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Detection of Atrial Fibrillation Using a Modified Microlife Blood Pressure Monitor

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BACKGROUND
Hypertension is a major risk factor for the development of atrial fibrillation (AF) and for stroke due to AF. Asymptomatic AF can result in a stroke, in patients with risk factors, if it is not detected and treated appropriately. This study evaluated the sensitivity and specificity of an automatic oscillometric sphygmomanometer designed to detect AF.

METHODS
The sphygmomanometer incorporates an algorithm for detecting AF while reducing false positive readings due to premature beats. A total of 405 unselected outpatients seen in two cardiology offices were evaluated by taking three sequential device readings and one electrocardiogram (EKG) on each patient.

RESULTS
For detecting AF, the sensitivity was 95% and the specificity 86% with a positive predictive value of 68% and a negative predictive value of 98% for single device readings. For the three sequential device readings grouped together, the sensitivity was 97% and the specificity was 89%. The device correctly categorized most of the non-AF, abnormal rhythms. The specificity for those in sinus rhythm was 97%.

CONCLUSIONS
This device is able to detect AF with high sensitivity and specificity. Use of this device by patients who monitor their blood pressure at home may help detect asymptomatic AF and allow for treatment prior to the development of a stroke.

Am J Hypertens 2009; **22**:848-852 © 2009 American Journal of Hypertension, Ltd.

A stroke may be the first manifestation of atrial fibrillation (AF).[1] The percentage of patients who develop a stroke due to AF without a previous diagnosis of AF depends on the method used to screen for it. From the Framingham study, 4% of stroke patients were found to have newly diagnosed AF on hospital admission.[2] A review of published studies evaluating Holter monitoring following a stroke found new AF in 3.8–6.1% of patients. Event loop recorders used for up to a week found AF in 5.7–7.7% of patients.[3] Assuming that 4% of stroke patients were found to have AF on hospital admission as in the Framingham study, then the additional 5.7–7.7% of patients found to have AF in the studies using event loop records makes the total percentage of patients with newly diagnosed AF following a stroke to be 9.7–11.7%. This may still be an underestimation of the total stroke risk due to AF because AF may not recur for over 3 months in some patients with intermittent AF.[4] This suggests that >10% of all strokes are due to asymptomatic AF.

Screening for asymptomatic AF and treating newly diagnosed AF patients with warfarin should help prevent most of these strokes.[5] A recent study suggested that episodes of AF that last less than a few hours do not carry the same risk of stroke as longer episodes.[6] This suggests that intermittent screening for AF may be adequate to identify the patients who are at high risk of developing a stroke due to AF. Home screening for asymptomatic AF by self-assessment of the pulse irregularity has been recommended by the National Stroke Association (http://www.strokeheart.org/CYPA/basics.html). However, application of this approach in the community has shown only limited success, with a sensitivity and specificity of ~70% in the elderly.[7] Another method of screening for AF uses an automatic blood pressure monitor to detect the pulse irregularity.[8] Because hypertension is the most common risk factor associated with AF, using an automatic blood pressure monitor to detect AF would benefit the large number of hypertensive patients who monitor their blood pressure at home,[9] The first blood pressure monitor modified to detect AF was shown to have a very high sensitivity but a relatively lower specificity. The specificity was limited mostly by the effects of premature beats on the pulse irregularity.[8] This device was given to outpatients who had a previous episode of AF to monitor their heart rhythm at home on a daily basis.[10] Out of the 19 subjects in the study, the device detected seven episodes of recurrent AF with three false positive readings. A new algorithm was developed for this device to improve the specificity by reducing the effect of premature beats. This study was a two center trial designed to assess the sensitivity and specificity of an automated oscillometric device using a new AF algorithm. A secondary aim of the study was to evaluate the effect of specific rhythm abnormalities on the specificity for AF.

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Received 25 January 2009; first decision 8 March 2009; accepted 5 May 2009; advance online publication 28 May 2009. doi:10.1038/ajh.2009.98

METHODS

An oscillometric automatic blood pressure monitor (model BP3MQ1-2D; Microlife USA, Dunedin, FL) with an irregular heartbeat detection feature was modified such that the irregular heartbeat icon flashes when AF was detected. The device measures the last 10 pulse intervals during cuff deflation and calculates the mean and standard deviation of the intervals. An irregularity index is defined as the standard deviation divided by the mean of the time intervals. In order to reduce the effect of premature beats on the irregularity index, a cutoff value of 25% was chosen so that each of the ten pulse beat intervals that is 25% greater than or 25% less than the mean time interval is deleted. The remaining time intervals are used to calculate the irregularity index. If the irregularity index exceeds a threshold value of 0.06, the rhythm is considered irregular. The number of beats analyzed, and the irregularity index threshold value of 0.06 were chosen to maximize sensitivity for detecting AF. This was done by analyzing heartbeat time intervals from 12-lead electrocardiograms (EKGs) obtained in hospitalized patients as described in the previous study by Wiesel *et al.*[8] The cutoff value was selected by analyzing the pulse beat time intervals obtained from the patients in this previous study. The cutoff value was chosen to improve the specificity while maintaining a high sensitivity for AF. Despite the use of the cutoff values, a premature beat whose time interval is close to the mean time interval would not be deleted and may result in a rhythm that would be considered irregular.

Unselected general cardiology outpatients seen for scheduled visits in two different cardiology offices in Queens, NY were enrolled in the study. Patients with pacemakers or defibrillators were excluded from the study. Demographic data and the presence of risk factors for stroke due to AF, including diabetes mellitus, hypertension, congestive heart failure, and coronary artery disease, were documented. Medication use was not documented because this did not impact on the accuracy of the device based on our previous experience. After informed consent, a standard 12-lead EKG and three sequential device readings were obtained within a few minutes of each other on each patient by a trained technician. EKGs were usually done within 2 min of the device reading but in all cases the EKG was done during the same 15 min office visit as the device reading. The EKGs were read by a board certified cardiologist who was only given the EKGs and had no knowledge of the device readings. The device readings were compared to the EKG readings for each of the three readings individually and for the three sequential readings combined. For the three-sequential readings, the final reading was considered to be irregular if two or three of the individual readings were irregular. If none or only one of the three readings was irregular, the combined three-sequential reading was considered regular.

For the individual readings, 95% confidence intervals were calculated using a bootstrap approach. Bootstrapping is a statistical procedure in which the sample of data is treated as if it were the true population.[11] Bootstrap samples are created by repeatedly sampling with replacement from the original sample. This was done a large number of times (1,999 times) and then estimates of sensitivity and specificity were derived. Because the bootstrap samples are derived by sampling the data with replacement, the derived estimates vary across the bootstrap samples. Through this repeated sampling procedures, statistical tests can be conducted that, practically, do not involve any assumptions about the data. The large resampling based approach says the average of these bootstrap estimates will converge to the true estimates. Confidence intervals for the three-sequential readings were calculated according to the efficient-score method (corrected for continuity) described by Newcombe, based on the procedure outlined by Wilson.[12,13] As Newcombe notes, the familiar normal approximation is ill suited to situations where the proportion is quite small, as is often the case with prevalence measures, or quite large, as is optimally the case with measures of sensitivity and specificity.

The study was also designed to evaluate the non-AF arrhythmias that may cause false positive readings with the device. The non-AF EKGs were classified as sinus rhythm if no abnormal rhythm was seen on the 12-lead EKG. If any abnormal rhythm was noted on the 12-lead EKG, the EKG was classified based on that abnormal rhythm.

The study was approved by the New York Hospital Queens institutional review board. Written informed consent was obtained from all patients before participation in the study.

RESULTS

A total of 405 patients were enrolled in the two sites, 205 from the first site and 200 from the second site. Demographic data and selected cardiac risk factors are listed in **Table 1**. The study population is representative of those patients who are at risk for AF: the elderly and those with hypertension or underlying heart disease. Over 50% of the patients had hypertension. Eighteen percent of the patients were nonwhite.

Of the 405 patients, 93 (i.e., 23%) patients had AF based on the EKG readings. The association between the EKG readings and both the individual and the three-sequential device readings were analyzed using the χ^2-test. The χ^2-test resulted in a

Table 1 | Patient demographics and cardiac risk factors

Patients (no.)	405
Mean age (years)	73.0
Age range (years)	34–98
Male (%)	51
Race	
White (%)	82
Black (%)	8
Other (%)	10
CHF	27
HTN	209
DM	60
CAD	151

CAD, coronary artery disease; CHF, congestive heart failure; DM, diabetes mellitus; HTN, hypertension.

Table 2 | Comparison of individual device readings to the rhythm as determined by the EKG readings

	EKG		Sensitivity (%)	Specificity (%)
Device reading	AF	Non-AF		
Irregular	266	127	95.3	86.4
Regular	13	809	(92.8–97.6)	(84.3–88.7)

Sensitivity and specificity with 95% confidence intervals in parentheses are shown in the last two columns. Derivation of confidence intervals adjusted for the clustered/repeated data through the Rao–Scott method.[14]
AF, atrial fibrillation; EKG, electrocardiogram.

Table 3 | Comparison of the three-sequential device readings to the rhythm as determined by the EKG readings

	EKG		Sensitivity (%)	Specificity (%)
Device reading	AF	Non-AF		
Irregular	90	35	96.8	88.8
Regular	3	277	(91–99)	(85–92)

Sensitivity and specificity with 95% confidence intervals in parentheses are shown in the last two columns.
AF, atrial fibrillation; EKG, electrocardiogram.

significant association of both the individual readings and the three-sequential readings to the EKG readings ($P < 0.0001$). The individual device readings compared to the EKG readings are shown in Table 2 (ref. 14) The individual device readings resulted in a sensitivity of 95% and a specificity of 86%. In this population of patients with a very high prevalence of AF, for individual device readings the positive predictive value was 68% and the negative predictive value was 98%. The three-sequential device readings compared to the EKG are shown in Table 3. The mean sensitivity and specificity for the three-sequential readings is higher than for individual readings but it is not statistically different.

The most frequent abnormal non-AF rhythm was ventricular premature contractions occurring in 7% of the non-AF patients (Table 4). The next most common arrhythmia was atrial premature contractions which occurred in 6% of non-AF patients. The remaining arrhythmias, which include atrial flutter, sinus arrhythmia, wandering atrial pacemaker, supraventricular tachycardia and second degree atrio-ventricular block, each occurred in ≤2% of the non-AF patients. For the individual readings, the device was able to classify 62% of EKGs with premature ventricular contractions correctly as non-AF rhythms. It was less specific with the premature atrial contractions classifying only 43% correctly as non-AF rhythms. Overall, the algorithm was able to correctly classify over 50% of these abnormal rhythms as non-AF rhythms. The specificity of the device for AF in the 248 patients in sinus rhythm, with no abnormal beats seen on EKG was 97%.

Table 4 | Specificity for AF in patients with non-AF rhythms

Rhythm	Number	Specificity (%)
VPC	23	62
APC	20	43
A flutter	7	48
WAP	5	53
SVT	2	83
AV block	1	100
SA	6	33
Sinus	248	97

The number column lists the number of patients with that specific rhythm noted on electrocardiogram.
A flutter, atrial flutter; AF, atrial fibrillation; APC, atrial premature contraction; AV block, atrio-ventricular block; SA, sinus arrhythmia; SVT, supraventricular tachycardia; VPC, ventricular premature contraction; WAP, wandering atrial pacemaker.

DISCUSSION

The oscillometric blood pressure monitor with the AF detecting algorithm has a sensitivity of 95% and a specificity of 86% for single readings and a sensitivity of 97% and a specificity of 89% for three-sequential readings. This means, that for the large majority of patients, this device is very likely to detect AF if it is present at the time of the blood pressure reading. This early detection of AF, would allow patients to be treated with anticoagulation earlier, thereby, possibly preventing strokes. With over 10% of strokes due to undetected AF, widespread use of this device has the potential to prevent thousands of strokes each year.

The specificity of this device in the general population is likely to differ from the results of this study. In this study population, 14% of the patients were found to have false positive results with single device readings. Because the study population was recruited from cardiology offices, these patients can be expected to have a higher prevalence of underlying heart disease than the general population and are, therefore, more likely to have abnormal heart rhythms. The true specificity for the general population can be expected to fall between the 86% found in this population of heart patients and the 97% that was calculated from those without documented abnormal rhythms on EKG. The majority of patients with AF in this study had persistent AF. Whether the device would have the same sensitivity for patients with paroxysmal AF is not known and will need to be determined in future studies.

Patients with premature beats were found to have a relatively low specificity of ~50%. Therefore, some might suggest that patients with these arrhythmias be told not to use this device. However, restricting this device to those without premature beats means that the half of the patients with premature beats that could use this device would not get to benefit from it. In addition, screening all the patients by first obtaining an EKG prior to using this device would, likely, be more costly than having all the patients use this device and then obtaining an EKG on the small percentage with abnormal readings.

There is a subgroup of patients that would benefit the most from using this device. Because the device is designed to detect AF prior to the development of a stroke, it would make sense to limit its use to only those at risk of a stroke from AF. Those are patients with hypertension, diabetes mellitus, congestive heart failure, a previous stroke or those aged ≥65 years.[1] A study

needs to be conducted to evaluate the specificity and sensitivity of this device in these high-risk patients. In addition, long-term studies following patients using this device at home needs to be conducted to determine the number of new episodes of AF detected and the cost of the false positive readings.

The natural inclination, for someone who has an abnormal heart rhythm reading when taking their blood pressure, is to repeat the reading. Based on our data, repeating the reading three times improves both the sensitivity and specificity for AF detection. Those who have multiple abnormal pulse readings would be told to visit their physician to assess their rhythm with an EKG. Those with newly diagnosed AF can then be treated appropriately. Those found to have a non-AF abnormal rhythm would be informed that they cannot use the device to monitor for AF. Those found to have a normal rhythm at the time of the office visit would require further evaluation to determine the cause of the abnormal device reading. In a previous study of patients with a history of AF, 2 out of 19 patients had intermittent abnormal device readings that were diagnosed by use of an EKG event monitor.[10] This is similar to the evaluation that these patients would have if they were seen by their physicians complaining of intermittent palpitations that was not diagnosed by the office 12-lead EKG. Though visiting their physician for a false positive reading may be inconvenient and add some cost, it does not result in any harm to the patient. Typical medical costs of a false positive reading would be $80 for an office visit and an EKG with the possibility of an additional $250 if an EKG event monitor was needed to diagnose the arrhythmia. There may be some anxiety experienced by patients with an abnormal reading prior to seeing their physician, due to concern about having AF. This is inevitable with any home screening technique, such as breast self-examination for women. Yet, if the technique can save lives or prevent strokes, then it is still reasonable to recommend it.

Anticoagulation is recommended prior to cardioversion for patients with AF for over 48 h.[1] Based on the recent TRENDS study, AF needs to be present longer than 5.5 h to increase the risk of stroke.[6] The precise amount of time that is required for a thrombus to form in a patient with AF has not yet been determined. However, it is clear that AF needs to be present for hours before the risk of a stroke increases. Therefore, intermittent monitoring for AF using this blood pressure device would be reasonable. The maximum time period between readings that would ensure detection of AF that could cause a stroke has yet to be determined. Until this period is determined, taking once daily readings is a reasonable compromise for maintaining patient compliance while providing a good likelihood of detecting AF that could cause a stroke.

In some patients, AF is transient and lasts for only a few minutes or hours. However, current recommendations suggest anticoagulation for patients with AF and stroke risk factors, independent of the length of the AF episode. The reason for this is that patients with brief episodes of AF are at risk of developing prolonged episodes of asymptomatic AF which could result in a stroke. Regular use of this device is likely to detect prolonged asymptomatic episodes of AF. Whether this device can be used to defer treatment with anticoagulation in these patients until a prolonged episode of AF is detected will need to be determined by future clinical trials.

Home monitoring of blood pressure for patients with hypertension has been shown to be of clinical value.[15] Because hypertension is the most common risk factor associated with AF, the use of a home blood pressure monitor to detect asymptomatic AF could provide additional benefit. The Microlife AF detection blood pressure monitor with the new algorithm has high sensitivity and is able to correctly classify the majority of non-AF rhythms. Use of this oscillometric blood pressure monitor with AF detection by high-risk patients may have the potential to significantly reduce the risk of strokes due to asymptomatic AF.

Acknowledgment: This study was supported by a grant from: Microlife USA, Inc., Dunedin, FL.

Disclosure: J.W. has a patent for the atrial fibrillation algorithm. The other authors declared no conflict of interest.

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