

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

4,400

Open access books available

117,000

International authors and editors

130M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Screening for Atrial Fibrillation and the Role of Digital Health Technologies

Edward Richardson, Angela Hall and Andrew R.J. Mitchell

Abstract

Atrial fibrillation is the commonest clinical arrhythmia and a leading cause of hospital admission, morbidity and mortality. New digital health technologies are now allowing patients and the general population to identify heart rhythm abnormalities before any encounter with a medical professional. This chapter will include an overview of the prevalence of atrial fibrillation and explore the current recommendations on methods for arrhythmia screening. We discuss different risk factors as well as physiological and structural markers for atrial fibrillation onset. We explore in detail the application of novel digital health technologies such as wearables, watches and mobile devices which may have an impact on screening detection rates. The article concludes with a discussion about how to manage patients with screen detected atrial fibrillation.

Keywords: atrial fibrillation, screening, digital health, wearables, arrhythmia, technology, cardiology, ECG, apple watch, Alivecor, Kardia, Omron HeartScan, Zenicor ECG, Miniscope, Reka e100, Zio Patch, guidelines, Holter monitor, ambulatory ECG, patient centred care, artificial intelligence, iPhone, android, apple, stroke, photoplethysmography

1. Introduction

Atrial fibrillation (AF) is increasing in prevalence with a lifetime risk of one in four people developing this common arrhythmia [1]. Its detection is of rising importance as it is a leading cause of mortality and morbidity. A recent meta-analysis showed a person with AF had an increased risk of all-cause mortality by 46%, of ischaemic heart disease by 61%, of chronic kidney disease by 64%, a 96% higher risk of a major cardiovascular event, and an 88% higher risk of sudden cardiac death. Furthermore, it more than doubled the risk of stroke and increased the risk of congestive heart failure fivefold [2]. Whilst the mechanism behind some of these are unknown, the identification of AF can be used to help reduce the risk of several of the complications, by starting anticoagulation for example. Often persons with AF can be asymptomatic and therefore it may be detected late, such as after a stroke. Around 10% of all ischaemic strokes are associated with a new diagnosis of AF and it is present in around a quarter of all patients with stroke. Screening for AF has received significant focus with a dedicated collaboration established in 2016 called AF Screen. Their aim it is to promote

discussion and research about unknown or untreated AF, as a means to reduce stroke and associated mortality [3, 4].

2. Screening

Screening for AF has received considerable attention due to the increasing numbers of patients with the arrhythmia and projections for further increases over the coming years [5]. A variety of screening methods exist from a manual pulse check to the use of novel digital screening tools [3, 6].

Public health screening has increased dramatically over the last few decades through a need and desire to address the growing burden of disease [7]. This exponential growth has been partly achievable through innovations in digital technology and an enhanced ability to detect a growing number of conditions. The rationale for screening is straightforward: detecting disease in its infancy and treating to reduce morbidity, mortality and associated healthcare and societal costs [8]. A paradigm shift has resulted in a more proactive approach whereby early detection of disease has renewed importance over the confines of diagnosis of clinically overt disease. Putting this into context, up to two-thirds of people with AF report that it disrupts their lives [9]. Medical attention may be sought early on, but it is not uncommon for the symptoms of AF to go unnoticed until there is decompensation. If AF is of the paroxysmal nature, it may go undetected unless the practitioner has the insight to investigate symptoms suggestive of an arrhythmia. However, AF can be silent, in other words exhibit no symptoms even in the persistent form and the first diagnosis may not be until there are signs of haemodynamic compromise. Unfortunately it is not uncommon for AF to also be detected when the patient presents with a thromboembolic complication such as stroke [3, 4, 10, 11].

The World Health Organisation lists criteria that should be considered when implementing screening of disease (**Table 1**) [12]. The criteria states that the condition should be an important health problem with accepted treatment. While this work is nearly 50 years old, little has changed in screening criteria. More recent updates suggest consideration of economic implications, quality assurance and informed choice alongside equity and access of screening to the entire target population [7]. This is an important consideration and one yet to achieve consensus in terms of AF screening [13].

Screening approaches vary and include opportunistic, and systematic that can be broken down to targeted, population and mass screening. There remains a lack of consensus regarding the optimal method with a range of studies exploring and evaluating AF screening, with some studies choosing opportunistic, some

-
1. The condition should be an important health problem.
 2. There should be a treatment for the condition.
 3. Facilities for diagnosis and treatment should be available.
 4. There should be a latent stage of the disease.
 5. There should be a test or examination for the condition.
 6. The test should be acceptable to the population.
 7. The natural history of the disease should be adequately understood.
 8. There should be an agreed policy on whom to treat.
 9. The total cost of finding a case should be economically balanced in relation to medical expenditure.
 10. Case-finding should be a continuous process, not just a “once and for all” project.
-

Table 1.
Principles and practice of screening for disease [12].

systematic, and others both. In all studies, older age groups are frequently targeted due to perceived cost effectiveness and anticipated positive findings. However, targeting the younger population may help address contributory lifestyle factors, reducing complications that may result. In addition to age, high risk patient groups are further targets for screening. Hypertension, diabetes and heart failure are commonly cited as chronic disease populations at higher risk of cardiovascular complications [11, 14]. As such, these patient groups have often been selected in targeted screening programmes [15–19].

Whilst the European Society of Cardiology guidelines do recommend screening asymptomatic patients for AF, the NICE and the UK National Screening Committee guidance does not [10, 20, 21]. The rationale is the lack of evidence to support it benefiting those identified by screening. This recommendation is currently under review. There are increasing numbers of studies that suggest benefit in screening. A paper in 2014 using the data from the 2004 SAFE trial, showed that of the 78–83% of those identified in the screening for AF were eligible for anticoagulation [22, 23]. Whilst there have been further papers on the cost-effectiveness of screening in AF, unfortunately several of these have continued to rely on the data from the SAFE trial [24]. An ongoing major issue is that few studies have been able to prove better health outcomes from those asymptomatic adults that were screened [25, 26]. This is at least partially due to the difficulty in proving an intervention has prevented a stroke. As such and on the recommendations of collaborations such as AF-SCREEN and the European Society of Cardiology several charities now conduct some level of screening, with most suggesting a simple pulse check [4, 27].

3. Wearable technologies

Digital health technologies have revolutionised health screening, not least within cardiology [28]. Traditional ambulatory Holter monitors (HM) connected by electrodes to the precordium, are still used regularly but have limitations. They can be used for varying lengths of time but can be inconvenient and require laborious analysis. The time and duration of wear may also be incongruent with symptoms and therefore ineffectual [29]. Modern applications can now be utilised through technological advancements, which can enable more ad-hoc monitoring. These vary from new devices to applications on mobile phones. These options can offer more advanced screening with enhanced specificity and sensitivity [29–32].

There are increasing numbers of new technologies being developed that can be used in the screening of AF. We will discuss some of the more well-known options however there will be a focus on the devices where there are published studies that demonstrate their efficacy and diagnostic accuracy. Unfortunately, there are few studies that compare results across the different devices, however, where there is sufficient evidence then we shall try and compare the technologies.

The majority of devices use a single lead, normally analogous to lead I. They do this by providing two electrodes to capture electrical signals from the fingers, thumb, wrist, or palm of each hand [33]. One of the best known is the AliveCor. It has been used in clinical practice since 2011 and there is a plethora of research where AliveCor, or Kardia as it has been more recently branded, has been the tool of choice. The AliveCor has demonstrated high sensitivity and specificity in screening studies and is U.S. Food and Drug Association (FDA) as well as Conformité Européenne (CE) approved [16, 31, 32, 34, 35]. This device creates a single lead, by providing two electrodes for 2 or more fingers of each hand. The data generated is wirelessly transmitted to a smart phone and produces a tracing. The application will notify the user if the tracing is normal or AF. The information can be securely sent to an encrypted AliveCor cloud server or a healthcare professional. The presence

of an enhanced filter provides a much smoother tracing. Studies also suggest that even elderly patients found the device easy to use and that it did not restrict activities or cause anxiety [16, 33, 36]. It has been shown to be more likely to diagnose a symptomatic underlying rhythm than an HM [37]. Limiting factors include requiring access to a smartphone and not being recommended for use in children, or those with implanted electronic devices [33, 36].

The Omron HeartScan is another single lead device, similar to the AliveCor. However, with the HeartScan one of the electrodes on the device can also be placed on the chest. It is a stand-alone device so does not require a smart phone, but it is more expensive. There is evidence to suggest that like the AliveCor, it is more likely to successfully diagnose AF, especially if symptomatic, than an HM [33, 38–40].

There are some single lead devices such as the Zio Patch, which aim to provide more continuous monitoring. The Zio Patch is a single use water-resistant adhesive patch similar to a traditional HM but with a few advantages. It can record for longer, 14 days versus 7, and it has no wires, which means it is more discreet and reduces the interference. It is generally well tolerated and studies suggest it may have a higher diagnostic yield for arrhythmia [28, 33, 41–45].

Some other single lead devices are targeted more towards screening. One example, the RhythmPad^{GP}, is designed around the screening of non-symptomatic individuals in a general practice (GP) Surgery. As yet there are no studies showing its efficacy [46]. Another device that is aimed at screening is the Microlife Modified Blood Pressure (BP) monitor. It screens for AF via the detection of an irregularly irregular pulse during the inflation of an automatic blood pressure cuff. BP checks are commonly performed in the primary care setting and increasingly by people in their own homes; the design of the device monopolises on this. The evidence suggests it may even be more accurate than a pulse check [19, 47].

AF detecting devices are ever increasing in number and too numerous to detail here, however, some more well-known examples include: MyDiagnostick, the Reka e100, Miniscope M3, InstantCheck, AfibAlert, and Zenicore EKG. There are less studies associated with these but all show merit in their own way [33, 48–52].

Photoplethysmographic (PPG) technology has also shown promise and works in the same way as a pulse oximeter. Whilst PPG can be more susceptible to movement artefact, [53] they are low cost and widely available commercially including in the Apple Watch and Fitbit [54–56]. Movement artefact can be reduced with the intelligent use of accelerometers in the device [53]. The Cardio Rhythm smartphone application uses the phone's camera to detect heart rate. It has been shown to be comparable to the AliveCor in sensitivity and specificity [34, 57].

The Apple Watch initially used PPG, however the latest iteration, the Apple Watch 4, now has the ability to perform a single lead ECG. The mechanism is similar to the other single lead ECG devices. One electrode is incorporated in the back of the watch and the second in the crown at the side. The user puts one finger on the crown and is able to obtain an estimation of lead I [56, 58, 59]. Apple are currently funding a study, called the Apple Heart Study, that aims to demonstrate the ability of the Apple Watch to detect previously unknown AF by identifying pulse variability and irregularity. This has the potential to be one of the largest studies on AF identification, with over 400,000 participants, and therefore should be highly powered. Conversely, previous studies are relatively small in size. Additionally, the Apple Heart Study should help provide data for a much wider population than previous studies and therefore potentially help appraise the practicalities of screening large groups [56]. The study has released some preliminary results, which have indicated the Apple watches over all generations had a 71% positive predictive value. The data released also showed that 84% of the time during an irregular pulse notification the patient was in AF [60].

The Apple Heart Study, alongside the GARMIN AF study [61] are part of many ongoing projects; a search of clinical trials revealed frequent utilisation of modern devices within ongoing research projects. The Clinical Trials database exposed 92 trials on a recent search, where screening for AF was the primary outcome [62]. These incorporated an array of screening tools and whilst the majority focused on targeted populations, this was not exclusive. Similarly, the European Union Trials Register revealed 80 studies of a comparable nature, highlighting the ongoing interest in screening for undiagnosed AF [63].

4. Current guidelines

There are multiple different guidelines on the management of AF, in this section we have summarised the areas relating to screening as well as recommendations for anticoagulation.

4.1 European guidelines

The European Society of Cardiology (ESC) 2016 guidelines and recommendations [10] are summarised below with regards to AF screening and stroke prevention in AF:

1. Screening for AF is recommended:

- a. In elderly populations with a suggested age cut off at 65 years on an opportunistic basis.
- b. ECG screening in a more systematic manner may be considered in those at high risk of stroke or aged over 75 years of age.
- c. In Patients with a Transient Ischaemic Attack (TIA) or ischaemic stroke with a short-term ECG recording followed by ECG monitoring for at least 72 hours. There is also the suggestion that non-invasive monitors or implanted loop recorders can also be considered especially in those patients with cryptogenic stroke.
- d. Via Implantable Cardioverter Defibrillators (ICDs) and pacemakers. These should be interrogated on a regular basis for evidence of atrial high rate episodes (AHRE). This is because AHRE are associated with an increased risk of overt AF.

2. Stroke prevention in AF recommendations are:

- a. CHA₂DS₂-VASc Score (**Table 2**) and if the score is equal to or greater than 1 for a male or 2 for a female then oral anticoagulation can be considered. It should also be noted that female sex will only add to the score if another risk factor is present. Anticoagulation should also be continued even if the patient has surgical exclusion or occlusion of their left atrial appendage in at-risk patient groups.
- b. Oral anticoagulation is recommended in the form of a Novel Oral Anticoagulant (NOAC) unless the patient has a mechanical heart valve or moderate to severe mitral stenosis where a vitamin K antagonist (VKA) is recommended. NOACs should also be avoided in women planning a

Risk factor	Points
Congestive heart failure—signs or symptoms of or objective evidence of reduced LVEF	+1
Hypertension—on BP medication or resting BP >140/90 on a minimum of at least two occasions	+1
Age greater than or equal to 75 years old	+2
Diabetes mellitus—on hypoglycaemic agent or fasting glucose of >7 mmol/l (>125 mg/dl)	+1
Previous thromboembolism, including stroke and transient ischaemic attack	+2
Vascular disease—including peripheral artery disease, aortic plaque, or previous myocardial infarction	+1
Age between 65 and 74 years old	+1
Female sex	+1

Table 2.
CHA₂DS₂-VASc modified from ESC guidelines [10].

pregnancy or those that are already pregnant. If a VKA is used then the target International Normalised Ratio (INR) is 2.0–3.0, unless it is required to be higher for another comorbidity. Those on VKAs should have their INRs closely monitored, with the aim to keep the time in the therapeutic range as high as possible. There is also no requirement for genetic testing before the initiation of VKAs as these have been evaluated to have little or no effect on the bleeding risk.

- c. Antiplatelet monotherapy is not recommended for the prevention of stroke in patients with AF irrespective of stroke risk. Combinations of antiplatelets and oral anticoagulants should be avoided unless there is another indication for antiplatelet therapy. This is due to the increased risk of bleeding.
- d. In patients with stroke and AF immediate anticoagulation with low molecular weight heparin or heparin is not recommended
- e. Patients with hypertrophic cardiomyopathy (HCM) that develop AF should have lifelong oral anticoagulation for stroke prevention.
- f. Atrial flutter should be treated with ablation of the cavotricuspid isthmus if antiarrhythmic treatment fails, or as a potential first line treatment depending on patient preference. Anticoagulation should be treated under the same guidelines as AF.
- g. Oral anticoagulation should be interrupted in patients with severe ongoing, active bleeding, until resolution of the underlying cause.
- h. Bleeding risk scores should be considered before starting anticoagulation but with the aim of identifying modifiable risk factors than to recommend the holding of anticoagulants.

4.2 Comparison with American guidelines

The American Heart Association (AHA), American College of Cardiology (ACC), and Heart Rhythm Society (HRS) Guidelines [64] as of their 2019 update

[65, 66] are similar to the ESC guideline. In fact, the major changes in the 2019 compared to the 2014 guideline bring it closer to the ESC guidance. For example, the inclusion of Edoxaban as a NOAC.

More relevantly, the AHA/ACC/HRS guideline moved from referring to “nonvalvular AF” as the exclusion criteria for the CHA₂DS₂-VASc Score to using the narrower criteria of moderate to severe mitral stenosis or a mechanical heart valve. It is also the exclusion criteria for NOACs, as VKA should be used in these patients. This more closely aligns with the ESC guideline. The AHA/ACC/HRS guideline has also changed the classification for women within the CHA₂DS₂-VASc Score; female sex now confers no points if it is the lone risk factor. Both have the same scoring cut-offs for anticoagulation, they also both recommend NOACs over VKAs, in those eligible and similarly do not recommend aspirin in those with low CHA₂DS₂-VASc Score.

However, whilst the ESC guidance does recommend some opportunistic screening as a class I recommendation with level B evidence, the AHA/ACC/HRS guidelines are less forthcoming. Though the American guidance does suggest monitoring in those with cryptogenic stroke including the use of implantable cardiac monitors, such as loop recorders, it does not comment on more generalised screening. Both guidelines recommend interrogating the recordings of those with ICDs or pacemakers for the presence of AHREs, prompting further investigation for AF. The ESC guidance takes this further and acknowledges the recent studies demonstrating the possibilities for a more generalised approach and even recognises the potential role for the new devices mentioned above [10, 51, 64–66].

4.3 Screening after stroke

AF Screening after an ischaemic stroke or TIA is commented on in the ESC guidelines where it recognises how commonly AF is detected in stroke survivors. As mentioned above, not only does it recommend monitoring patients for at least 72 hours it also states that extensive screening should be considered. It is worth noting that the guidelines go as far as to recommend implantable loop recorders in those with “cryptogenic stroke”, where no other cause could be identified, such as carotid artery stenosis. This is a class IIa recommendation with Level B evidence.

4.4 Guidance on atrial high rate episodes

AHREs are mentioned in both sets of guidelines. The definition of AHREs can differ but most studies have used a length of greater than 5 minutes as a cut off but some going for a cut off of 6 minutes [67]. The actual atrial rate chosen also varies with some citing 175 bpm and others up to 220 bpm [68–70]. The ESC guideline defines them as lasting 5–6 minutes or greater and a rate faster than 180 bpm [10]. Recent studies have suggested they are quite common with a 30–70% incidence in those with an implantable device [70, 71]. Whilst it is difficult to adjust for confounding factors, AHREs are associated with an elevated risk of stroke, death, and subsequent AF [67]. However, a study in 2017 showed that a temporal relationship between a stroke and an episode of AHRE was only seen in 15% of those with an implanted device [71].

Both the ESC and the AHA/ACC/HRS guidelines recommend further investigation of those patients identified to have AHRE. The AHA/ACC/HRS guideline mainly recommends further investigation to establish if true AF is present [10, 65]. The ESC guideline echoes this, however, suggests the inclusion of patient preference and accepts that rarely anticoagulation may be considered in patients without documented AF.

5. Patient centred care and the role of technology

Both the ESC and NICE recommend that patients be involved in the decision making where possible, as do the AHA/ACC/HRS guidelines to a lesser extent [10, 21, 64–66]. This can be achieved by simply informing them of the risks and benefits of different options, and ideally tailoring them to the patient but advancements in technology means that we may have other ways of individualising care.

Given the AF detecting technologies above, several papers have suggested this may be used to enable patients to self-diagnose and manage their own conditions to a greater or lesser degree depending on the estimated accuracy of the product [53, 56, 72]. This could coalesce perfectly with certain AF treatment strategies such as “pill in the pocket” cardioversion. Other ways this could be useful is in judging the effectiveness of rate or rhythm control in asymptomatic patients [33, 73]. In symptomatic individuals it may also help guide them on when to seek help [33]. Some tracings may even be able to check for complications from medications, such as QT interval monitoring on patients receiving anti-arrhythmic drug therapy [74]. The technology and software in devices such as the Zio patch or Apple watch could allow rate and rhythm monitoring over a longer period of time than would normally be possible without a device such as a loop recorder [38, 41, 48].

Furthermore certain devices, such as the AliveCor, HeartScan, or Apple watch, could be used to capture an ad-hoc single lead ECG for intermittent symptoms [53]. Considering palpitations are a common complaint in primary care and the time limitations on HMs, these devices could enable patients to obtain a reading for symptoms that may be longer than a week apart [16, 39, 73, 75]. They have also been shown to be effective in the paediatric setting [52].

Devices can also be used to provide lifestyle advice, motivation, and educational messages. These can be linked to a daily ECG tracing such as in the ongoing iHEART trial [76]. If this concept were to be expanded, personalised health promotion advice could be provided to patients. This could be extended to providing patients with reminders to take medication and therefore increase their compliance [10, 77]. It could also provide data to patients and researchers alike to establish what, if anything, seem to trigger their symptoms, fast ventricular response, or re-initiation of an episode of AF. Devices could also make it easier to target select groups and enrol them in further research [78, 79]. Additionally, this could provide insights into the demographics of AF and help further narrow down any screening attempts.

While the evidence remains unclear, the level of burden of AF could help dictate the need for anticoagulation in patients. Data gathered at a population and individual level could help personalise the requirement for anticoagulation and the risks thereof [26, 80].

The ESC guidelines recommend the use of technology to support care of patients with AF for multiple reasons. It increases coherent exchange of information between the patient and health care professionals. The guidelines also suggest that it may increase the implementation of evidence-based care, and therefore improve outcomes, by using adjuncts such as decision support software. This may help personalise care for each patient, whilst strengthening adherence to guidelines.

Artificial intelligence (AI) may help personalise care further. AI has been suggested for the diagnosis of AF since the early 1990s [81]. There has even been suggestion more recently that it can be used to predict when AF will occur up to an hour before the event in those with non-permanent AF [82, 83]. AI has many more potential benefits, from helping gather the most useful data on a patient before a consultation to outpatient monitoring and subsequent prioritisation [36, 84–87].

Patients appear to be embracing these new technologies. For example, a recent survey by the Kings Fund [88] showed the majority of people surveyed were willing to use video consultations with their GP especially for minor ailments. The wearables market is also continuing to increase in size, with International Data Corporation's 2017 prediction that the number of wearables sold will almost double by 2021 [89, 90].

There is also an increasing body of evidence that patients having access to their clinical notes and data increases satisfaction and compliance [91, 92]. There is an appetite for patient-controlled records and data. The development of applications such as Apple Health on patients' devices has helped enable patients to keep track of everything from their own BP readings to their list of medications and allergies. Some of these are even more advanced, including GenieMD, which integrate with telemedicine consultations, check for drug interactions, and remind patients when to file for a repeat prescription [93]. Patient controlled records would empower patients and would enable them to take the relevant information with them wherever they go [94–96]. This is not a new concept, it has been used in paper form within maternity [97] and paediatrics [98] settings for a substantial period of time. Evidence shows they are effectively used [99]. Furthermore, there is a move to digitalise both of these [98, 100].

6. Review of the evidence for screening

There are two main types of screening mentioned in the studies, opportunistic and systematic. The evidence shows that an equivocal number of patients were identified with either method [22, 23, 26]. This implies that opportunistic screening is more cost effective [101]. Pulse palpation is an example of this kind of screening and is the limit recommended by the NICE guidance and even then it is under certain indications [21]. Unfortunately pulse palpation lacks specificity [102] and could therefore generate multiple false positives. The novel devices may help improve this as they have been shown to have a better specificity with most being above or around 90% and the lowest being 87%, [26] compared to 71% [101] for pulse palpation alone. Devices can either simulate lead I, use PPG, or BP cuff pulse detection. They have a good sensitivity and specificity, are generally quite easy to use, and therefore may increase the accuracy and feasibility. Whilst they may require further validation with larger studies [33] and more heterogeneous populations, some larger studies have still shown them to be cost effective and effective in potential screening scenarios.

The type of screening matters, with targeted and opportunistic screening potentially cost-effective or even cost reducing when aimed at higher risk populations. However, there is limited evidence with regards to the AF detected by these devices having any effect on clinical outcomes, as these were extrapolated from existing studies [6, 16, 32, 34, 103–111]. There is no evidence behind anticoagulation of potentially very short lived runs of AF or AHREs that can be picked up by some devices. Potential harms have not been studied in great depth, nor the cost of incidental findings in these studies [25, 26]. Despite this some of these risks can be mitigated, many devices only simulate one lead or even just pulse pattern, and therefore reduce the chance of picking up other ECG findings, such as T-wave inversion, that may then warrant further investigation.

Given the association between stroke and TIA with AF it is sensible and recommended to include screening in the work up of these patients. Current guidelines suggest the use of ILRs and external loop recorders in those with cryptogenic stroke. The novel devices that provide long term monitoring, rather than short

tracings, could be highly useful in these instances. They are less cumbersome and less invasive. The Zio Patch was reported to detect a higher number of arrhythmias than a traditional HM in one study, however, the longer monitoring period may account for this [4, 10, 26, 29, 41, 73, 111].

Those patients identified by screening may need to go on and have further ECGs depending on the method of identification. If the method did not utilise an ECG lead, then the patient will need to have a confirmatory ECG. Once AF is confirmed then rate control or anticoagulation would need to be considered via the CHA₂DS₂-VASc Score in accordance to the guidelines. In some instances, rhythm control may also be considered on an elective basis [10, 64, 65].

7. Conclusion

AF is an important, common disease, with an increasing incidence and the potential for multiple complications. It remains underdiagnosed and could potentially fit the criteria for screening, but the guidelines are divided as to whether this is recommended or not. There are multiple different novel devices that are designed to detect for AF, of which several are beginning to acquire a meaningful evidence base. Such devices might be used to increase the ease and specificity of screening for AF compared to traditional methods, they may also increase the sensitivity. There are multiple clinical trials ongoing where screening for AF is the primary outcome, which should help provide further evidence. However, there still needs to be further research before screening wide populations becomes viable. Further studies are needed comparing the different devices to each other, especially in a screening capacity. There needs to be further research into what duration of AHREs or AF increases the risk of stroke, as well as whether screening really does improve clinical outcomes.

Conflict of interest


The authors confirm that there are no conflicts of interest.

Author details

Edward Richardson, Angela Hall and Andrew R.J. Mitchell*
Department of Cardiology, Jersey General Hospital, St Helier, Jersey

*Address all correspondence to: mail@jerseycardiologist.com

IntechOpen

© 2019 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] Lloyd-Jones DM, Wang TJ, Leip EP, Larson MG, Levy D, Vasan RS, et al. Lifetime risk for development of atrial fibrillation: The Framingham heart study. *Circulation*. 2004;**110**(9): 1042-1046
- [2] Odotayo A, Wong CX, Hsiao AJ, Hopewell S, Altman DG, Emdin CA. Atrial fibrillation and risks of cardiovascular disease, renal disease, and death: Systematic review and meta-analysis. *BMJ*. 2016;**354**:i4482
- [3] Engdahl J, Andersson L, Mirskaya M, Rosenqvist M. Stepwise screening of atrial fibrillation in a 75-year-old population: Implications for stroke prevention. *Circulation*. 2013;**127**(8): 930-937
- [4] Freedman B, Camm J, Calkins H, Healey JS, Rosenqvist M, Wang J, et al. Screening for atrial fibrillation: A report of the AF-SCREEN international collaboration. *Circulation*. 2017;**135**(19): 1851-1867
- [5] Schnabel RB, Yin X, Gona P, Larson MG, Beiser AS, McManus DD, et al. 50 year trends in atrial fibrillation prevalence, incidence, risk factors, and mortality in the Framingham heart study: A cohort study. *The Lancet*. 2015; **386**(9989):154-162
- [6] Jacobs MS, Kaasenbrood F, Postma MJ, van Hulst M, Tieleman RG. Cost-effectiveness of screening for atrial fibrillation in primary care with a handheld, single-lead electrocardiogram device in the Netherlands. *EP Europace*. 2016;**20**(1):12-18
- [7] Andermann A, Blancquaert I, Beauchamp S, Dery V. Revisiting Wilson and Jungner in the genomic age: A review of screening criteria over the past 40 years. *Bulletin of the World Health Organization*. 2008;**86**(4): 317-319
- [8] Saquib N, Saquib J, Ioannidis JP. Does screening for disease save lives in asymptomatic adults? Systematic review of meta-analyses and randomized trials. *International Journal of Epidemiology*. 2015;**44**(1):264-277
- [9] Markides V, Schilling RJ. Atrial fibrillation: Classification, pathophysiology, mechanisms and drug treatment. *Heart (British Cardiac Society)*. 2003;**89**(8):939-943
- [10] Kirchhof P, Benussi S, Kotecha D, Ahlsson A, Atar D, Casadei B, et al. 2016 ESC guidelines for the management of atrial fibrillation developed in collaboration with EACTS. *Europace: European Pacing, Arrhythmias, and Cardiac Electrophysiology: Journal of the Working Groups on Cardiac Pacing, Arrhythmias, and Cardiac Cellular Electrophysiology of the European Society of Cardiology*. 2016;**50**(5): e1-e88
- [11] Krishnamoorthy S, Lip GY. Hypertension, stroke and the impact of atrial fibrillation. *Expert Review of Cardiovascular Therapy*. 2008;**6**(10): 1287-1289
- [12] Wilson JM, Glover JG, Organization WH. Principles and practice of screening for disease. *The Journal of the Royal College of General Practitioners*. 1968;**16**(4):318
- [13] Lown M, Moran P. Should we screen for atrial fibrillation? *BMJ*. 2019;**364**:l43
- [14] Kotecha D, Piccini JP. Atrial fibrillation in heart failure: What should we do? *European Heart Journal*. 2015; **36**(46):3250-3257
- [15] Davis RC, Hobbs FD, Kenkre JE, Roalfe AK, Iles R, Lip GY, et al. Prevalence of atrial fibrillation in the general population and in high-risk groups: The ECHOES study. *Europace*:

European Pacing, Arrhythmias, and Cardiac Electrophysiology: Journal of the Working Groups on Cardiac Pacing, Arrhythmias, and Cardiac Cellular Electrophysiology of the European Society of Cardiology. 2012;**14**(11): 1553-1559

[16] Halcox JPJ, Wareham K, Cardew A, Gilmore M, Barry JP, Phillips C, et al. Assessment of remote heart rhythm sampling using the AliveCor heart monitor to screen for atrial fibrillation: The REHEARSE-AF study. *Circulation*. 2017;**136**(19):1784-1794

[17] Samol A, Masin M, Gellner R, Otte B, Pavenstadt HJ, Ringelstein EB, et al. Prevalence of unknown atrial fibrillation in patients with risk factors. *Europace: European Pacing, Arrhythmias, and Cardiac Electrophysiology: Journal of the Working Groups on Cardiac Pacing, Arrhythmias, and Cardiac Cellular Electrophysiology of the European Society of Cardiology*. 2013;**15**(5): 657-662

[18] Verberk WJ, Omboni S, Kollias A, Stergiou GS. Screening for atrial fibrillation with automated blood pressure measurement: Research evidence and practice recommendations. *International Journal of Cardiology*. 2016;**203**:465-473

[19] Wiesel J, Arbesfeld B, Schechter D. Comparison of the microlife blood pressure monitor with the Omron blood pressure monitor for detecting atrial fibrillation. *The American Journal of Cardiology*. 2014;**114**(7): 1046-1048

[20] King S, Fitzgerald A, Bartlett C, Mahon J, Arber M, Carr E, et al. Evidence Summary for Screening for Atrial Fibrillation in Adults. External Review against Programme Appraisal Criteria for the UK National Screening Committee. London: UK National Screening Committee; 2018

[21] National Clinical Guideline C. National Institute for Health and Clinical Excellence: Guidance. *Atrial Fibrillation: The Management of Atrial Fibrillation*. London: National Institute for Health and Care Excellence (UK); 2014

[22] Fitzmaurice DA, Hobbs FD, Jowett S, Mant J, Murray ET, Holder R, et al. Screening versus routine practice in detection of atrial fibrillation in patients aged 65 or over: Cluster randomised controlled trial. *BMJ*. 2007; **335**(7616):383

[23] Swancutt D, Hobbs R, Fitzmaurice D, Mant J, Murray E, Jowett S, 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 the over 65s: (SAFE) [ISRCTN19633732]. *BMC Cardiovascular Disorders*. 2004;**4**:12

[24] Welton NJ, McAleenan A, Thom HH, Davies P, Hollingworth W, Higgins JP, et al. Screening strategies for atrial fibrillation: A systematic review and cost-effectiveness analysis. *Health Technology Assessment*. 2017;**21**(29): 1-236

[25] Jonas DE, Kahwati LC, Yun JDY, Middleton JC, Coker-Schwimmer M, Asher GN. Screening for atrial fibrillation with electrocardiography: Evidence report and systematic review for the US preventive services task force. *Journal of the American Medical Association*. 2018;**320**(5):485-498

[26] Zungsontiporn N, Link MS. Newer technologies for detection of atrial fibrillation. *BMJ*. 2018;**363**:k3946

[27] Lobban T, Breakwell N, Hamed N, Antoniou S, Alves De Costa F, Tous S, et al. Identifying the undiagnosed AF patient through “know your pulse” community pharmacy based events held

- in ten countries during arrhythmia Alliance world heart rhythm week 2017. *European Heart Journal*. 2018;**39** (suppl_1):263
- [28] Turakhia MP, Desai SA, Harrington RA. The outlook of digital health for cardiovascular medicine: Challenges but also extraordinary opportunities. *JAMA Cardiology*. 2016; **1**(7):743-744
- [29] Zimetbaum P, Goldman A. Ambulatory arrhythmia monitoring: Choosing the right device. *Circulation*. 2010;**122**(16):1629-1636
- [30] Harris K, Edwards D, Mant J. How can we best detect atrial fibrillation? *The Journal of the Royal College of Physicians of Edinburgh*. 2012;**42** (Suppl 18):5-22
- [31] Lau JK, Lowres N, Neubeck L, Brieger DB, Sy RW, Galloway CD, et al. iPhone ECG application for community screening to detect silent atrial fibrillation: A novel technology to prevent stroke. *International Journal of Cardiology*. 2013;**165**(1):193-194
- [32] Lowres N, Neubeck L, Salkeld G, Krass I, McLachlan AJ, Redfern J, et al. Feasibility and cost-effectiveness of stroke prevention through community screening for atrial fibrillation using iPhone ECG in pharmacies. The SEARCH-AF study. *Thrombosis and Haemostasis*. 2014;**111**(6):1167-1176
- [33] Bansal A, Joshi R. Portable out-of-hospital electrocardiography: A review of current technologies. *Journal of Arrhythmia*. 2018;**34**(2):129-138
- [34] Chan PH, Wong CK, Poh YC, Pun L, Leung WW, Wong YF, et al. Diagnostic performance of a smartphone-based Photoplethysmographic application for atrial fibrillation screening in a primary care setting. *Journal of the American Heart Association*. 2016;**5**(7):e003428
- [35] Chan P-H, Wong C-K, Pun L, Wong Y-F, Wong MM-Y, Chu DW-S, et al. Head-to-head comparison of the AliveCor heart monitor and microlife WatchBP office AFIB for atrial fibrillation screening in a primary care setting. *Circulation*. 2017;**135**(1):110-112
- [36] National Institute for Health and Care Excellence. AliveCor Heart Monitor and AliveECG app (Kardia Mobile) for detecting atrial fibrillation. National Institute for Health and Care Excellence. 2015. Report No.: 978-1-4731-1373-2 [Accessed: 05/06/2019]
- [37] Reed MJ, Grubb NR, Lang CC, O'Brien R, Simpson K, Padarenga M, et al. Multi-Centre randomised controlled trial of a smart phone-based event recorder alongside standard care versus standard care for patients presenting to the emergency department with palpitations and pre-syncope - the IPED (investigation of palpitations in the ED) study: Study protocol for a randomised controlled trial. *Trials*. 2018;**19**(1):711
- [38] de Asmundis C, Conte G, Sieira J, Chierchia GB, Rodriguez-Manero M, Di Giovanni G, et al. Comparison of the patient-activated event recording system vs. traditional 24 h Holter electrocardiography in individuals with paroxysmal palpitations or dizziness. *Europace: European Pacing, Arrhythmias, and Cardiac Electrophysiology: Journal of the Working Groups on Cardiac Pacing, Arrhythmias, and Cardiac Cellular Electrophysiology of the European Society of Cardiology*. 2014;**16**(8): 1231-1235
- [39] Kaleschke G, Hoffmann B, Drewitz I, Steinbeck G, Naebauer M, Goette A, et al. Prospective, multicentre validation of a simple, patient-operated electrocardiographic system for the detection of arrhythmias and electrocardiographic changes. *Europace: European Pacing, Arrhythmias, and*

- Cardiac Electrophysiology: Journal of the Working Groups on Cardiac Pacing, Arrhythmias, and Cardiac Cellular Electrophysiology of the European Society of Cardiology. 2009;**11**(10): 1362-1368
- [40] Kearley K, Selwood M, Van den Bruel A, Thompson M, Mant D, Hobbs FR, et al. Triage tests for identifying atrial fibrillation in primary care: A diagnostic accuracy study comparing single-lead ECG and modified BP monitors. *BMJ Open*. 2014; **4**(5):e004565
- [41] Barrett PM, Komatireddy R, Haaser S, Topol S, Sheard J, Encinas J, et al. Comparison of 24-hour Holter monitoring with 14-day novel adhesive patch electrocardiographic monitoring. *The American Journal of Medicine*. 2014;**127**(1):95.e11-95.e17
- [42] Rosenberg MA, Samuel M, Thosani A, Zimetbaum PJ. Use of a noninvasive continuous monitoring device in the management of atrial fibrillation: A pilot study. *Pacing and Clinical Electrophysiology*. 2013;**36**(3): 328-333
- [43] Schreiber D, Sattar A, Drigalla D, Higgins S. Ambulatory cardiac monitoring for discharged emergency department patients with possible cardiac arrhythmias. *The Western Journal of Emergency Medicine*. 2014; **15**(2):194-198
- [44] Tung CE, Su D, Turakhia MP, Lansberg MG. Diagnostic yield of extended cardiac patch monitoring in patients with stroke or TIA. *Frontiers in Neurology*. 2015;**5**:266
- [45] Walsh JA 3rd, Topol EJ, Steinhubl SR. Novel wireless devices for cardiac monitoring. *Circulation*. 2014; **130**(7):573-581
- [46] Cardiocity. RhythmPadGP. Available from: <http://www.cardiocity.com/?portfolio=rhythm-pad-gp> [Accessed: 06/06/2019]
- [47] Wiesel J, Fitzig L, Herschman Y, Messineo FC. Detection of atrial fibrillation using a modified microlife blood pressure monitor. *American Journal of Hypertension*. 2009;**22**(8): 848-852
- [48] Doliwa PS, Frykman V, Rosenqvist M. Short-term ECG for out of hospital detection of silent atrial fibrillation episodes. *Scandinavian Cardiovascular Journal*. 2009;**43**(3): 163-168
- [49] Rekhviashvili A, Baganashvili E, Tan K, Raymakers F, Sakandelidze T. Reproducibility and diagnostic value of E100 event recorder for patients with complains on heart arrhythmias and no changes on multiple routine ECGs and 24-hour holter monitoring. *Georgian Medical News*. 2012;**203**:29-33
- [50] Schuchert A, Behrens G, Meinertz T. Evaluation of infrequent episodes of palpitations with a patient-activated hand-held electrocardiograph. *Zeitschrift für Kardiologie*. 2002;**91**(1): 62-67
- [51] Tieleman RG, Plantinga Y, Rinkes D, Bartels GL, Posma JL, Cator R, et al. Validation and clinical use of a novel diagnostic device for screening of atrial fibrillation. *Europace: European Pacing, Arrhythmias, and Cardiac Electrophysiology: Journal of the Working Groups on Cardiac Pacing, Arrhythmias, and Cardiac Cellular Electrophysiology of the European Society of Cardiology*. 2014;**16**(9): 1291-1295
- [52] Usadel L, Haverkämper G, Herrmann S, Löber R, Weiss K, Opgen-Rhein B, et al. Arrhythmia detection in pediatric patients: ECG quality and diagnostic yield of a patient-triggered Einthoven Lead-I event recorder

- (Zenicor EKG-2™). *Pediatric Cardiology*. 2016;**37**(3):491-496
- [53] Eerikainen LM, Bonomi AG, Schipper F, Dekker LRC, Vullings R, de Morree HM, et al. Comparison between electrocardiogram- and photoplethysmogram-derived features for atrial fibrillation detection in free-living conditions. *Physiological Measurement*. 2018;**39**(8): 084001
- [54] Allen J. Photoplethysmography and its application in clinical physiological measurement. *Physiological Measurement*. 2007;**28**(3):R1-R39
- [55] Haghayegh S, Khoshnevis S, Smolensky MH, Diller KR. Accuracy of PurePulse photoplethysmography technology of Fitbit charge 2 for assessment of heart rate during sleep. *Chronobiology International*. 2019; **36**(7):927-933
- [56] Turakhia MP, Desai M, Hedlin H, Rajmane A, Talati N, Ferris T, et al. Rationale and design of a large-scale, app-based study to identify cardiac arrhythmias using a smartwatch: The apple heart study. *American Heart Journal*. 2019;**207**:66-75
- [57] Yan BP, Chan CK, Li CK, To OT, Lai WH, Tse G, et al. Resting and postexercise heart rate detection from fingertip and facial photoplethysmography using a smartphone camera: A validation study. *JMIR mHealth and uHealth*. 2017; **5**(3):e33
- [58] Apple. Apple Watch Series—Health. 2019. Available from: <https://www.apple.com/apple-watch-series-4/health/> [Accessed: 06/06/2019]
- [59] Apple. Taking an ECG with the ECG app on Apple Watch Series 4. 2019. Available from: <https://support.apple.com/en-us/HT208955> [Accessed: 06/06/2019]
- [60] Stanford University School of Medicine. Apple Heart Study demonstrates ability of wearable technology to detect atrial fibrillation. Available from: <http://med.stanford.edu/news/all-news/2019/03/apple-heart-study-demonstrates-ability-of-wearable-technology.html> [Accessed: 17/06/2019]
- [61] U.S. National Library of Medicine. Atrial Fibrillation Detection Using Garmin Wearable Technology (GARMIN AF). 2018 NCT03566836.
- [62] Clinical Trial Database [Internet]. Available from: <https://clinicaltrials.gov/> [Accessed: 06/06/2019]
- [63] EU Clinical Trials Register [Internet]. Available from: <https://www.clinicaltrialsregister.eu/> [Accessed: 06/06/2019]
- [64] January CT, Wann LS, Alpert JS, Calkins H, Cigarroa JE, Cleveland JC Jr, et al. 2014 AHA/ACC/HRS guideline for the management of patients with atrial fibrillation: Executive summary: A report of the American College of Cardiology/American Heart Association task force on practice guidelines and the Heart Rhythm Society. *Circulation*. 2014;**130**(23):2071-2104
- [65] January CT, Wann LS, Calkins H, Chen LY, Cigarroa JE, Cleveland JC Jr, et al. 2019 AHA/ACC/HRS focused update of the 2014 AHA/ACC/HRS guideline for the Management of Patients with Atrial Fibrillation: A report of the American College of Cardiology/American Heart Association task force on clinical practice guidelines and the Heart Rhythm Society. *Journal of the American College of Cardiology*. 2019;**74**(1):104-132
- [66] January CT, Wann LS, Calkins H, Field ME, Chen LY, Furie KL, et al. AHA/ACC/HRS focused update of the 2014 AHA/ACC/HRS guideline for the Management of Patients with Atrial

Fibrillation: A report of the American College of Cardiology/American Heart Association task force on clinical practice guidelines and the Heart Rhythm Society. *Heart Rhythm*. 2019; **64**(21):e1-e76

[67] Camm AJ, Simantirakis E, Goette A, Lip GY, Vardas P, Calvert M, et al. Atrial high-rate episodes and stroke prevention. *Europace: European Pacing, Arrhythmias, and Cardiac Electrophysiology: Journal of the Working Groups on Cardiac Pacing, Arrhythmias, and Cardiac Cellular Electrophysiology of the European Society of Cardiology*. 2017;**19**(2): 169-179

[68] Glotzer TV, Hellkamp AS, Zimmerman J, Sweeney MO, Yee R, Marinchak R, et al. Atrial high rate episodes detected by pacemaker diagnostics predict death and stroke: Report of the atrial diagnostics ancillary study of the MOfE selection trial (MOST). *Circulation*. 2003;**107**(12): 1614-1619

[69] Kawakami H, Nagai T, Saito M, Inaba S, Seike F, Nishimura K, et al. Clinical significance of atrial high-rate episodes for thromboembolic events in Japanese population. *Heart Asia*. 2017; **9**(2):e010954

[70] Dhutia H. Impact and Management of Atrial High Rate Events Detected by Implantable Cardiac Devices. *British Cardiovascular Society Editorial [Internet]*. 2017. Available from: https://www.bcs.com/pages/news_full.asp?NewsID=19792648 [Accessed: 08/06/2019]

[71] Freedman B, Boriani G, Glotzer TV, Healey JS, Kirchhof P, Potpara TS. Management of atrial high-rate episodes detected by cardiac implanted electronic devices. *Nature Reviews Cardiology*. 2017;**14**(12):701-714

[72] Giron NA, Millan CA, Lopez DM. Systematic review on features extracted

from PPG signals for the detection of atrial fibrillation. *Studies in Health Technology and Informatics*. 2019;**261**: 266-273

[73] Turakhia MP, Hoang DD, Zimetbaum P, Miller JD, Froelicher VF, Kumar UN, et al. Diagnostic utility of a novel leadless arrhythmia monitoring device. *The American Journal of Cardiology*. 2013;**112**(4):520-524

[74] Garabelli P, Stavrakis S, Albert M, Koomson E, Parwani P, Chohan J, et al. Comparison of QT interval readings in Normal sinus rhythm between a smartphone heart monitor and a 12-Lead ECG for healthy volunteers and inpatients receiving Sotalol or Dofetilide. *Journal of Cardiovascular Electrophysiology*. 2016;**27**(7):827-832

[75] Abi Khalil C, Haddad F, Al Suwaidi J. Investigating palpitations: The role of Holter monitoring and loop recorders. *BMJ*. 2017;**358**:j3123

[76] Hickey KT, Hauser NR, Valente LE, Riga TC, Frulla AP, Masterson Creber R, et al. A single-center randomized, controlled trial investigating the efficacy of a mHealth ECG technology intervention to improve the detection of atrial fibrillation: The iHEART study protocol. *BMC Cardiovascular Disorders*. 2016;**16**:152

[77] Peleg M, Michalowski W, Wilk S, Parimbelli E, Bonaccio S, O'Sullivan D, et al. Ideating Mobile health behavioral support for compliance to therapy for patients with chronic disease: A case study of atrial fibrillation management. *Journal of Medical Systems*. 2018; **42**(11):234

[78] Baca-Motes K, Edwards AM, Waalen J, Edmonds S, Mehta RR, Ariniello L, et al. Digital recruitment and enrollment in a remote nationwide trial of screening for undiagnosed atrial fibrillation: Lessons from the randomized, controlled mSToPS trial.

Contemporary Clinical Trials
Communications. 2019;**14**:100318

[79] Guo X, Vittinghoff E, Olgin JE, Marcus GM, Pletcher MJ. Volunteer participation in the health eHeart study: A comparison with the US population. *Scientific Reports*. 2017;**7**(1):1956

[80] Glotzer TV, Ziegler PD. Silent atrial fibrillation as a stroke risk factor and anticoagulation indication. *The Canadian Journal of Cardiology*. 2013;**29** (7 Suppl):S14-S23

[81] Yang TF, Devine B, Macfarlane PW. Artificial neural networks for the diagnosis of atrial fibrillation. *Medical and Biological Engineering and Computing*. 1994;**32**(6):615-619

[82] Chesnokov YV. Complexity and spectral analysis of the heart rate variability dynamics for distant prediction of paroxysmal atrial fibrillation with artificial intelligence methods. *Artificial Intelligence in Medicine*. 2008;**43**(2):151-165

[83] Ebrahimzadeh E, Kalantari M, Joulani M, Shahraki RS, Fayaz F, Ahmadi F. Prediction of paroxysmal atrial fibrillation: A machine learning based approach using combined feature vector and mixture of expert classification on HRV signal. *Computer Methods and Programs in Biomedicine*. 2018;**165**:53-67

[84] Buch VH, Ahmed I, Maruthappu M. Artificial intelligence in medicine: Current trends and future possibilities. *British Journal of General Practice*. 2018;**68**(668):143-144

[85] Fernandes CO, Lucena CJ. A software framework for remote patient monitoring by using multi-agent systems support. *JMIR Medical Informatics*. 2017;**5**(1):e9

[86] Rialle V, Lamy JB, Noury N, Bajolle L. Telemonitoring of patients at

home: A software agent approach. *Computer Methods and Programs in Biomedicine*. 2003;**72**(3):257-268

[87] Shahid N, Rappon T, Berta W. Applications of artificial neural networks in health care organizational decision-making: A scoping review. *PLoS One*. 2019;**14**(2):e0212356

[88] Castle-Clarke S. What will new technology mean for the NHS and its patients?: The Kings Fund and Nuffield Trust. 2018. Available from: https://www.kingsfund.org.uk/sites/default/files/2018-06/NHS_at_70_what_will_new_technology_mean_for_the_NHS_0.pdf.

[89] Lamkin P. Wearable Tech Market To Double By 2021: Forbes. 2017. Available from: <https://www.forbes.com/sites/paullamkin/2017/06/22/wearable-tech-market-to-double-by-2021/#619dc577d8f3> [Accessed: 09/06/2019]

[90] Yang H, Yu J, Zo H, Choi M. User acceptance of wearable devices: An extended perspective of perceived value. *Telematics and Informatics*. 2016;**33**(2):256-269

[91] DesRoches CM, Bell SK, Dong Z, Elmore J, Fernandez L, Fitzgerald P, et al. Patients managing medications and Reading their visit notes: A survey of OpenNotes participants. *Annals of Internal Medicine*. 2019;**171**(1):69-71

[92] Jacob JA. Patient access to physician notes is gaining momentum. *Journal of the American Medical Association*. 2016;**315**(23):2510-2511

[93] GenieMD. Available from: <https://geniemd.com/> [13/06/2019]

[94] Archer N, Fevrier-Thomas U, Lokker C, McKibbin KA, Straus SE. Personal health records: A scoping review. *Journal of the American Medical Informatics Association*. 2011;**18**(4):515-522

- [95] Dameff C, Clay B, Longhurst CA. Personal health records: More promising in the smartphone era? *Journal of the American Medical Association*. 2019; **321**(4):339-340
- [96] Davies P. Should patients be able to control their own records? *BMJ [British Medical Journal]*. 2012;**345**:e4905
- [97] Hamilton SG. Obstetric record card for use in general practice. *The Practitioner*. 1956;**176**(1051):79-81
- [98] Health Policy Team. Personal Child Health Record (PCHR): Royal College of Paediatrics and Child Health. Available from: <https://www.rcpch.ac.uk/resources/personal-child-health-record-pchr> [Accessed: 09/06/2019]
- [99] Walton S, Bedford H, Dezateux C. Use of personal child health records in the UK: Findings from the millennium cohort study. *BMJ*. 2006;**332**(7536): 269-270
- [100] Hawley G, Jackson C, Hepworth J, Wilkinson SA. Sharing of clinical data in a maternity setting: How do paper hand-held records and electronic health records compare for completeness? *BMC Health Services Research*. 2014;**14**: 650
- [101] Hobbs FD, Fitzmaurice DA, Mant J, Murray E, Jowett S, Bryan S, 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 Technology Assessment*. 2005;**9**(40):iii-iv, ix-x):1-74
- [102] Taggar JS, Coleman T, Lewis S, Heneghan C, Jones M. Accuracy of methods for detecting an irregular pulse and suspected atrial fibrillation: A systematic review and meta-analysis. *European Journal of Preventive Cardiology*. 2016;**23**(12):1330-1338
- [103] Berge T, Brynildsen J, Larssen HKN, Onarheim S, Jenssen GR, Ihle-Hansen H, et al. Systematic screening for atrial fibrillation in a 65-year-old population with risk factors for stroke: Data from the Akershus cardiac examination 1950 study. *Europace: European Pacing, Arrhythmias, and Cardiac Electrophysiology: Journal of the Working Groups on Cardiac Pacing, Arrhythmias, and Cardiac Cellular Electrophysiology of the European Society of Cardiology*. 2018;**20**(Fi_3): f299-f305
- [104] Chan N-Y, Choy C-C. Screening for atrial fibrillation in 13 122 Hong Kong citizens with smartphone electrocardiogram. *Heart*. 2017;**103**(1): 24-31
- [105] Chan P-H, Wong C-K, Pun L, Wong Y-F, Wong MM-Y, Chu DW-S, et al. Diagnostic performance of an automatic blood pressure measurement device, microlife WatchBP home a, for atrial fibrillation screening in a real-world primary care setting. *BMJ Open*. 2017;**7**(6):e013685
- [106] Kaasenbrood F, Hollander M, Rutten FH, Gerhards LJ, Hoes AW, Tieleman RG. Yield of screening for atrial fibrillation in primary care with a hand-held, single-lead electrocardiogram device during influenza vaccination. *Europace: European Pacing, Arrhythmias, and Cardiac Electrophysiology: Journal of the Working Groups on Cardiac Pacing, Arrhythmias, and Cardiac Cellular Electrophysiology of the European Society of Cardiology*. 2016;**18**(10): 1514-1520
- [107] Svennberg E, Engdahl J, Al-Khalili F, Friberg L, Frykman V, Rosenqvist M. Mass screening for untreated atrial fibrillation: The STROKESTOP study. *Circulation*. 2015;**131**(25):2176-2184
- [108] Tavernier R, Wolf M, Kataria V, Philips T, Huys R, Taghji P, et al.

Screening for atrial fibrillation in hospitalised geriatric patients. *Heart*. 2018;**104**(7):588-593

[109] Turakhia MP, Ullal AJ, Hoang DD, Than CT, Miller JD, Friday KJ, et al. Feasibility of extended ambulatory electrocardiogram monitoring to identify silent atrial fibrillation in high-risk patients: The screening study for undiagnosed atrial fibrillation (STUDY-AF). *Clinical Cardiology*. 2015;**38**(5): 285-292

[110] Wiesel J, Salomone TJ. Screening for atrial fibrillation in patients ≥ 65 years using an automatic blood pressure monitor in a skilled nursing facility. *The American Journal of Cardiology*. 2017; **120**(8):1322-1324

[111] Aronsson M, Svennberg E, Rosenqvist M, Engdahl J, Al-Khalili F, Friberg L, et al. Cost-effectiveness of mass screening for untreated atrial fibrillation using intermittent ECG recording. *Europace: European Pacing, Arrhythmias, and Cardiac Electrophysiology: Journal of the Working Groups on Cardiac Pacing, Arrhythmias, and Cardiac Cellular Electrophysiology of the European Society of Cardiology*. 2015;**17**(7): 1023-1029