How can we best detect atrial fibrillation?

[1]K Harris, [2]D Edwards, [3]J Mant

[1]Academic Clinical Fellow; [2]Clinical Research Associate; [3]Professor; General Practice & Primary Care Research Unit, Strangeways Research Laboratory, University of Cambridge, Cambridge, UK

ABSTRACT

Atrial fibrillation (AF) is an arrhythmia of increasing prevalence associated with a reducible risk of stroke. We conducted a systematic review to address five questions relating to how we can best detect AF:

1. **Are there useful screening tests to determine who should have a 12-lead electrocardiogram (ECG)?** Potential screening tests, all with acceptable sensitivity, include pulse palpation, single-lead ECG and newer technologies such as modified sphygmomanometers or a finger probe device. Pulse palpation has a high number of false positives, but is the cheapest method.
2. **Is it more effective to offer 12-lead ECGs to the whole population (or specific sub-groups) or only to those who screen positive for AF?** The cost-effectiveness of new devices, such as a modified blood pressure monitor, needs to be assessed. It is more cost-effective to opportunistically screen people rather than to offer a 12-lead ECG to everybody.
3. **How accurate are different healthcare professionals and interpretative software at diagnosing AF on ECG?** Definitive diagnosis of AF should be by 12-lead ECG, interpreted by someone with appropriate expertise. Computer software is not currently sensitive enough to be used alone to diagnose AF on ECG. Primary care practitioners may not accurately detect AF on ECG, but consistently high accuracy can be achieved by healthcare professionals with adequate training.
4. **How best can we diagnose paroxysmal atrial fibrillation (PAF)?** In patients in whom PAF is suspected, longer periods of monitoring will detect more cases of PAF.
5. **What is the impact of the use of different ECG monitoring strategies (e.g. Holter monitoring, serial ECGs, continuous ECG) on AF detection rates post-stroke?** In patients post-stroke, a single ECG will miss cases of PAF which can be detected by longer duration monitoring such as Holter monitoring, cardiac event recorders and serial ECGs. Further research into the cost-effectiveness of these methods, the duration of monitoring required and the clinical significance of the PAF detected is needed.

DECLARATION OF INTERESTS Professor Mant has received consultancy fees (lapsed personal; current non-personal) from Boehringer Ingelheim. Dr Harris and Dr Edwards have no interests to declare.

Correspondence to J Mant
General Practice & Primary Care Research Unit, Strangeways Research Laboratory, University of Cambridge, Wort's Causeway, Cambridge CB1 8RN, UK

jm677@medschl.cam.ac.uk

INTRODUCTION

Atrial fibrillation (AF) is an arrhythmia present in around 1% of the population.[1] It is characterised by an irregular heartbeat and is associated with symptoms such as palpitations, chest pain, breathlessness and dizziness. On an electrocardiogram (ECG) AF is characterised by an absence of consistent P waves.[2] The prevalence is strongly associated with age, with over 8% of people aged 65 or over in AF.[3] Indeed, 85% of people in AF are aged 65 or over.[1] AF is becoming more common, not only in association with an ageing population, but also as a result of an increase in age-specific incidence,[4] likely to be due to improved survival of people with ischaemic heart disease, which is linked to the majority of cases of AF.[5] The presence of AF is associated with a five-fold increased risk of stroke, independent of other risk factors[6] but it is often asymptomatic and the first presentation may be with a stroke.[7] If AF is detected, the risk of stroke can be substantially reduced by oral anticoagulation, whether with vitamin K antagonists (VKA)[8] or with one of the newer anticoagulants such as dabigatran.[9]

The chronic forms of AF can be divided into paroxysmal AF (more than one episode with spontaneous termination within seven days, but usually within 48 hours); persistent AF (not self-terminating, or lasting more than seven days) and permanent AF (not terminated, terminated but relapsed or no cardioversion attempt made). Silent or asymptomatic AF may occur in any of

these temporal forms, and carries a similar prognosis to symptomatic AF.[10,11] About a quarter of AF is paroxysmal,[1] which carries a similar prognosis to permanent AF.[12]

The accepted investigation for diagnosing permanent AF is a 12-lead ECG. This will only pick up paroxysmal AF if the test is performed while a paroxysm is in progress. How best to detect AF may be operationalised into a number of different research questions:

1. Are there useful screening tests to determine who should have a 12-lead ECG? Potential such tests include pulse palpation, single-lead ECGs or new technologies such as finger probes or modified blood pressure monitors.
2. Is it more effective to offer 12-lead ECGs to the whole population (or specific sub-groups) or only to those who screen positive for AF?
3. How accurate are different healthcare professionals and interpretative software at diagnosing AF on ECG?
4. How best can we diagnose paroxysmal AF?

A particular sub-group of people in whom there is particular interest in diagnosing AF is in people who have had a stroke/transient ischaemic attack (TIA), since their recurrent risks of stroke are very high. While the major focus of this review is on community detection of AF, we also look at the impact of different methods of diagnosing AF after acute stroke, addressing the question:

5. What is the impact of the use of different ECG monitoring strategies (e.g. Holter monitoring, serial ECGs, continuous ECG) on AF detection rates post-stroke?

METHODS

This narrative literature review uses papers cited in the 2006 NICE guidance on AF and a systematic search of Medline and Embase using the MeSH terms 'atrial fibrillation' and 'sensitivity and specificity' and 'electrocardiography' or 'pulse' or 'electrocardiography, ambulatory' or 'diagnostic techniques, cardiovascular' or 'sphygmomanometers', limiting our search to English language publications from 2006 onwards. After identifying all potentially relevant papers we then reviewed their references to find additional publications. We excluded from our search papers considering incidental detection of AF by devices such as pacemakers.

DESCRIPTION OF STUDIES

1. Are there useful screening tests to determine who should have a 12-lead ECG?

a) Pulse palpation

We found four relevant studies which were all set in UK general practices and involved pulse palpation by a practice nurse (Table 1). When the assessment was for any pulse irregularity, pulse palpation was reasonably sensitive (87%–97%), but not very specific (70%–81%). The largest study, which involved 25 general practices and is probably the most representative of clinical practice, found the lowest sensitivity.[13] In the general population, the majority (70–87%) of people with any pulse irregularity will not have AF, as demonstrated by the low positive predictive values. Morgan et al[14] found that specificity could be improved (and correspondingly, positive predictive value) if continuous pulse irregularity was sought, but at the cost of a big drop in sensitivity (from 91% to 54%).

b) Single-lead ECGs

A single-lead ECG avoids the need for the patient to remove clothing and is quicker to perform than a 12-lead ECG. However, inevitably some information is lost which may lead to a reduced ability to detect AF. Our search revealed four relevant studies which are summarised in Table 2. When interpreting such studies, it is important to distinguish between the effect of using a simpler ECG, and the effect of using (as would usually be the case in clinical practice) a non-expert to interpret the trace. Who reads the ECG appears to be a much more important factor than how the reading was obtained. Thus, in the study by Mant et al[15] the relatively poor results of single-lead ECGs (sensitivity of 83-85% and specificity of 87–89% when interpreted by GPs) were similar to the results obtained for 12-lead ECGs when read by GPs (Table 3). In contrast, Doliwa et al[16] and Somerville et al[17] found high sensitivity (92% and 96%) and high specificity (96% and 98%) when a bipolar 'thumb' ECG was read by a cardiologist, and a bipolar ECG was read by an experienced GP, respectively.

c) New technologies

We found four relevant studies that considered two devices which could be used for screening for AF in the general population. The studies are summarised in Table 3. The device described by Lewis et al[18] is a finger probe similar to that used in general practice for pulse oximetry which uses the principle of photoplethysmography. The two studies by Wiesel et al[19,20] and that by Stergiou et al[21] consider a modified blood pressure monitor similar to those used by patients to monitor their blood pressure at home. This could either be used by people monitoring their own blood pressure to self-screen for AF or by primary care professionals to opportunistically screen patients. These devices benefit from the ability to modify thresholds of detection in order to achieve maximum sensitivity to optimise their value as screening devices.

In general, a screening test needs to have high sensitivity so it doesn't miss cases. The higher the specificity, the fewer people who need to have the reference standard investigation. The reference standard test in diagnosing AF, a 12-lead ECG, is readily available, non-invasive and relatively inexpensive. Its main drawbacks are that it is time consuming to use and requires some degree of

TABLE 1 Studies of the accuracy of pulse palpation in the diagnosis of atrial fibrillation.

Study	**Population**	**Reference standard**	**Method being tested**	**Sensitivity** % (95% confidence interval where known)	**Specificity** % (95% confidence interval where known)	**Positive predictive value** (95% confidence interval where known)
Morgan et al (2001)[14]	1,099 patients aged over 65 randomly selected from four general practices. Prevalence of AF 6.1%.*	Single lead (lead II) rhythm strip interpreted by the first author, who is a GP	Nurse pulse assessment of any pulse irregularity	91 (82–97)	74 (72–77)	19 (15–23)
			Nurse pulse assessment of frequent or continuous pulse irregularity	72 (59–82)	94 (93–96)	44 (35–54)
			Nurse pulse assessment of continuous pulse irregularity	54 (41–66)	98 (97–99)	61 (47–73)
Sudlow et al (1998)[33]	916 patients aged over 65 from nine GP practices in Northumberland. Prevalence AF 4.6%.*	Limb-lead ECG	Nurse pulse assessment of any pulse irregularity	95 (85–98)*	70 (67–73)*	13
Somerville et al (2000)[17]	86 patients selected from a single GP practice by inviting all patients aged over 65 with recorded AF and an equal number of patients over 65 without a diagnosis of AF. Prevalence of AF 30%.	12-lead ECG interpreted by a cardiologist	Nurse pulse assessment of any pulse irregularity	97	79	68+
Hobbs et al (2005)[13]	2,578 randomly selected people aged over 65 from 25 GP practices taking part in the SAFE randomised control trial between 2001 and 2003. Prevalence of AF 8.5%.	12-lead ECG interpreted by two independent cardiologists with a third cardiologist arbitrating if they were in disagreement	Nurse pulse assessment of any pulse irregularity	87	81	30

* Extra information from review by Cooke et al.[34]
\+ Note the population used in this study had a much higher prevalence of AF than in the other studies.

privacy to perform. With regard to potential screening tests for AF, the simplest is pulse palpation. With a sensitivity of approximately 90%, this is a reasonable screening test. The specificity is only moderate, with the result that in community settings, for every case of AF that is diagnosed, a further four people will have had an ECG that does not show AF. Thus, there is potential interest in screening tests with higher specificity, such as 'cut down' versions of 12-lead ECGs. Ignoring the issue of who reads the 'cut down' ECG, such tests are more specific than pulse palpation. Somerville et al[17] for example found a specificity of 98% using a bipolar ECG. This would translate to a positive predictive value of 77% in a population with a 7% prevalence of AF if the test sensitivity was 90% (i.e. three cases of AF would be diagnosed for every four 12-lead ECGs performed as a result of a positive bipolar ECG). However, in practice, who reads the ECGs needs to be taken into account as well. The study by Gregg et al[22] found that interpretative software applied to a 'cut down' ECG only led to a

TABLE 2 Studies of the accuracy of electrocardiograms with less than 12-leads in diagnosis of atrial fibrillation.

Study	**Population**	**Reference standard**	**Method being tested**	**Sensitivity** % (95% confidence interval where known)	**Specificity** % (95% confidence interval where known)	**Positive predictive value** (95% confidence interval where known)
Somerville et al (2000)[17]	86 patients selected from a single GP practice by inviting all patients aged 65 or over with recorded AF and an equal number of patients over 65 without a diagnosis of AF.	12-lead ECG interpreted by a cardiologist	Bipolar ECG interpreted by a GP	96 (80–100)	98 (91–100)	96
			Bipolar ECG interpreted by a nurse	94	92.5	84
Gregg et al (2008)[22]	1,785 ECGs randomly selected from teaching hospital database.	12-lead ECG interpreted by a cardiologist	12-lead ECG with leads V1-V6 reconstructed from V2,V5 interpreted by inter-pretative software	84 (76–90)	99 (98–99)	84
			12-lead ECG with leads V1-V6 reconstructed from V1,V4 interpreted by inter-pretative software	88 (81–93)	99 (98–99)	85
Doliwa et al (2008)[16]	100 patients with AF, atrial flutter or sinus rhythm from cardiology clinic.+	12-lead ECG interpreted by a cardiologist	Bipolar 'thumb' ECG interpreted by a cardiologist	92	96	96
Mant et al (2007)[15]	2,595 randomly selected people aged 65 or over from 25 practices taking part in the SAFE randomised controlled trial between 2001 and 2003.	12-lead ECG interpreted by two independent cardiologists with a third cardiologist arbitrating if they were in disagreement	Single lead thoracic placement ECG interpreted by a GP	84.8 (78.7–91.0)	86.4 (84.6–88.3)	
			Single-lead limb lead ECG interpreted by a GP	82.5 (74.8–88.7)	88.5 (86.9–90.2)	
			Single-lead thoracic placement ECG interpreted by a nurse	68.7 (60.1–76.4)	82.8 (80.7–84.8)	
			Single-lead limb lead ECG interpreted by a nurse	72.0 (63.9–80.1)	83.4 (81.4–85.4)	
+ Cases of atrial flutter were included in detection rates for AF in this study						

sensitivity of 84–88%, no better than pulse palpation. Studies evaluating newer technologies such as finger probes and modified blood pressure readings suggest that a sensitivity of greater than 90% could be achieved while maintaining reasonable specificity (84%–92%) (Table 3). In considering the potential role of these

TABLE 3 Studies of the accuracy of alternative technologies in the diagnosis of atrial fibrillation.

Study	Population	Reference standard	Method being tested	Sensitivity % (95% confidence interval where known)	Specificity % (95% confidence interval where known)	Positive predictive value (95% confidence interval where known)
Lewis et al (2010)[18]	594 patients aged over 60 years old attending hospital outpatient clinics or inpatients at two hospitals in South Wales or New York.	12-lead ECG interpreted by a cardiologist	Finger probe with threshold set after reference standard results available so sensitivity 100% with highest possible coexisting specificity	100	91.1	
Wiesel et al (2004)[19]	125 cardiology outpatients seen between April and August 2002.	12-lead ECG	Modified blood pressure monitor, single reading threshold set after reference standard results available so sensitivity 100% with highest possible coexisting specificity	100	92	90
	450 cardiology outpatients seen between April and August 2002.	12-lead ECG	Modified blood pressure monitor, single reading	100	84	
			Modified blood pressure monitor, two readings where final result irregular if both readings are irregular	100	91	
Wiesel et al (2009)[20]	405 cardiology outpatients in two cardiology departments in New York.	12-lead ECG interpreted by a cardiologist	Modified blood pressure monitor, single reading	95.3 (92.8–97.6)	86.4 (84.3–97.6)	68
			Modified blood pressure monitor, three readings where final result irregular if two out of three readings are irregular	96.8 (91–99)	88.8 (85–92)	72
Stergiou et al (2009)[21]	73 patients aged over 35 with known AF or other arrhythmias and controls with sinus rhythm from an outpatient hypertension clinic, patients admitted to a medical ward and healthy volunteers.	12-lead ECG interpreted by an author and verified by a cardiologist	Modified blood pressure monitor, single reading	93 (74–99)	89 (76–96)	83
			Modified blood pressure monitor, three readings where final result irregular if two out of three readings are irregular	100 (94–100)	89 (75–96)	84

screening tools, the added costs of the screening needs to be set against the value of the detection of new cases of AF. A cost-effectiveness analysis comparing the use of a 12-lead ECG or 'cut down' ECGs found that the incremental cost per new case identified was similar.[13] However, given that a 12-lead ECG would be indicated in someone who is in AF (a cost not taken into account in the cost-effectiveness analysis), this would raise the relative cost of a strategy that screened for AF using simplified ECGs. Nevertheless, there would be a potential advantage in using a device that detected AF while performing another function (e.g. measuring blood

TABLE 4 Studies of the detection rates of atrial fibrillation through screening.

Study	Population	Allocation	Systematic screening arm	Opportunistic screening arm	Results
Fitzmaurice et al (2007)[3]	14,802 patients aged 65 or over in 50 GP practices between October 2001 and February 2003.	GP practices divided into 25 intervention and 25 control practices. Patients in the intervention practices were randomly allocated to systematic or opportunistic screening	Requested to attend for ECG	Notes flagged to encourage pulse check during routine consultation, with ECG if found to be irregular	Detection rate of new cases of AF of 1.64% with systematic screening and 1.62% with opportunistic screening compared with 1.04% in control practices. There was no significant difference between opportunistic and systematic screening (difference 0.02%, -0.5% to 0.5%)
Morgan et al (2001)[14]	3,001 patients from four GP practices.	Patients randomly allocated to either systematic or opportunistic arm	Requested to attend for pulse palpation by nurse and ECG	Flag inserted in notes to request that if pulse checked as part of normal practice results recorded and ECG if suspicious of AF	In the screening arm 1,099 (73.3%) patients had pulse assessments and 439 (29.2%) patients in the opportunistic arm. In the screening arm 67 (4.5%) patients had AF compared to 19 (1.3%) in the opportunistic arm, with a difference in percentage detected of 3.2% (95% confidence interval 2.0–4.4). In 82% of those detected in the systematic screening arm AF had previously been recorded somewhere in their notes

pressure), since there will be minimal additional time costs. We did not identify any cost-effectiveness analyses of the use of such devices.

2. Is it more effective to offer 12-lead ECGs in the whole population (or specific sub-groups) or only to those who screen positive for AF?

Given that the reference standard test (12-lead ECG) is relatively straightforward to perform, an important question to address is whether screening should simply be carried out with this tool, without using any prior investigations. A related question is whether screening should be systematic (i.e. invite all people over a certain age for screening or in a particular sub-group) or opportunistic (i.e. screen for AF when a patient attends the general practice for another reason). These questions are linked as systematic screening is likely to be with a 12-lead ECG, and opportunistic screening with one of the approaches discussed above.

We found two studies that addressed this question (Table 4). The largest of these, the SAFE study, involved randomisation of 50 practices to either screening or no screening.[3] Within the 25 practices randomised to screening, there was further randomisation at an individual patient level to opportunistic or systematic screening. In the opportunistic arm, a 'flag' (paper or electronic) was placed in the patient record to prompt a member of the primary care team to take the patient's pulse if they attended the practice. If the pulse was found to be irregular, then a 12-lead ECG was offered. In the systematic screening arm, patients were invited to attend the practice for a 12-lead ECG. The detection rate of new cases of AF was significantly higher in the screening practices as compared to the control practices, but there was no difference in the detection rate between systematic or opportunistic arms in the intervention practices. An economic analysis showed that opportunistic screening performed better than systematic screening (it was as effective but cost less), and was likely to be cost-effective in terms of cost per Quality Adjusted Life Year (QALY) gained as a result of reduced stroke incidence.

The second study randomised patients from four practices to systematic or opportunistic screening.[14] In contrast to the SAFE study,[3] this found systematic screening to be more effective than opportunistic screening. The take-up of opportunistic screening in this study was lower than in SAFE (29% over a six-month period vs 69% over a year), and the take-up of systematic screening higher (73% vs 53%). The clinical implications of the second study are less clear, since the majority of

TABLE 5 Studies of the accuracy of GPs, practice nurses and interpretive software in diagnosing atrial fibrillation on electrocardiogram.

Study	Population	Reference standard	Method being tested	Sensitivity % (95% confidence interval where known)	Specificity % (95% confidence interval where known)	Positive predictive value (95% confidence interval where known)
Mant et al (2007)[15]	2,595 randomly selected people aged 65 or over from 25 practices taking part in the SAFE randomised control trial between 2001 and 2003.	Two independent cardiologists with a third cardiologist arbitrating if they were in dis-agreement	ECG interpretation by GPs	80 (71–87)	92 (90–93)	40.9
			ECG interpretation by practice nurses	77 (67–85)	85 (83–87)	27.2
			ECG interpretation by interpretative software	83	99	89.5
			ECG interpretation by GP and interpretative software	Either positive: 92 Both positive: 71	91 99.8	42.9 95.9
Somerville et al (2000)[17]	86 patients selected from a single GP practice by inviting all patients aged over 65 with recorded AF and an equal number of patients over 65 without a diagnosis of AF.	Single cardiologist	ECG interpretation by GP	100 (87–100)	98 (91–100)	96.0
			ECG interpretation by practice nurses	97	88	79.0
Anh et al (2006)[24]	2,298 consecutive ECGs with a software interpretation of AF from a hospital database between December 2001 and June 2002.	Two independent electro-physiologists	ECG interpretation by interpretative software			81
Poon et al (2005)[35]	4,297 consecutive inpatient or outpatient ECGs from a teaching hospital.	One of two independent cardiologists with the second checking any ECGs where the first cardiologist disagreed with the initial computer inter-pretation	ECG interpretation by interpretative software	90.8	98.9	84.7

patients identified through systematic screening (82%) already had a diagnosis of AF in their records, as compared to only 59% of the opportunistically screened group.

An integral part of determining screening strategy is to decide what population to include. Both these studies involved people aged 65 or over. SAFE also included a sub-study of the potential impact of screening in 'high-risk' people over the age of 65, i.e. those with a previous diagnosis of heart failure, hypertension, rheumatic heart disease, ischaemic heart disease, hyperthyroidism, or stroke/TIA.[13] A strategy of opportunistic screening of all people was both more effective and cost less than a strategy of systematic invitations to people in these sub-groups.

3. How accurate are different healthcare professionals and interpretative software at diagnosing AF on ECG?

A systematic review by Salerno et al in 2003[23] of ECG interpretation accuracy studies found that both physicians and computer software frequently made errors compared to expert electrocardiographers, however there was also frequent disagreement in interpretation between experts.

Our search identified four studies which are summarised in Table 5. The largest study, by Mant et al[15] investigated the ability of 42 general practitioners and 41 practice nurses to detect AF on ECGs generated during the SAFE study. Overall, primary care practitioners could not detect AF on an ECG with sufficient accuracy to guide therapy (GP sensitivity 80%; specificity 92%; practice nurse sensitivity 77%; specificity 85%). Interpretative software was found to be highly specific (99%), but insufficiently sensitive (83%). In practice, most ECG machines have interpretative software, but combining interpretative software with GP interpretation only improved the sensitivity to 92%.

In contrast, Somerville et al[17] found much higher sensitivity (100%) and specificity (98%) in their study of the performance of a single general practitioner. This is consistent with the findings of Mant et al[15] in that some GPs in this study did perform as well as this (though the majority did not). This suggests that GPs can detect AF on ECGs accurately, with appropriate training. Indeed, it is of interest that the two cardiologists in the SAFE study, who independently read 2,592 ECGs, only disagreed on the presence of AF in seven (0.27%) cases.

The accuracy of interpretative software will of course depend upon the diagnostic algorithm that it uses. In the study by Mant et al[15] all the ECGs were read using the same computer software. The two other studies that evaluated the accuracy of computer software for detecting AF found similar results to Mant et al[15] even though different software was employed, suggesting that there may be some consistency between the algorithms used. Interpretative software is probably not yet good enough to be a diagnostic gold standard, but it is conceivable that improvements in the diagnostic algorithms in the future may make this possible.

These studies suggest that quality control of the interpretation of ECGs is an important aspect of diagnosis of AF in primary care. Two potential strategies to address this are to provide training to healthcare professionals who regularly read ECGs for AF, or to have ECGs centrally read. Of note with regard to the latter strategy, Anh et al[24] found that in the case of incorrect computer diagnosis, cardiologists corrected the ECGs more often than other specialists when they had ordered the ECG (94% vs 71%). However, when cardiologists had no patient contact and were presumably re-reading multiple ECGs, they corrected significantly less incorrect AF diagnoses than when they were the ordering physician (72 vs 94%).

4. How best can we diagnose paroxysmal atrial fibrillation?

While a 12-lead ECG is the accepted reference standard for diagnosing permanent AF, it will only pick up some cases of paroxysmal AF, since the ECG recording is made at a fixed point in time which may or may not coincide with an episode of AF. Many patients with AF do not experience symptoms and there is not always a good correlation between symptoms and episodes of AF.[25] We found no studies evaluating multiple-moment-in-time ECG monitoring in the asymptomatic general population. We found two studies where patients had been referred for suspected arrhythmias because of symptoms (usually palpitations, Table 6). Both studies compare the use of Holter monitoring (over 24–48 hours) with longer term monitoring (up to 90 days).

Reiffel et al[26] found that the use of memory loop recorders for 30 days detected significantly more cases of AF than a 24-hour Holter monitor did, and that auto-triggered memory loop recorders detected more AF than standard memory loop recorders. This study involved a retrospective review of records, so it is possible that there was indication bias (i.e. the clinician may have used memory loop recorders in patients where they thought there was a higher likelihood of detecting AF).

Kinlay et al[27] performed a randomised crossover trial comparing the use of Holter monitoring for 48-hours against the use of a trans-telephonic post-event recorder, a handheld device that the patient activates when symptoms occur. The event monitors detected eight clinically important arrhythmias (including two cases of AF) in 43 patients, while Holter monitoring detected none.

TABLE 6 Studies of the detection rates in patients with suspected atrial fibrillation using Holter monitors and event recorders.

Study	Population	Method being tested	Detection rate (%)
Reiffel et al (2005)[26]	600 patients retrospectively randomly selected from a database of recordings from patients referred for monitoring of known or suspected arrhythmias during 2003.	24-hour Holter monitor	4.5
		30-day memory loop recording	12.5
		30-day autotriggered memory loop recording	24.3
Kinlay et al (1996)[27]	43 patients referred to an Australian hospital for first time Holter monitoring for palpitations.	48-hour Holter monitor	0
		Three-month trans-telephonic event monitor	4.7

5. What is the impact of the use of different ECG monitoring strategies on AF detection rates post-stroke?

In contrast to the relative lack of studies on the detection of paroxysmal AF in the general population, we found several studies looking at detection rates of AF following stroke (Table 7). Performing an ECG on admission is standard practice but will miss some cases of PAF. The detection rates in these studies vary widely from 0% to 45%. This variation reflects differences in study population, method of ECG monitoring used (e.g. serial ECGs, Holter monitors, continuous ECG monitoring, cardiac event recorders), minimum duration of AF required for diagnosis and length of time that the ECG monitoring was carried out. It is therefore difficult to draw any firm conclusions, other than that the longer the monitoring is carried out, the more cases of AF are detected (Figure 1). Newer technologies are emerging in this rapidly developing field. For example, implantable cardiac event monitors can be used which potentially allow for long-term detection of AF.[28] Before firm recommendations can be made on the optimal strategy for detecting AF post-stroke, stronger evidence is needed on the utility of detection of these additional cases of AF. While there is evidence that paroxysmal AF carries a similar prognosis to permanent AF[29,12] data are required to confirm that AF detected using these novel approaches carries the same risk. Recently, Healey et al found that subclinical atrial tachyarrhythmias lasting at least six minutes detected by implanted devices were associated with an increased risk of ischaemic stroke or systemic embolism (hazard ratio: 2.5, 95% CI 1.3–4.9)[30], but this is lower than that associated with clinical AF. It should be noted that several of the studies listed in Table 7 defined AF using time periods considerably shorter than six minutes. Comparative evidence of the cost-effectiveness of the different monitoring strategies is required, ideally from randomised controlled trials.

TOWARDS A STRATEGY TO DETECT AF

It is likely to be cost-effective to opportunistically screen patients aged over 65 annually for AF. This means opportunistically checking the patient's pulse when they

TABLE 7 Studies of the detection rates of atrial fibrillation in acute stroke/transient ischaemic attack (TIA) patients.

Study	Population	Method being tested	Time to starting measurement	Definition of paroxysmal atrial fibrillation	Detection rate (%)
Gunalp et al (2006)[36]	26 patients presenting with acute stroke and an ischaemic lesion >3 cm, excluding those with a rhythm disturbance on admission ECG and those taking certain medications.	24-hour Holter ECG			45 (n=11)
Tagawa et al (2007)[37]	308 consecutive patients presenting with acute ischaemic stroke at a Japanese hospital between November 2001 and May 2004.	24-hour Holter ECG	Mean 5.8 days (range 2–18 days)		31.5

TABLE 7 (continued) Studies of the detection rates of atrial fibrillation in acute stroke/transient ischeamic attack (TIA) patients.

Study	Population	Method being tested	Time to starting measurement	Definition of paroxysmal atrial fibrillation	Detection rate (%)
Douen et al[38] (2008)	Retrospective study of 126 patients admitted to a stroke unit, excluding those with intra-cerebal haemorrhage during an 8.5 month period in 2005.	Holter ECG, duration not specified			9.5*
Yu et al[39] (2009)	Retrospective study of 96 patients admitted to a teaching hospital with ischaemic stroke, excluding those with known AF from January 2003 to December 2005.	24-hour Holter monitor	During admission		9.4
Alhadramy et al[40] (2010)	Retrospective study of 413 patients diagnosed with stroke or TIA, excluding those with history of AF, at a university stroke clinic between September 2005 and September 2006.	Holter ECG, average 22.6 hours	From a few days to three months	Any duration	9.2
				>30 seconds	2.5
Lazzaro et al[41] (2010)	133 patients admitted to a teaching hospital with ischaemic stroke or TIA between June 2007 and December 2008, excluding those with a history of AF or AF on admission ECG.	Holter ECG, mean duration 29.8 hours	During admission	>30 seconds	6.0
Barthelemy et al[42] (2003)	55 patients admitted to a university hospital with stroke or TIA, excluding those with AF detected on two admission ECGs between January and December 1998.	24-hour Holter ECG	During admission	>30 seconds	5.5
Jabaudon et al[43] (2004)	139 patients admitted with suspicion of acute stroke or TIA to a university hospital, excluding those with haemorrhagic stroke or recent history of AF or AF detected on initial ECG, between February and December 2002.	24-hour Holter ECG	Median 8 days (range 1–29)		5.0 (confidence interval 2.3–10.2)
Koudstaal et al[44] (1986)	Retrospective study of 100 patients admitted to a teaching hospital with a TIA who had a Holter monitor.	24-hour Holter ECG	Mean 15.2 days from onset of symptoms		5
Schaer et al[45] (2004)	Retrospective study of 425 hospitalised patients admitted with cerebral ischaemic event who had a Holter ECG between January 2000 and December 2002.	24-hour Holter ECG		>30 seconds	4.9

TABLE 7 (continued) Studies of the detection rates of atrial fibrillation in acute stroke/transient ischeamic attack (TIA) patients.

Study	Population	Method being tested	Time to starting measurement	Definition of paroxysmal atrial fibrillation	Detection rate (%)
Stahrenberg et al[46] (2010)	224 patients presenting with suspected stroke/TIA to an Emergency Department between March 2009 and February 2010 excluding those with AF on baseline ECG.	24-hour Holter ECG (average of seven 24-hour records)	Median 5.5 hours after admission	>30 seconds	4.8
		48-hour Holter ECG (average of six 48-hour records)	Median 5.5 hours after admission	>30 seconds	6.4
		Seven day Holter ECG	Median 5.5 hours after admission	>30 seconds	12.5
				>10 beats in a row	43.8
Rem et al[47] (1985)	151 patients with acute stroke or TIA admitted to a stroke unit, excluding those with a history of arrhythmia or detected on admission ECG or 48-hour cardiac monitoring, between January and December 1983.	24–48-hour Holter ECG			3.9
Hornig et al[48] (1996)	261 patients with acute focal brain ischaemia, excluding those in AF on admission ECG.	24-hour Holter ECG			3.8
Shafqat et al[49] (2003)	Retrospective study of 194 patients admitted to a teaching hospital with acute ischaemic stroke, excluding those with AF on admission ECG.	24-hour Holter ECG			2.6
Rizos et al[50] (2010)	120 patients aged over 60 presenting with acute stroke or TIA at a university hospital, excluding those with history of AF or AF shown on admission ECG or continuous ECG in first 24 hours, between July 2008 and March 2009.	24-hour Holter ECG	Median 49 hours	>30 seconds	2.5
Schuchert et al[51] (1999)	82 patients with acute ischaemic stroke, excluding those with a history of AF or AF on resting ECG.	24-hour Holter ECG	2–3 weeks	> 60 seconds	1.2
		48-hour Holter ECG		> 60 seconds	3.7
		72-hour Holter ECG		> 60 seconds	6.1
Gunalp et al[36] (2006)	26 patients presenting with acute stroke and an ischaemic lesion >3 cm, excluding those with a rhythm disturbance on admission ECG and those taking certain medications.	Three ECGs taken at six hourly intervals	Six hours after admission ECG		11 (n=3)
Kamel et al[52] (2009)	Retrospective study of 2,504 patients with acute stroke in the placebo arms of four randomised control trials, excluding those with a history of AF or AF on their admission ECG.	Serial ECGs up to 90 days	All patients enrolled within 12 hours of onset of symptoms, ECGs started on admission		6.9

TABLE 7 (continued) Studies of the detection rates of atrial fibrillation in acute stroke/transient ischeamic attack (TIA) patients.

Study	Population	Method being tested	Time to starting measurement	Definition of paroxysmal atrial fibrillation	Detection rate (%)
Douen et al[38] (2008)	Retrospective review of 126 patients admitted to a stroke unit, excluding those with intra-cerebal haemorrhage and those with a history of AF or AF detected on admission ECG during an 8.5 month period in 2005.	Serial ECGs in first 72 hours after admission			6.3*
Gaillard et al[53] (2010)	Retrospective study of 98 patients with acute stroke or TIA admitted to a stroke unit between December 2003 and January 2006 with a negative Holter ECG who had a trans-telephonic ECG.	Trans-telephonic ECG monitoring (patients self-recorded at least one ECG each day for one month and transmitted the results by telephone to a cardiology centre)	Within six months of presentation	>32 seconds	9.2
Rizos et al[50] (2010)	136 patients aged over 60 presenting with acute stroke or TIA at a university hospital, excluding those with a history of AF or AF shown on admission ECG between July 2008 and March 2009.	Continuous bedside ECG monitoring, median duration 97 hours (interquartile range [IQR] 82–144) with confirmation 12-lead ECG of suspected episodes	Immediately on admission to ward		21
Rem et al[47] (1985)	160 patients with acute stroke or TIA admitted to a stroke unit, excluding those with a history of arrhythmia or one detected on admission ECG between January and December 1983.	48-hour bedside cardiac monitoring			2.5
Lazzaro et al[41] (2010)	133 patients admitted to a teaching hospital with ischaemic stroke or TIA between June 2007 and December 2008, excluding those with a history of AF or AF on admission ECG.	Continuous bedside cardiac telemetry, mean duration 73.6 hours with nurse review every eight hours or if abnormal rate/rhythm detected by device	During admission	>30 seconds	0
Barthelemy et al[42] (2003)	52 patients admitted to a university hospital with stroke or TIA, excluding those with AF detected on two admission ECGs or on Holter ECG between January and December 1998.	Automatic self-analysing cardiac event recorders, mean duration 70.1 hours	Mean 10 +/-2 days	>/= 30 seconds	7.7
Tayal et al[54] (2008)	Retrospective study of 56 patients admitted to hospital with TIA/stroke without clear cause between January 2006 and May 2007, excluding those with a history of AF or AF on admission ECG or 24-hour Holter ECG.	21 day mobile cardiac outpatient telemetry monitoring (auto-triggered device which transmits possible AF events to a physician for review)	Median 20 days from onset symptoms	>30 seconds	5.3
				Any duration	23

TABLE 7 (continued) Studies of the detection rates of atrial fibrillation in acute stroke/transient ischaemic attack (TIA) patients.

Study	Population	Method being tested	Time to starting measurement	Definition of paroxysmal atrial fibrillation	Detection rate (%)
Elijovich et al[55] (2009)	Retrospective study of 21 patients with stroke or TIA without clear cause admitted to a university stroke centre or seen in outpatient stroke clinic from June 2006 to March 2007 who were referred for 30-day cardiac event monitor.	30-day ambulatory cardiac event monitor (auto-triggered and patient-triggered recordings were sent to a cardiologist for review)		>30 seconds	20 (n=4)
Jabaudon et al[43] (2004	88 patients admitted with suspicion of acute stroke or TIA to a university hospital, excluding those with haemorrhagic stroke or a recent history of AF or AF detected on initial ECG or 24-hour Holter monitoring and those that refused the test between February and December 2002.	Seven day event loop recording device with auto-triggered and patient-triggered recording	Median 55 days		5.7 (confidence interval 2.1 to 12.9)
Dion et al[56] (2010)	24 patients diagnosed with cryptogenic stroke or TIA who had normal 12-lead ECG, 24-hour Holter monitoring and echocardiography.	Implantable loop recorder, mean duration 14.5 months	Within four months of diagnosis	Any duration	4.2 (n=1)
* The serial ECG detection rate has been calculated from the data available in the paper; it was not possible to calculate the detection rate for Holter ECG excluding those already detected on ECG or history.					

attend the GP surgery for an unrelated reason (e.g. an appointment with the practice nurse for a flu jab) and arranging an ECG if the pulse is irregular. This strategy would have the potential to detect AF in the estimated 97% of patients aged over 65 who see a member of the general practice team at least once annually.[33] Given that the prevalence of AF is over 8% in this age group[3] and average consultation rates are over seven consultations per person-year[34] it would also be good practice to consider checking the pulse for irregularity whenever the opportunity arises.

CONCLUSION

Existing guidelines are summarised in Table 8. The following conclusions may be drawn from this review of the evidence base for the detection of AF.

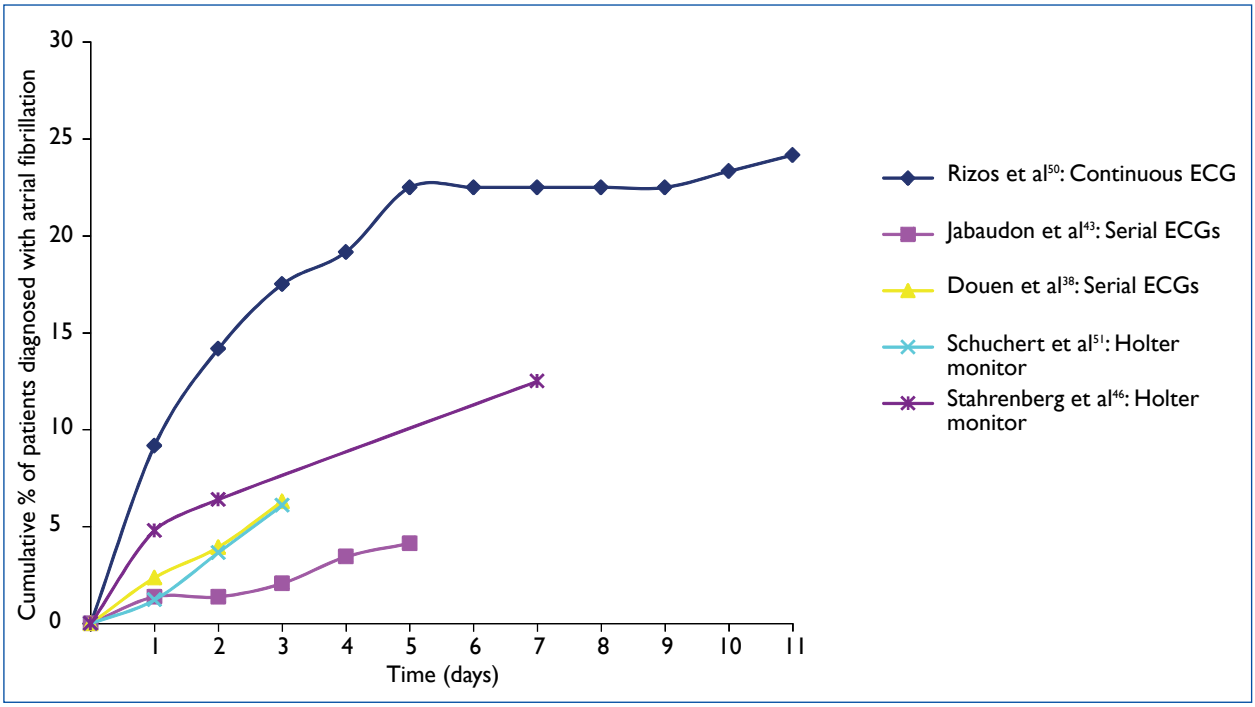
1. In the general population (Figure 2):
- Opportunistic screening is more cost-effective than systematic screening.

Considerations of whom to screen opportunistically will depend on an understanding of the epidemiology of AF. Prevalence of AF and the risk of stroke rise significantly with age, so both potential yield and potential benefit from treatment increases in older age groups. The evidence base for screening is largely in people aged 65 and over.

- A number of methods may be employed to screen opportunistically. The cheapest of these is pulse palpation. The cost-effectiveness of newer technologies such as modified blood pressure monitors need to be assessed.
- 12-lead ECG remains the standard investigation, but the accuracy of this investigation falls if it is read by someone without adequate training.

2. In the symptomatic population (e.g. post-stroke or with symptoms such as palpitations):
- If a 12-lead ECG fails to show AF, then a number of different technologies are available that allow for longer term ECG monitoring. The relative cost-effectiveness of these technologies needs to be evaluated before a firm recommendation can be made in favour of any specific approach.

FIGURE 1 Detection rate of atrial fibrillation versus time post-stroke



ECG: Electrocardiogram

TABLE 8 Summary of current guidance.

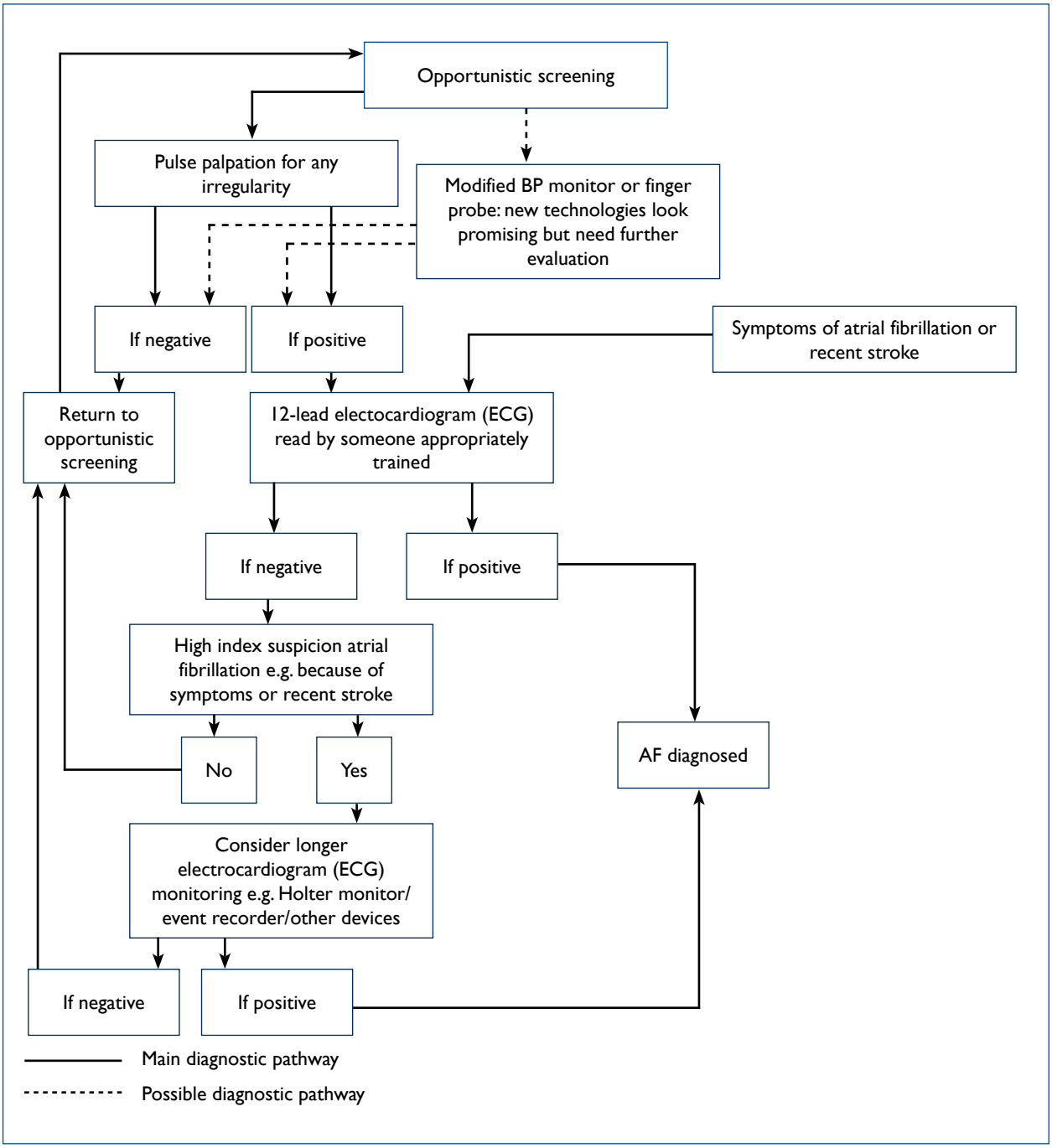
Guidelines	Guidance
ACC/AHA/ESC Guidelines for the management of patients with atrial fibrillation (2006)[57]	The diagnosis of AF requires ECG documentation by at least a single-lead ECG recording during the dysrrhythmia, which may be facilitated by a review of emergency department records, Holter monitoring, or trans-telephonic or telemetric recordings. A portable ECG recording tool may help establish the diagnosis in cases of paroxysmal AF and provide a permanent ECG record of the dysrrhythmia. If episodes are frequent, then a 24-hour Holter monitor can be used. If episodes are infrequent, then an event recorder, which allows the patient to transmit the ECG to a recording facility when the arrhythmia occurs, may be more useful.
NICE Atrial fibrillation guidelines: national clinical guideline for management in primary and secondary care (2006)[2]	In patients presenting with any of the following: breathlessness/dyspnoea, palpitations, syncope/dizziness, chest discomfort, stroke/transient ischaemic attack (TIA): • Manual pulse palpation should be performed to assess for the presence of an irregular pulse that may indicate underlying AF. • An ECG should be performed in all patients, whether symptomatic or not, in whom AF is suspected because an irregular pulse has been detected. In patients with suspected paroxysmal AF undetected by standard ECG recording: • A 24-hour ambulatory ECG monitor should be used in those with suspected asymptomatic episodes or symptomatic episodes less than 24 hours apart. • An event recorded ECG should be used in those with symptomatic episodes more than 24 hours apart.

TABLE 8 (continued) Summary of current guidance.

Guidelines	Guidance
SIGN Cardiac arrhythmias in coronary heart disease (2007)[58]	No specific guidance on how to detect AF.
SIGN Management of patients with stroke or TIA: assessment, investigation, immediate management and secondary prevention (2008)[59]	Guidelines recommend frequent ECG monitoring in the acute phase post-stroke, but does not mention anything specific about detecting AF.
European Stroke Organisation: Guidelines for management of ischaemic stroke and transient ischaemic attack (2008)[60]	It is recommended that all acute stroke and TIA patients should have a 12-lead ECG. In addition, continuous ECG recording is recommended for ischaemic stroke and TIA patients. It is recommended that for stroke and TIA patients seen after the acute phase, 24-hour Holter ECG monitoring should be performed when arrhythmias are suspected and no other causes of stroke are found.
NICE stroke guidance: National clinical guideline for diagnosis and initial management of acute stroke and transient ischaemic attack (TIA) (2008)[61]	No specific guidance on how to detect AF.
ESC Clinical practice guidelines: atrial fibrillation (management of) (2010)[11]	The diagnosis of AF requires documentation by ECG. • In patients with suspected AF, an attempt to record an ECG should be made when symptoms suggestive of AF occur. • In patients with suspected symptomatic AF, additional ECG monitoring should be considered in order to document the arrhythmia. • Additional ECG monitoring should be considered for detection of 'silent' AF in patients who may have sustained an AF-related complication.
Canadian Cardiovascular Society Atrial fibrillation guidelines 2010: prevention of stroke and systematic thromboembolism in atrial fibrillation and flutter[62]	No specific guidance on how to detect AF.
Canadian Cardiovascular Society Atrial fibrillation guidelines 2010: etiology and initial investigations[63]	Does not deal specifically with the detection of AF but does advise that a 12-lead ECG should be part of the baseline evaluation for all patients with AF.
AHA/ASA Guidelines for the prevention of stroke in patients with stroke or transient ischemic attack (2011)[64]	No specific guidance on how to detect AF.

K Harris, D Edwards, J Mant

FIGURE 2 Summary of an evidence-based strategy for the detection of atrial fibrillation in the general population



J R Coll Physicians Edinb 2012; 42(Suppl 18):5–22

REFERENCES

1 Mant J, Wade DT, Winner S. Health care needs assessment: stroke. In: Stevens A, Raftery J, Mant J, Simpson S, editors. *Health care needs assessment: the epidemiologically based needs assessment reviews*. Oxford: Radcliffe Medical Press; 2004. p. 141–244.

2 National Collaborating Centre for Chronic Conditions. *Atrial fibrillation: national clinical guideline for management in primary and secondary care*. London: Royal College of Physicians; 2006.

3 Fitzmaurice DA, Hobbs FD, Jowett S et al. Screening versus routine practice in detection of atrial fibrillation in patients aged 65 or over: cluster randomised controlled trial. *BMJ* 2007; 335:383. http://dx.doi.org/10.1136/bmj.39280.660567.55

4 Wolf PA, Benjamin EJ, Belanger AJ et al. Secular trends in the prevalence of atrial fibrillation: the Framingham Study. *Am Heart J* 1996; 131:790–5. http://dx.doi.org/10.1016/S0002-8703(96)90288-4

5 Furberg CD, Psaty BM, Manolio TA et al. Prevalence of atrial fibrillation in elderly subjects (the Cardiovascular Health Study). *Am J Cardiol* 1994; 74:236–41. http://dx.doi.org/10.1016/0002-9149(94)90363-8

6 Wolf PA, Abbott RD, Kannel WB. Atrial fibrillation as an independent risk factor for stroke: the Framingham Study. *Stroke* 1991; 22:983–8. http://dx.doi.org/10.1161/01.STR.22.8.983

7 Dewar RI, Lip GY, Guidelines Development Group for the NICE clinical guideline for the management of atrial fibrillation. Identification, diagnosis and assessment of atrial fibrillation. *Heart* 2007; 93:25–8. http://dx.doi.org/10.1136/hrt.2006.099861

8 Hart RG, Pearce LA, Aguilar MI. Meta-analysis: antithrombotic therapy to prevent stroke in patients who have nonvalvular atrial fibrillation. *Ann Intern Med* 2007; 146:857–67.

9 Connolly SJ, Ezekowitz MD, Yusuf S et al. Dabigatran versus warfarin in patients with atrial fibrillation. *New Engl J Med* 2009; 361:1139–51. http://dx.doi.org/10.1056/NEJMoa0905561

10 Flaker GC, Belew K, Beckman K et al. Asymptomatic atrial fibrillation: Demographic features and prognostic information from the Atrial Fibrillation Follow-up Investigation of Rhythm Management (AFFIRM) study. *Am Heart J* 2005; 149:657–63. http://dx.doi.org/10.1016/j.ahj.2004.06.032

11 Camm AJ, Kirchhof P, Lip GY et al. Guidelines for the management of atrial fibrillation: the Task Force for the Management of Atrial Fibrillation of the European Society of Cardiology (ESC). *Eur Heart J* 2010; 31:2369–429. http://dx.doi.org/10.1093/eurheartj/ehq278

12 van Walraven C, Hart RG, Singer DE et al. Oral anticoagulants vs aspirin in non-valvular atrial fibrillation: an individual patient meta-analysis. *JAMA* 2002; 288:2441–8. http://dx.doi.org/10.1001/jama.288.19.2441

13 Hobbs FD, Fitzmaurice DA, Mant J et al. A randomised controlled trial and cost-effectiveness study of systematic screening (targeted and total population screening) versus routine practice for the detection of atrial fibrillation in people aged 65 and over. The SAFE study. *Health Technol Assess* 2005; 9:iii–iv, ix–x, 1–74.

14 Morgan S, Mant D. Randomised trial of two approaches to screening for atrial fibrillation in UK general practice. *Br J Gen Pract* 2002; 52: 373–4, 377–80.

15 Mant J, Fitzmaurice DA, Hobbs FD et al. Accuracy of diagnosing atrial fibrillation on electrocardiogram by primary care practitioners and interpretative diagnostic software: analysis of data from screening for atrial fibrillation in the elderly (SAFE) trial. *BMJ* 2007; 335:380. http://dx.doi.org/10.1136/bmj.39227.551713.AE

16 Doliwa PS, Frykman V, Rosenqvist M. Short-term ECG for out of hospital detection of silent atrial fibrillation episodes. *Scand Cardiovasc J* 2009; 43:163–8. http://dx.doi.org/10.1080/14017430802593435

17 Somerville S, Somerville J, Croft P et al. Atrial fibrillation: a comparison of methods to identify cases in general practice. *Br J Gen Pract* 2000; 50:727–9.

18 Lewis M, Parker D, Weston C et al. Screening for atrial fibrillation: sensitivity and specificity of a new methodology. *Br J Gen Pract* 2011; 61:38–9. http://dx.doi.org/10.3399/bjgp11X548956

19 Wiesel J, Wiesel D, Suri R et al. The use of a modified sphygmomanometer to detect atrial fibrillation in outpatients. *Pacing Clinical Electrophysiol* 2004; 27:639–43. http://dx.doi.org/10.1111/j.1540-8159.2004.00499.x

20 Wiesel J, Fitzig L, Herschman Y et al. Detection of atrial fibrillation using a modified microlife blood pressure monitor. *Am J Hypertens* 2009; 22:848–52. http://dx.doi.org/10.1038/ajh.2009.98

21 Stergiou GS, Karpettas N, Protogerou A et al. Diagnostic accuracy of a home blood pressure monitor to detect atrial fibrillation. *J Hum Hypertens* 2009; 23:654–8. http://dx.doi.org/10.1038/jhh.2009.5

22 Gregg RE, Zhou SH, Lindauer JM et al. Where do derived precordial leads fail? *J Electrocardiol* 2008; 41:546–52. http://dx.doi.org/10.1016/j.jelectrocard.2008.07.018

23 Salerno SM, Alguire PC, Waxman HS. Competency in interpretation of 12-lead electrocardiograms: a summary and appraisal of published evidence. *Ann Intern Med* 2003; 138:751–60.

24 Anh D, Krishnan S, Bogun F. Accuracy of electrocardiogram interpretation by cardiologists in the setting of incorrect computer analysis. *J Electrocardiol* 2006; 39:343–5. http://dx.doi.org/10.1016/j.jelectrocard.2006.02.002

25 Mehall JR, Kohut RM Jr, Schneeberger EW et al. Absence of correlation between symptoms and rhythm in 'symptomatic' atrial fibrillation. *Ann Thorac Surg* 2007; 83:2118–21. http://dx.doi.org/10.1016/j.athoracsur.2007.02.084

26 Reiffel JA, Schwarzberg R, Murry M. Comparison of autotriggered memory loop recorders versus standard loop recorders versus 24-hour Holter monitors for arrhythmia detection. *Am J Cardiol* 2005; 95:1055–9. http://dx.doi.org/10.1016/j.amjcard.2005.01.025

27 Kinlay S, Leitch JW, Neil A et al. Cardiac event recorders yield more diagnoses and are more cost-effective than 48-hour Holter monitoring in patients with palpitations. A controlled clinical trial. *Ann Intern Med* 1996; 124:16–20.

28 Hindricks G, Pokushalov E, Urban L et al. Performance of a new leadless implantable cardiac monitor in detecting and quantifying atrial fibrillation: Results of the XPECT trial. *Circ Arrhythm Electrophysiol* 2010; 3:141–7. http://dx.doi.org/10.1161/CIRCEP.109.877852

29 Hohnloser SH, Pajitnev D, Pogue J et al. Incidence of stroke in paroxysmal versus sustained atrial fibrillation in patients taking oral anticoagulation or combined antiplatelet therapy: an ACTIVE W substudy. *J Am Coll Cardiol* 2007; 50:2156–61. http://dx.doi.org/10.1016/j.jacc.2007.07.076

30 Healey JS, Connolly SJ, Gold MR et al. Subclinical atrial fibrillation and the risk of stroke. *N Engl J Med* 2012; 366:120–9. http://dx.doi.org/10.1056/NEJMoa1105575

31 ISD Scotland National Statistics. *Estimated number of patients seen/not seen in Scotland by either a general practitioner (GP) or practice nurse* [Internet]. Edinburgh: ISD Scotland; 2011 [cited 2011 Dec 14]. Available from: http://www.isdscotland.org/Health-Topics/General-Practice/Publications/2011-11-29/PTI_Nov11_Fig10_PyramidChart.xls

32 QResearch and The Health and Social Care Information Centre. *Trends in consultation rates in general practice 1995/1996 to 2008/2009: analysis of the QResearch database* [Internet]. Leeds: The Information Centre; 2009 [cited 2011 Dec 14]. Available at: http://www.ic.nhs.uk/webfiles/publications/gp/Trends_in_Consultation_Rates_in_General_Practice_1995_96_to_2008_09.pdf

33 Sudlow M, Rodgers H, Kenny RA et al. Identification of patients with atrial fibrillation in general practice: a study of screening methods. *BMJ* 1998; 317:327–8. http://dx.doi.org/10.1136/bmj.317.7154.327

34 Cooke G, Doust J, Sanders S. Is pulse palpation helpful in detecting atrial fibrillation: a systematic review. *J Fam Pract* 2006; 55:130–4.

35 Poon K, Okin PM, Kligfield P. Diagnostic performance of a computer-based ECG rhythm algorithm. *J Electrocardiol* 2005; 38:235–8. http://dx.doi.org/10.1016/j.jelectrocard.2005.01.008

36 Gunalp M, Atalar E, Coskun F et al. Holter monitoring for 24 hours in patients with thromboembolic stroke and sinus rhythm diagnosed in the emergency department. *Adv Ther* 2006; 23:854–60. http://dx.doi.org/10.1007/BF02850206

37 Tagawa M, Takeuchi S, Chinushi M et al. Evaluating patients with acute ischemic stroke with special reference to newly developed atrial fibrillation in cerebral embolism. *Pacing Clin Electrophysiol* 2007; 30:1121–8. http://dx.doi.org/10.1111/j.1540-8159.2007.00823.x

38 Douen AG, Pageau N, Medic S. Serial electrocardiographic assessments significantly improve detection of atrial fibrillation 2.6-fold in patients with acute stroke. *Stroke* 2008; 39:480–2. http://dx.doi.org/10.1161/STROKEAHA.107.492595

39 Yu EH, Lungu C, Kanner RM et al. The use of diagnostic tests in patients with acute ischemic stroke. *J Stroke Cerebrovasc Dis* 2009; 18:178–84.http://dx.doi.org/10.1016/j.jstrokecerebrovasdis.2008.09.004

40 Alhadramy O, Jeerakathil TJ, Majumdar SR et al. Prevalence and predictors of paroxysmal atrial fibrillation on Holter monitor in patients with stroke or transient ischemic attack. *Stroke* 2010; 41:2596–600. http://dx.doi.org/10.1161/STROKEAHA.109.570382

41 Lazzaro MA, Krishnan K, Prabhakaran S. Detection of atrial fibrillation with concurrent Holter monitoring and continuous cardiac telemetry following ischemic stroke and transient ischemic attack. *J Stroke Cerebrovasc Dis* 2012; 21:89–93. Epub 2010 Jul 24 http://dx.doi.org/10.1016/j.jstrokecerebrovasdis.2010.05.006

42 Barthélémy JC, Féasson-Gérard S, Garnier P et al. Automatic cardiac event recorders reveal paroxysmal atrial fibrillation after unexplained strokes or transient ischaemic attacks. *Ann Noninvasive Electrocardiol* 2003; 8:194–9. http://dx.doi.org/10.1046/j.1542-474X.2003.08305.x

43 Jabaudon D, Sztajzel J, Sievert K. Usefulness of ambulatory 7-day ECG monitoring for the detection of atrial fibrillation and flutter after acute stroke and transient ischemic attack. *Stroke* 2004; 35:1647–51. http://dx.doi.org/10.1161/01.STR.0000131269.69502.d9

44 Koudstaal PJ, van Gijn J, Klootwijk AP et al. Holter monitoring in patients with transient and focal ischemic attacks of the brain. *Stroke* 1986; 17:192–5. http://dx.doi.org/10.1161/01.STR.17.2.192

45 Schaer BA, Zellweger MJ, Cron TA et al. Value of routine holter monitoring for the detection of paroxysmal atrial fibrillation in patients with cerebral ischemic events. *Stroke* 2004; 35:e68–70. http://dx.doi.org/10.1161/01.STR.0000117568.07678.4B

46 Stahrenberg R, Weber-Kruger M, Seegers J et al. Enhanced detection of paroxysmal atrial fibrillation by early and prolonged continuous Holter monitoring in patients with cerebral ischemia presenting in sinus rhythm. *Stroke* 2010; 41:2884–8. http://dx.doi.org/10.1161/STROKEAHA.110.591958

47 Rem JA, Hachinski VC, Boughner DR et al. Value of cardiac monitoring and echocardiography in TIA and stroke patients. *Stroke* 1985; 16:950–6. http://dx.doi.org/10.1161/01.STR.16.6.950

48 Hornig CR, Haberbosch W, Lammers C et al. Specific cardiological evaluation after focal cerbral ischemia. *Acta Neurol Scand* 1996; 93:297–302. http://dx.doi.org/10.1111/j.1600-0404.1996.tb00524.x

49 Shafqat S, Kelly PJ, Furie KL. Holter monitoring in the diagnosis of stroke mechanism. *Intern Med J* 2004; 34:305–9. http://dx.doi.org/10.1111/j.1444-0903.2004.00589.x

50 Rizos T, Rasch C, Jenetzky E et al. Detection of paroxysmal atrial fibrillation in acute stroke patients. *Cerebrovasc Dis* 2010; 30:410–7. http://dx.doi.org/10.1159/000316885

51 Schuchert A, Behrens G, Meinertz T. Impact of long-term ECG recording on detection of paroxysmal atrial fibrillation in patients after an acute ischemic stroke. *Pacing Clin Electrophysiol* 1999; 22:1082–4. http://dx.doi.org/10.1111/j.1540-8159.1999.tb00574.x

52 Kamel H, Lees KR, Lyden PD et al. Delayed detection of atrial fibrillation after ischemic stroke. *J Stroke Cerebrovasc Dis* 2009; 18:453–7. http://dx.doi.org/10.1016/j.jstrokecerebrovasdis.2009.01.012

53 Gaillard N, Deltour S, Vilotijevic B et al. Detection of paroxysmal atrial fibrillation with transtelephonic EKG in TIA or stroke patients. *Neurology* 2010; 74:1666–70. http://dx.doi.org/10.1212/WNL.0b013e3181e0427e

54 Tayal AH, Tian M, Kelly KM et al. Atrial fibrillation detected by mobile cardiac outpatient telemetry in cryptogenic TIA or stroke. *Neurology* 2008; 71:1696–1701. http://dx.doi.org/10.1212/01.wnl.0000325059.86313.31

55. Elijovich L, Josephson SA, Fung GL et al. Intermittent atrial fibrillation may account for a large proportion of otherwise cryptogenic stroke: a study of 30-day cardiac event monitors. *J Stroke Cerebrovasc Dis* 2009; 18:185–9. http://dx.doi.org/10.1016/j.jstrokecerebrovasdis.2008.09.005

56 Dion F, Saudeau D, Bonnaud I et al. Unexpected low prevalence of atrial fibrillation in cryptogenic ischemic stroke: a prospective study. *J Interv Card Electrophysiol* 2010; 28:101–7. http://dx.doi.org/10.1007/s10840-010-9485-5

57 Fuster V, Rydén LE, Asinger RW et al. ACC/AHA/ESC guidelines for the management of patients with atrial fibrillation. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the European Society of Cardiology Committee for Practice Guidelines and Policy Conferences (Committee to develop guidelines for the management of patients with atrial fibrillation) developed in collaboration with the North American Society of Pacing and Electrophysiology. *Eur Heart J* 2001; 22:1852–923. http://dx.doi.org/10.1053/euhj.2001.2983

58 Scottish Intercollegiate Guidelines Network (SIGN). *Cardiac arrhythmias in coronary heart disease. A national clinical guideline* [Internet]. Edinburgh: SIGN; 2007 [cited 2011 Dec 5]. Available from: www.sign.ac.uk/pdf/sign94.pdf

59 Scottish Intercollegiate Guidelines Network (SIGN). *Management of patients with stroke or TIA: assessment, investigation, immediate management and secondary prevention. A national clinical guideline* [Internet]. Edinburgh: SIGN; 2008 [cited 2011 Dec 5]. Available from: www.sign.ac.uk/pdf/sign108.pdf

60 European Stroke Organisation (ESO) Executive Committee and the ESO Writing Committee. Guidelines for management of ischaemic stroke and transient ischaemic attack 2008. *Cerebrovasc Dis* 2008; 25:457–507. http://dx.doi.org/10.1159/000131083

61 National Collaborating Centre for Chronic Conditions. *Stroke: national clinical guideline for diagnosis and initial management of acute stroke and transient ischaemic attack (TIA)* [Internet]. London: Royal College of Physicians; 2008 [cited 2011 Dec 5]. Available from: www.nice.org.uk/nicemedia/pdf/CG68FullGuideline.pdf

62 Cairns JA, Connolly S, McMurtry S et al. Canadian Cardiovascular Society atrial fibrillation guidelines 2010: prevention of stroke and systemic thromboembolism in atrial fibrillation and flutter. *Can J Cardiol* 2011; 27:74–90. http://dx.doi.org/10.1016/j.cjca.2010.11.007

63 Healey JS, Parkash R, Pollak T et al. Canadian Cardiovascular Society atrial fibrillation guidelines 2010: etiology and initial investigations. *Can J Cardiol* 2011; 27:31–7. http://dx.doi.org/10.1016/j.cjca.2010.11.015

64 Furie KL, Kasner SE, Adams RJ et al. Guidelines for the prevention of stroke in patients with stroke or transient ischemic attack: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke* 2011; 42: 227–76. http://dx.doi.org/10.1161/STR.0b013e3181f7d043