 70.3 ± 6.6 years at the index date [Table 1]. Of the overall participants, 78.5% of participants were in the 65–74-year-old age group and 21.5% were in the ≥ 75-year-old age group. The prespecified grouping by the number of ECG testing resulted in over half of the patients (n=112,340; 53.1%) not having any ECG test during the study period. In addition, 51,644 (24.4%) had one ECG; 24,914 (11.8%) had two ECGs; while 22,617 (10.7%) had three or more ECGs [Figure 2]. Patients in the three or more ECG group were older and had a higher prevalence of AF risk factors compared with the other groups.

Multivariate logistic regression analysis for indices associated with at least 1 ECG testing [Table 2] demonstrated that among other indices (e.g., age and female sex), obstructive sleep apnea, COPD, and hyperlipidemia had the strongest

Figure 1. Flow chart: selection of the study population

AF = atrial fibrillation, CHF = chronic heart failure, CVD = cardiovascular disease, IHD = ischemic heart disease, OACs = oral anticoagulants, PVD = peripheral vascular disease, VTE = venous thromboembolism

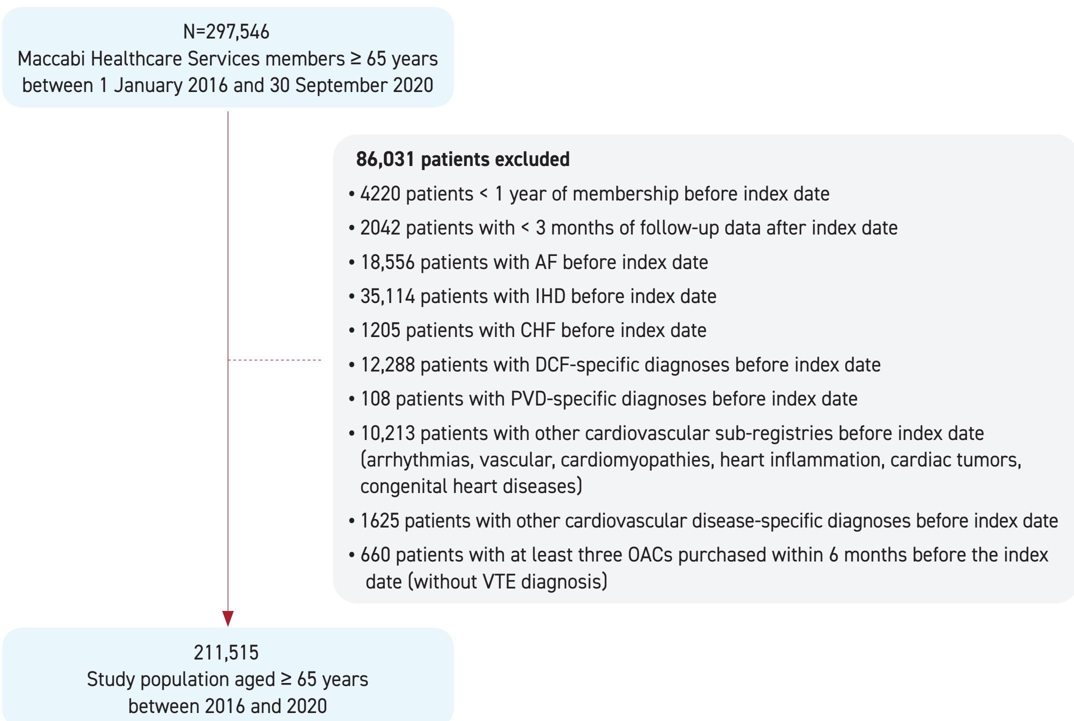

Table 1. Baseline characteristics of participants who underwent ECG testing versus participants without ECG testing during 2016–2020

	No ECG, n=112,340	1 ECG, n=51,644	2 ECGs, n=24,914	≥ 3 ECGs, n=22,617	All, n=211,515
Female n (%)	65,777 (58.6%)	30,674 (59.4%	15,336 (61.6%)	14,623 (64.7%)	126,410 (59.8%)
Age at index date*, mean ± SD	70.0 ± 7.1	70.1 ± 6.)	70.7 ± 5.9	71.4 ± 5.8	70.3 ± 6.6
Age group at index*, n (%)					
65–74 years	88,940 (79.2%)	41,115 (79.6%)	19,309 (77.5%)	16,603 (73.4%)	165,967 (78.5%)
≥ 75 years	23,400 (20.8%)	10,529 (20.4%)	5,605 (22.5%)	6,014 (26.6%)	45,548 (21.5%)
Prior smoking history*, n (%)	12,383 (11.0%)	5,364 (10.4%)	2,337 (9.4%)	1,980 (8.8%)	22,064 (10.4%)
Diabetes mellitus*, n (%)	24,299 (21.6%)	12,251 (23.7%)	6,298 (25.3%)	6,085 (26.9%)	48,933 (23.1%)
Hypertension*, n (%)	58,063 (51.7%)	29,712 (57.5%)	15,197 (61.0%)	15,294 (67.6%)	118,266 (55.9%)
COPD*, n (%)	5,866 (5.2%)	3,454 (6.7%)	1,977 (7.9%)	2,191 (9.7%)	13,488 (6.4%)
CKD*, n (%)	34,273 (30.5%)	17,508 (33.9%)	9,273 (37.2%)	9,406 (41.6%)	70,460 (33.3%)
Hyperlipidemia*,‡, n (%)	16,699 (14.9%)	9,205 (17.8%)	4,903 (19.7%)	4,922 (21.8%)	35,729 (16.9%)
Obstructive sleep apnea*,‡, n (%)	1,220 (1.1%)	821 (1.6%)	432 (1.7%)	499 (2.2%)	2972 (1.4%)
Rheumatoid arthritis*,‡, n (%)	649 (0.6%)	349 (0.7%)	211 (0.8%)	213 (0.9%)	1422 (0.7%)
CHA2DS2-VASc score*, mean ± SD	2.5 ± 1.0	2.6 ± 1.0	2.7 ± 1.0	2.9 ± 1.0	2.6 ± 1.0
BMI* (kg/m2), n (%)					
< 25	34,047 (30.3%)	14,326 (27.7%)	6,416 (25.8%)	5,458 (24.1%)	60,247 (28.5%)
25–29.9*	43,681 (38.9%)	21,375 (41.4%)	10,506 (42.2%)	9,254 (40.9%)	84,816 (40.1%)
≥ 30	30,292 (27.0%)	15,713 (30.4%)	7,961 (32.0%)	7,895 (34.9%)	61,861 (29.2%)
Missing	4320 (3.8%)	230 (0.4%)	31 (0.1%)	10 (0.04%)	4591 (2.2%)
SES*, n (%)					
Low (1–4)	20,338 (18.1%)	8475 (16.4%)	4,223 (17.0%)	4,227 (18.7%)	37,263 (17.6%)
Medium (5–7)	57,854 (51.5%)	26,803 (51.9%)	13,331 (53.5%)	12,380 (54.7%)	110,368 (52.2%)
High (8–10)	33,922 (30.2%)	16,286 (31.5%)	7,312 (29.3%)	5,976 (26.4%)	63,496 (30.0%)
Chronic medication prescription					
Any OAC**,‡‡, n (%)	596 (0.5%)	294 (0.6%)	147 (0.6%)	166 (0.7%)	1,203 (0.6%)
Beta blocker*, n (%)	19,860 (17.7%)	10,579 (20.5%)	5,578 (22.4%)	6,318 (27.9%)	42,335 (20.0%)
ACEi*, n (%)	19,090 (17.0%)	9,895 (19.2%)	5,069 (20.3%)	4,943 (21.9%)	38,997 (18.4%)
ARB*, n (%)	19,177 (17.1%)	10,695 (20.7%)	5,645 (22.7%)	6,054 (26.8%)	41,571 (19.7%)
Diuretic*, n (%)	7,421 (6.6%)	3,725 (7.2%)	1,938 (7.8%)	2,107 (9.3%)	15,191 (7.2%)
Statin*, n (%)	42,668 (38.0%)	23,595 (45.7%)	12,175 (48.9%)	11,961 (52.9%)	90,399 (42.7%)
Ezetimibe*, n (%)	1,615 (1.4%)	909 (1.8%)	439 (1.8%)	484 (2.1%)	3,447 (1.6%)
Aspirin*, n (%)	21,415 (19.1%)	12,615 (24.4%)	6,873 (27.6%)	7,333 (32.4%)	48,236 (22.8%)
Clopidogrel*, n (%)	1,512 (1.3%)	825 (1.6%)	440 (1.8%)	577 (2.6%)	3,354 (1.6%)
Follow-up time (years), median [IQR]	5 [1.78–5]	5 [3.17–5]	5 [4.03–5]	5 [4.77–5]	5 [4.77–5]

ACEi = angiotensin-converting enzyme inhibitors; ARBs = angiotensin receptor blockers; BMI = body mass index; CHA_2DS_2-VASc = congestive heart failure, hypertension, age > 75 years, diabetes mellitus, stroke, vascular disease, age 65-74 years, sex category [female]; CKD = chronic kidney disease; COPD = chronic obstructive pulmonary disease; CVD = cardiovascular disease; ECG = electrocardiogram; IQR = interquartile range; OAC = oral anticoagulants; PVD = peripheral vascular disease; SD = standard deviation; SES = socioeconomic status

*Intergroup differences are statistically significant (*P*-value < 0.001)

**Intergroup differences are statistically significant (*P*-value = 0.003)

‡Within 1 year before index date

‡‡Within 6 months before index date

association with the odds of undergoing at least 1 ECG test.

To explore patient compliance with ECG referral, we evaluated the performance of ECG within 2 months of documented referral by HCP. Of all participants who had at least one documented ECG referral (n=83,137) within the study period, 67,433 (81.1%) had an ECG test within 2 months following the referral. The median time from ECG referral to testing was 5 days (IQR 1–15 days). Among participants in the 65–74-year-old age group (n=57,798), 46,571 (80.6%) had an ECG test within 2 months following the referral. In the ≥ 75-year-old age group (n=25,339), 20,862 (82.3%) had an ECG test within 2 months following the referral.

Figure 2. Frequency of ECG testing (all participants)

Each bar shows the percentage of participants who underwent ECG tests (out of overall participants) separated by the number of ECG tests (i.e., subgroups of 0 ECGs, 1 ECG, 2 ECGs, and ≥ 3 ECGs)

ECG = electrocardiogram

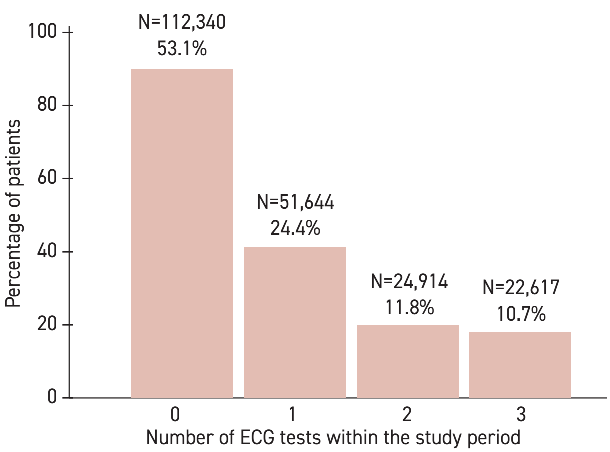

Table 2. Logistic regression for ECG testing

Index	OR (95%CI)
Age (years)	1.01 (1.01–1.01)
Female sex	1.07 (1.05–1.09)
Hypertension	1.21 (1.18–1.23)
Intermediate socioeconomic group	1.13 (1.10–1.15)
High socioeconomic group	1.13 (1.11–1.17)
BMI 25–29.9	1.20 (1.17–1.22)
BMI ≥ 30	1.25 (1.22–1.28)
Chronic kidney disease	1.12 (1.10–1.14)
Obstructive sleep apnea	1.47 (1.37–1.59)
Chronic obstructive pulmonary disease	1.43 (1.38–1.48)
Inflammatory bowel disease	1.25 (1.14–1.37)
Hyperlipidemia	1.29 (1.26–1.32)
Rheumatoid arthritis	1.25 (1.12–1.39)
Beta-blockers	1.12 (1.09–1.15)

95%CI = confidence interval, BMI = body mass index, OR = odds ratio

DISCUSSION

The main findings of this study, which included a cohort of 211,515 members at a high-risk for AF from the second largest health fund in Israel, indicate that within a median follow-up time of 5 years. Although at a relatively high risk for AF and stroke, 53.1% of participants did not undergo an ECG test while 24.4% had one ECG test throughout the entire follow-up time. Female sex, older age, sleep apnea, and COPD were among the indices independently associated with ECG testing. Referral for ECG testing resulted in ECG performance within a median time of 5 days for most patients, with higher compliance in the ≥ 75-years-old age group.

Cardiovascular diseases (CVDs) are a leading cause of morbidity and mortality worldwide. Together with atherosclerotic disease, AF is one of the common CVDs associated with dire outcomes and significant economic burden, prompting efforts toward early detection [11]. Although ECG is a low-cost and readily available test, the frequency and timing of AF screening via ECG are under debate, and no consensus exists regarding a cost-effective strategy that yields high rates of early detection. The present study adds insights regarding the real-world use of ECG in a large-scale cohort of high-risk elderly patients.

The fact that over half of the patients did not undergo any ECG test within the 5-year follow-up period is important. Given that the prevalence of multiple CVDs is age-dependent, it may seem surprising that these patients did not undergo any ECG test.

Denmark has the largest population-based, real-world, digital ECG database including all patients who underwent at least one ECG test since the year 2000. A 2024 publication reported that this dataset included data on > 2.4 million unique patients with a median age of 57 years at the time of the first ECG test. In contrast to our cohort, 97% of ECG recordings in this dataset were performed in hospitals, which may indicate that a major clinical event had some impact on the incentive to perform the test. The predominant age group in this cohort was 61–80 years (45%). Patients older than 80 years comprised only 18% of the population. Similar to the present study, no sex differences were recorded in the number of ECGs performed. However, unlike our cohort, in which 52% of patients had only one ECG test, in Denmark, 34% had one ECG test, while 42% had between two and five ECG tests. This discrepancy may be attributed to the long follow-up period (~20 years) in the Danish cohort and the fact that most tests were conducted in hospitals [12]. To the best of our knowledge, aside from this cohort, no other large-scale studies have reported the true prevalence of ECG testing in this patient population.

Suggested indices associated with ECG testing included high BMI, sleep apnea, hyperlipidemia, and hypertension. This observation suggests that conventional risk factors for CVD are associated with a higher prevalence of ECG testing. This finding in accordance with prior evidence indicating that higher odds for ECG abnormalities are expected in patients with multiple risk factors [13-16].

Patient compliance with ECG referrals was encouraging in the present analysis, with 81.1% of referred patients undergoing an ECG test within a median time of 5 days. This finding underscores that the lower performance rates are not attributable to patient compliance or ECG availability, which further reinforces ECG as a readily accessible screening tool for high-risk populations.

Our findings align with and extend recent evidence on AF screening. While the 2022 USPSTF report concluded that evidence was insufficient to support routine ECG-based screening in asymptomatic adults [17], more recent randomized evidence suggests potential benefit. A metaanalysis of seven randomized controlled trials, including STROKESTOP, LOOP, and GUARDAF, demonstrated that systematic screening was associated with increased AF detection and oral anticoagulant initiation, as well as a modest but statistically significant 7% relative reduction in stroke or systemic embolism, without an increase in bleeding or mortality [18]. Consistent findings have also been reported in the AMALFI trial, which similarly showed higher AF detection with screening strategies [19]. These findings underscore the clinical relevance of our observation that over half of high-risk elderly individuals did not undergo ECG testing, highlighting a potential gap between evidence and practice.

Several limitations to this study should be acknowledged. First, this retrospective analysis is based on MHS records, and patients who underwent ECGs outside of MHS facilities were not included. Second, we lack information on the reasons for undergoing ECGs. As a result, we cannot distinguish between the rates of ECGs performed for symptoms versus screening. While some ECGs were clearly symptom-driven, excluding patients with prior or newly diagnosed CVDs likely reduced the risk of non-screening ECG referrals. This result suggests that the rate of ECGs performed for screening in asymptomatic patients is even lower.

CONCLUSIONS

In a real-world, large-scale cohort study, less than half of the patients older than 65 years of age who were at high risk for AF and stroke underwent an ECG within a 5-year follow-up period. When patients were referred to an ECG test, 81.1% complied with the referral within a median of 5 days. This finding supports professional guidelines advocating for systematic AF screening, particularly in high-risk populations [20].

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