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Comparison between automated electronic blood pressure monitor and electrocardiography in atrial fibrillation screen

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Atrial fibrillation (AF) is one of the most common cardiac arrhythmias and a major risk factor for embolic stroke and heart failure (HF).[1-3] According to the recent reports of the Global Burden of Diseases study, the number of patients with AF increased from 33.5 million in 2010 to 59.7 million people in 2019.[4,5] The number of attributable deaths to AF increased from 0.23 million in 2010 to 0.33 million in 2019.[4,5] One of the major problems in the management of AF is the low detection rate, because it is often asymptomatic and requires systematic or opportunistic screen. Nonetheless, if detected timely, it can either be reversed to sinus rhythm with various treatments or its risk can be substantially reduced with the use of anticoagulants. Screening therefore is key to improving the management of AF.

Current guidelines and consensus recommend opportunistic screening for AF in high-risk populations.[6] Electrocardiography (ECG) is cost-effective for the detection of AF. ECG testing more frequently, for instance, quarterly than annually with the use of a handheld device equipped with an artificial intelligence algorithm, is more efficient for the detection of AF.[7] However, ECG testing has to be performed individually and is not sufficient for the screening in millions of high-risk people. One of the emerging promising screening modalities is via blood pressure (BP) measurement with automatic electronic monitors.

Hypertension is a major risk factor of AF.[8] Home BP monitoring has been widely used for the management of hypertension. Some automatic BP monitors are equipped with new algorithms and capable of screening for AF by detecting irregular pulses during BP measurement, and showed high sensitivity and specificity for the detection of AF.[9-11] In the framework of the May Measurement Month project, we did AF screen using either a handheld ECG device or automatic electronic BP monitor in high-risk populations. In the present analysis, we compared the BP monitor with ECG in AF screen in an elderly Chinese population.

Our study was a part of the May Measurement Month project, which was a worldwide initiative involving adults aged ≥ 18 years. The protocol of the May Measurement Month project had been previously described in detail elsewhere.[12] The AF screen study was restricted to individuals aged ≥ 60 years. The study participants were recruited from 42 hospitals, community health centers, pharmacies, public areas (outdoors or indoors) and workplaces from May to August 2024. The only exclusion criterion was inability to complete the questionnaire.

Screen was performed with a single-lead ECG or with an electronic BP monitor. Only one of the two techniques was used in a screen center. The study protocol was approved by the Ethics Committee of Ruijin Hospital (No.2024-190), Shanghai Jiao Tong University School of Medicine, Shanghai, China. All participants gave written informed consent. In the screen centers with a BP monitor, the BP-77A1T electronic BP monitor (Omron Healthcare, Kyoto, Japan) was used for AF screen during BP measurement. The device works by analyzing pulse-to-pulse intervals (PPI), which are derived from the pressure pulse waves during the BP measurement. These PPI values are assessed using a machine learning algorithm based on AdaBoost, which incorporates over 300 mathematical indices. This sophisticated approach enables the device to identify irregularities in pulse intervals that may indicate potential AF. When irregularities are detected, the monitor displays a flashing icon

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reading "Possible AFib Detected".[13] In the screen centers with ECG, a single-lead ECG was recorded for 30 s with a handheld ECG device (AliveCor Heart Monitor, now Kardia Mobile, Mountain View, CA, USA). BP was measured with the HEM-9200T BP monitor (Omron Healthcare, Kyoto, Japan).

AF included both newly detected cases of AF with the BP monitor or handheld ECG device and those with a previous history of AF by questionnaire and with a sinus rhythm.

Trained health professionals measured each participant's BP three times consecutively on the non-dominant arm, after the participants had rested for at least 5 min in the sitting position. The HEM-9200T or BP77A1T BP monitor was used depending on screen site. These three BP readings were averaged for analysis. Hypertension was defined as a sitting BP of at least 140 mmHg systolic or 90 mmHg diastolic, or as the use of antihypertensive drugs. The same trained health professional administered a standardized questionnaire to collect information on medical history including previous history of AF, smoking habits, alcohol consumption, and the use of medications. A trained technician performed anthropometric measurements, including body height, body weight and waist circumferences. Body mass index was calculated as the body weight in kilograms divided by the body height in meters squared. Central obesity was defined as waist circumference > 90 cm for men and > 85 cm for women.[14]

Statistical analysis was performed using the R statistical software 4.3.2 (R Foundation for Statistical Computing, Vienna, Austria). Means and proportions were compared by the analysis of variance and the Pearson's chi-squared test, respectively. Multiple stepwise logistic regression analyses were performed to analyze the determinants of AF detected by single-lead ECG and BP monitor. Subgroup analyses were performed according to age (60-69 years *vs.* ≥ 70 years), sex, body mass index (< 25 kg/m^2 *vs.* ≥ 25 kg/m^2), systolic BP (< 140 mmHg *vs.* ≥ 140 mmHg) and diastolic BP (< 90 mmHg *vs.* ≥ 90 mmHg), pulse rate (< 90 beats/min *vs.* ≥ 90 beats/min), the status of current smoking and alcohol intake, and the presence and absence of central obesity, hypertension, treated hypertension, diabetes mellitus (DM) and a history of heart attack, HF and stroke. Multiple logistic regression analysis was applied to compute odds ratio (OR) with 95% CI for the comparison between electronic BP monitor and ECG screen for AF. All statistical tests were two-sided at the 0.05 significance level.

A total of 29,998 participants from 42 centers were enrolled for AF screen, with 10,799 participants from 18 centers with the single-lead ECG device and 19,199 participants from 24 centers with the BP monitor. The study participants differed between the two groups significantly ($P \leq 0.01$) in most of the demographic and clinical characteristics except for the proportion of current cigarette smokers and the proportion of participants with a history of HF ($P \geq 0.11$) (Table 1).

A total of 991 participants (3.3%) had AF, including 190 participants (0.6%) with a history of AF and sinus rhythm, and 801 participants (2.7%) with a newly detected AF. The prevalence of AF in the BP monitor group was significantly higher for those with a history of AF (0.72% *vs.* 0.47%, $P = 0.01$), but lower for the newly detected cases of AF than the ECG sites (2.3% *vs.* 3.2%, $P < 0.0001$). Patients with a history of AF were comparable between the BP monitor and ECG groups in most of the demographic and clinical characteristics, except for diastolic BP, prevalence of DM and a history of heart attack ($P \leq 0.04$). However, patients with a newly detected AF were significantly different ($P \leq 0.004$) between the BP monitor and ECG groups in waist circumference (82.6 cm *vs.* 79.6 cm), prevalence of DM (11.2% *vs.* 4.3%) and heart attack (20.1% *vs.* 9.4%), proportion of men (49.8% *vs.* 60.3%), systolic BP (120.8 mmHg *vs.* 128.5 mmHg), and pulse rate (76.5 beats/min *vs.* 79.3 beats/min) (Table 2).

In further multiple stepwise logistic regression analysis, the rate of the newly detected AF was significantly ($P \leq 0.01$) higher with age advancing, male gender, faster pulse rate, and a history of heart attack, or HF and lower in the presence of DM for the single-lead ECG group and was significantly ($P \leq 0.049$) higher with age advancing, the presence of hypertension and a history of heart attack for the BP monitor group (Table 3).

We performed subgroup analyses on the newly detected AF according to several characteristics. There was significant interaction ($P \leq 0.03$) between the screening group and some of the characteristics, such as central obesity, DM, and a history of heart attack. After adjustment for confounding factors, the BP monitor group, compared to the single-lead ECG group, had a significantly higher detection rate of AF among participants with a history of heart attack (OR = 1.55, 95% CI: 1.00–2.39), but had a significantly lower detection rate of AF in participants without central obesity (OR = 0.66, 95% CI: 0.56-0.78) or DM (OR = 0.67, 95% CI: 0.57-0.78) (Table 4). Statistical adjustment for center did not materially change the results.

The total prevalence of AF (3.3%) in the elderly (≥ 60 years) Chinese population in our study is higher than previ-

Table 1 Characteristics of the study participants.

Characteristic	Single-lead ECG (*n* = 10,799)	Blood pressure monitor (*n* = 19,199)	*P*-value
Age, yrs	68.7 ± 6.1	68.9 ± 6.9	0.01
Men	5489 (50.8%)	8950 (46.6%)	< 0.0001
Body mass index, kg/m^2	24.3 ± 2.4	24.5 ± 3.1	< 0.0001
Waist circumference, cm	78.8 ± 10.4	82.3 ± 11.6	< 0.0001
Systolic blood pressure, mmHg	128.6 ± 19.4	123.6 ± 18.6	< 0.0001
Diastolic blood pressure, mmHg	80.0 ± 11.6	77.9 ± 11.3	< 0.0001
Pulse rate, beats/min	77.5 ± 12.2	75.9 ± 11.2	< 0.0001
Cigarette smoking	781 (7.2%)	1363 (7.1%)	0.67
Alcohol consumption	723 (6.7%)	2494 (13.0%)	< 0.0001
Hypertension	4000 (37.0%)	7138 (37.2%)	< 0.0001
Treated hypertension	3665 (33.9%)	6688 (34.8%)	< 0.0001
Diabetes mellitus	800 (7.4%)	1877 (9.8%)	< 0.0001
Heart attack	410 (3.8%)	826 (4.3%)	< 0.0001
Heart failure	82 (0.8%)	180 (0.9%)	0.11
Stroke	84 (0.8%)	275 (1.4%)	< 0.0001

Data are presented as mean ± SD or *n* (%). ECG: electrocardiography.

Table 2 Characteristics of patients with AF.

Variable	Patients with a history of AF and sinus rhythm (*n* = 190)			Newly detected cases of AF (*n* = 801)		
	Single-lead ECG (*n* = 51)	Blood pressure monitor (*n* = 139)	*P*-value	Single-lead ECG (*n* = 353)	Blood pressure monitor (*n* = 448)	*P*-value
Age, yrs	71.3 ± 7.9	70.4 ± 8.0	0.51	70.8 ± 7.1	71.5 ± 7.3	0.22
Men	26 (51.0%)	66 (47.5%)	0.67	213 (60.3%)	223 (49.8%)	0.003
Body mass index, kg/m^2	23.7 ± 3.3	24.1 ± 3.2	0.49	24.3 ± 2.3	24.3 ± 3.2	0.83
Waist circumference, cm	81.9 ± 9.6	83.1 ± 9.4	0.42	79.6 ± 8.6	82.6 ± 12.2	< 0.0001
Systolic blood pressure, mmHg	124.0 ± 22.7	126.4 ± 19.7	0.49	128.5 ± 19.5	120.8 ± 19.0	< 0.0001
Diastolic blood pressure, mmHg	75.3 ± 11.0	79.4 ± 12.7	0.04	80.4 ± 12.0	79.3 ± 12.0	0.20
Pulse rate, beats/min	74.2 ± 12.0	74.8 ± 12.9	0.79	79.3 ± 14.5	76.5 ± 13.4	0.004
Cigarette smoking	3 (5.9%)	19 (13.7%)	0.14	32 (9.1%)	34 (7.6%)	0.45
Alcohol consumption	5 (9.8%)	11 (7.9%)	0.68	28 (7.9%)	53 (11.8%)	0.07
Hypertension	23 (45.1%)	79 (56.8%)	0.15	186 (52.7%)	240 (53.6%)	0.80
Treated hypertension	19 (37.3%)	60 (43.2%)	0.46	130 (36.8%)	184 (41.1%)	0.22
Diabetes mellitus	2 (3.9%)	23 (16.6%)	0.02	15 (4.3%)	50 (11.2%)	0.0004
Heart attack	12 (23.5%)	56 (40.3%)	0.03	33 (9.4%)	90 (20.1%)	< 0.0001
Heart failure	8 (15.7%)	20 (14.4%)	0.82	11 (3.1%)	16 (3.6%)	0.72
Stroke	3 (5.9%)	5 (3.6%)	0.49	6 (1.7%)	8 (1.8%)	0.93

Data are presented as means ± SD or *n* (%). AF: atrial fibrillation; ECG: electrocardiography.

ous studies.[15,16] In a previous study involving 3922 elderly Chinese participants, the prevalence of AF based on 12-lead ECG was 2.0% in 1718 men and 1.6% in 2204 women.[15] Similarly, another study in China reported a crude prevalence of 2.0% in elderly participants (≥ 60 years).[16] The higher prevalence in our study may be attributed to our screening methods, which used an electronic BP monitor or single-lead ECG. Those methods likely enhance the detection sensitivity compared to traditional 12-lead ECGs, enabling identification of AF in paroxysmal or asymptomatic ca-

Table 3 Logistic regression analysis on the determinants of AF detected by single-lead ECG and blood pressure monitor.

Variable	Single-lead ECG (n = 10,799)		Blood pressure monitor (n = 19,199)	
	Patients with a history of AF and sinus rhythm (n = 51)	Newly detected cases of AF (n = 353)	Patients with a history of AF and sinus rhythm (n = 139)	Newly detected cases of AF (n = 448)
Age	1.046 (1.004-1.087)	1.05 (1.04-1.07)	1.01 (0.98-1.03)	1.04 (1.03-1.05)
Men	0.67 (0.63-1.25)	1.48 (1.19-1.85)	0.93 (0.64-1.35)	1.12 (0.91-1.37)
Pulse rate	-	1.014 (1.006-1.023)	-	-
Current smoking	-	-	2.38 (1.35-1.01)	-
Alcohol intake	-	-	0.52 (0.26-0.96)	-
Hypertension	-	-	-	1.217 (1.002-1.479)
Diabetes mellitus	-	0.50 (0.28-0.82)	-	-
Heart attack	4.45 (1.96-9.28)	2.30 (1.51-3.39)	11.80 (7.88-17.4)	5.82 (4.51-7.45)
Heart failure	10.79 (4.00-26.4)	2.80 (1.33-5.42)	5.23 (2.86-9.27)	-
Stroke	7.58 (1.73-26.16)	-	-	-

In a logistic regression model, we forced age and sex, and considered body mass index, waist circumference, pulse rate, current smoking, alcohol intake, and the presence of hypertension, diabetes mellitus, heart attack, heart failure and stroke for entry and stay at a significance of $P \leq 0.05$. AF: atrial fibrillation; ECG: electrocardiography.

Table 4 Subgroup analysis on the newly detected AF.

	Number of participants with AF (rate per 100 participants)		Multivariable-adjusted*	$P_{interaction}$-value
	Single-lead ECG	Blood pressure monitor		
Age, yrs				0.96
60-69	170 (2.6)	198 (1.8)	0.68 (0.55-0.85)	
≥ 70	183 (4.4)	250 (3.2)	0.73 (0.60-0.89)	
Sex				0.06
Men	213 (3.9)	223 (2.5)	0.62 (0.51-0.76)	
Women	140 (2.6)	225 (2.2)	0.81 (0.65-1.01)	
Body mass index, kg/m^2				0.16
< 25	225 (3.1)	291 (2.4)	0.64 (0.50-0.82)	
≥ 25	128 (3.5)	157 (2.2)	0.75 (0.62-0.90)	
Central obesity				0.03
Yes	54 (2.6)	125 (2.4)	0.96 (0.69-1.34)	
No	299 (3.4)	323 (2.3)	0.66 (0.56-0.78)	
Systolic blood pressure, mmHg				0.22
< 140	259 (3.2)	377 (2.4)	0.74 (0.62-0.87)	
≥ 140	94 (3.4)	71 (2.0)	0.57 (0.41-0.78)	
Diastolic blood pressure, mmHg				0.11
< 90	285 (3.2)	366 (2.2)	0.64 (0.54-0.75)	
≥ 90	68 (3.7)	82 (3.2)	0.83 (0.59-1.18)	
Pulse rate, beats/min				0.18
< 90	278 (3.0)	385 (2.3)	0.73 (0.63-0.86)	
≥ 90	75 (4.7)	63 (3.0)	0.59 (0.41-0.85)	
Current smoking				0.69
Yes	32 (4.1)	34 (2.5)	0.59 (0.35-1.01)	
No	321 (3.2)	414 (2.3)	0.71 (0.61-0.83)	

Continued

	Number of participants with AF (rate per 100 participants)		Multivariable-adjusted*	$P_{interaction}$-value
	Single-lead ECG	Blood pressure monitor		
Alcohol intake				0.49
Yes	28 (3.9)	53 (2.1)	0.57 (0.35-0.93)	
No	325 (3.2)	395 (2.4)	0.71 (0.61-0.83)	
Hypertension				0.20
Yes	186 (3.4)	240 (2.7)	0.76 (0.62-0.93)	
No	167 (3.1)	208 (2.0)	0.65 (0.52-0.80)	
Treated hypertension				0.38
Yes	130 (3.6)	184 (2.8)	0.76 (0.60-0.95)	
No	223 (3.1)	264 (2.1)	0.68 (0.56-0.82)	
Diabetes mellitus				0.01
Yes	15 (1.9)	50 (2.7)	1.41 (0.76-2.59)	
No	338 (3.4)	398 (2.3)	0.67 (0.57-0.78)	
Heart attack				0.0003
Yes	33 (8.1)	90 (10.9)	1.55 (1.00-2.39)	
No	320 (3.1)	358 (2.0)	0.62 (0.53-0.73)	
Heart failure				0.81
Yes	11 (13.4)	16 (8.9)	0.60 (0.24-1.51)	
No	342 (3.2)	432 (2.3)	0.70 (0.61-0.82)	
Stroke				0.08
Yes	6 (7.1)	8 (2.9)	0.26 (0.07-0.93)	
No	347 (3.2)	440 (2.3)	0.71 (0.62-0.83)	
Overall	353 (3.3)	448 (2.3)	0.70 (0.61-0.81)	

*Refers to the analyses were adjusted for age, sex, body mass index, waist circumference, pulse rate, current smoking, alcohol intake, and the presence of hypertension, diabetes mellitus, heart attack, heart failure and stroke at baseline. AF: atrial fibrillation; ECG: electrocardiography.

ses and in turn increasing the overall detection rate. There are many automatic BP monitors that have integrated algorithms for the detection of AF by detecting pulse irregularities. Some of those electronic BP monitors were tested for accuracy in AF detection, and showed diagnostic accuracy of 91% to 94%, sensitivity of 88% to 100% and specificity of 89% to 100%.[17-20] At least one BP monitor equipped with a machine learning-based AF screening algorithm has also been validated previously, and showed an even diagnostic accuracy of 97.0%, a sensitivity of 95.1% and specificity of 98.6% for AF screen.[21]

Our study showed that the electronic BP monitor has higher detection rate of AF than single-lead ECG in participants with heart attack, but lower in participants without central obesity or DM. In fact, participants with cardiovascular risk factors have a higher incidence of AF than those without. A nationwide cross-sectional epidemiological study in China showed that AF was significantly associated with hypertension, coronary heart disease, chronic HF, valvular heart disease and stroke.[22] In addition, patients without obesity or DM also have a lower risk of AF.[23] However, this phenomenon is more obvious in screening for AF by a BP monitor. This finding suggests that the electronic BP monitor may be more effective in detecting AF in individuals with cardiovascular risk factors. Individuals with conditions such as heart attack often exhibit greater arterial stiffness and altered vascular hemodynamics, which may enhance the detectability of PPI irregularities, thereby improving AF screening sensitivity.[24,25] In contrast, single-lead ECG recordings may not always capture AF, particularly in individuals with poor signal quality due to comorbidities. These results highlight the potential value of BP monitors as a screening tool in high-risk populations. Further studies are needed to clarify whether this observation reflects over-detection by BP monitors or under-detection by ECG.

Our study should be interpreted within the context of its

limitations. Firstly, patients with screen-detected AF were not confirmed with a 12-lead ECG, which may have resulted in a higher false positive rate. Secondly, AF screening based on a single occasion BP measurement, potentially overlooking variability. Last but not least, our study was conducted in an elderly population. Whether the results of our study can be extrapolated to populations of wider age range remains under investigation.

In conclusion, our study showed that the detection rate of AF was similar with the electronic BP monitor and ECG. The difference between the two techniques in various subgroups warrants further investigation. The electronic BP monitor could be promoted as a convenient screening tool for AF in elderly patients with hypertension, facilitating the early detection, diagnosis, and treatment of AF.

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