**Mobile health applications for managing atrial fibrillation for healthcare professionals and patients: a systematic review**

# Authors

Deirdre A Lane1\* PhD, Naoimh McMahon2 PhD, Josephine Gibson2 PhD, Jo C Weldon2 MPH, Michal M. Farkowski3 MD, PhD, Radoslaw Lenarczyk4 PhD, Caroline L Watkins2 PhD, Polychronis Dilaveris5 PhD, Enrico G Caiani6 PhD, Tatjana S Potpara7\* PhD

1 Liverpool Centre for Cardiovascular Science, University of Liverpool and Liverpool Heart & Chest Hospital, Liverpool, United Kingdom

2 Faculty of Health and Wellbeing, University of Central Lancashire, Preston, United Kingdom

3 II Department of Heart Arrhythmia, National Institute of Cardiology, Warsaw, Poland

4 First Department of Cardiology and Angiology, Silesian Centre for Heart Disease, Zabrze, Poland

5 1st University Department of Cardiology, National & Kapodistrian University of Athens School of Medicine, Athens, Greece

6 Politecnico di Milano, Electronic, Information and Biomedical Engineering Department., Milan, Italy

7 School of Medicine, University of Belgrade, Belgrade, Serbia; Cardiology Clinic, Clinical Centre of Serbia, Belgrade, Serbia

**\***Joint Senior Authors

**Corresponding Author:** Dr Deirdre Lane, Liverpool Centre for Cardiovascular Science, University of Liverpool, Liverpool, United Kingdom, L7 8TX

[deirdre.lane@liverpool.ac.uk](mailto:deirdre.lane@liverpool.ac.uk)

**Running title:** m-Health apps for atrial fibrillation

**Total number of tables and figures:** Tables: 3; Figures: 1

**Keywords:** mobile health, m-health, apps, atrial fibrillation, management, patients, healthcare professionals, systematic review

**ABSTRACT**

**Background:** A plethora of mobile health applications (m-health apps) to support healthcare are available for both patients and healthcare professionals (HCPs) but content and quality vary considerably and few have undergone formal assessment.

**Objective:** To systematically review the literature on m-health apps for managing atrial fibrillation (AF) that examine the impact on knowledge of AF, patient and HCP behaviour, patients’ quality-of-life, and user engagement.

**Methods:** MEDLINE, EMBASE, CINAHL, and PsychInfo were searched from 1 January 2005 to 5 September 2019, with hand-searching of clinical trial registers and grey literature. Studies were eligible for inclusion if they reported changes in any of: (1) Knowledge of AF; (2) Provider behaviour (e.g. guideline adherence); (3) Patient behaviour (e.g. medication adherence); (4) Patient quality-of-life; (5) User engagement. Two reviewers independently assessed articles for eligibility. A narrative review was undertaken as included studies varied widely in their design, interventions, comparators and outcomes.

**Results:** Seven studies were included; six m-health apps aimed at patients and one at HCPs. m-health apps ranged widely in design, features, and method of delivery. Four studies reported patient knowledge of AF; three demonstrated significant knowledge improvement post-intervention or compared to usual care. One study reported greater HCP adherence to oral anticoagulation guidelines after m-health app implementation. Two studies reported on patient medication adherence and quality-of-life; both showed improved quality-of-life post-intervention but only one observed increased adherence. Regarding user engagement, five studies reported patient perspectives on usability, three on acceptability, and one on feasibility; overall all m-health apps were rated positively.

**Conclusion:** m-health apps demonstrate improvements in patient knowledge, behaviour and quality of life. Studies formally evaluating the impact of m-health on HCP behaviour are scarce and larger-scale studies with representative patient cohorts, appropriate comparators and longer-term assessment of the impact of m-health apps are warranted.

**INTRODUCTION**

The use of mobile health (m-health), primarily via smartphones, has the potential to allow wider dissemination of healthcare and could also support traditional healthcare delivery by promoting greater interaction between patients and healthcare professionals (HCPs).1, 2

Over the last decade there has been an explosion of m-health applications (m-health apps), with an estimated 3.7 billion downloaded globally between 2013 and 2017,3 including many for atrial fibrillation (AF) but very few have undergone formal assessment.4-6 Hence, the magnitude and impact of m-health apps for AF, and the degree of patient and HCP engagement and acceptability, are currently unknown. Given that patients and HCPs can easily access these apps, it is important to have some sense of their scope and content, acceptability to users and additionally, to examine the purpose of, and outcomes of, app implementation and usage. To date, no systematic review has evaluated the impact of the variety of m-health apps currently available for patients with AF and HCPs who manage this condition. Therefore, the current review will systematically assess this literature to examine the impact on knowledge of AF, patient and HCP behaviour, patients’ quality-of-life, and user engagement with the m-health app.

**METHODS**

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.7 A completed PRISMA checklist is provided in the supplementary material.

**Criteria for considering studies for the review**

Studies carried out in any setting and designed to evaluate m-health apps were eligible for inclusion. We included primary research which evaluated the effects of any m-health app for AF which was designed to enhance patient and/or HCP education, improve communication between patients and HCPs, or to encourage active patient involvement in the management of their condition. All types of study designs were considered with the exception of purely qualitative studies. Ongoing studies were considered and are presented in a separate table. We excluded e-health or m-health apps that only screened for or monitored AF, and remote monitoring of AF via ECG/implantable devices.

*Participants*

Adults (18 years and older) with AF and/or HCPs managing patients with AF were eligible for inclusion. Studies with mixed population groups which included patients with AF were also eligible for inclusion in this review, provided the majority were AF patients, and/or data regarding AF patients alone was available.

*Interventions*

Interventions designed to manage AF via the use of m-health apps (e.g. mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices etc.) were eligible for inclusion.

*Comparators*

Any comparator or usual care (i.e. no intervention) could be included.

*Outcomes*

Studies were eligible for inclusion in the review if they reported changes in any of the following outcomes: (1) Knowledge of AF (patient and/or HCP); (2) HCP behaviour (e.g. adherence to AF management guidelines); (3) Patient behaviour (e.g. medication adherence); (4) Patient quality-of-life. Studies were also eligible for inclusion if they reported only process outcomes e.g. user engagement and perspectives on acceptability and usage patterns of the m-health app, but not if they were solely qualitative in nature.

**Search strategy**

The search strategy was developed by the research team. Medical Subject Headings and keywords such as atrial fibrillation, mobile health, smartphone, mobile applications, etc. were used (see **Supplementary Table 1**) to search bibliographic databases. MEDLINE, EMBASE, CINAHL, and PsychInfo were searched from 1 January 2005 to 5 September 2019 for relevant studies. We restricted the publication date to the year 2005 onwards as m-health is a relatively new phenomenon, and also to capture only the more recent and relevant empirical research reflective of changes in clinical practice guidelines around stroke prevention for AF. There were no language restrictions. Availability of the full-text publication was a requirement.

Reference lists of included studies were manually searched. Additional unique records were identified through hand-searching trials registers (Cochrane Central Register of Controlled Trials, Clinical Trials ([www.clinicaltrials.gov](http://www.clinicaltrials.gov)) and ISCTRN ([www.isrctn.com/)](http://www.isrctn.com/)) by entering key search terms (e.g., atrial fibrillation, mobile health, smartphones etc.) into the websites search function. Grey literature was addressed by contacting key opinion leaders for unpublished data. Search results were managed using Covidence.

**Study selection**

Two reviewers (DL/NM) independently screened the titles and abstracts against the search criteria. The full texts of all potentially relevant articles were retrieved and independently assessed by both reviewers. Disagreements were resolved through discussion and assessment by a third reviewer (JG).

**Data extraction**

Data were extracted by one reviewer (DL) and checked by another reviewer (JW). The following information was extracted: (i) authors, year, country; (ii) study aim; (iii) study characteristics (study design and sample size); (iv) participant characteristics (age, sex, ethnicity, comorbidities); (v) intervention (type of m-health delivery, features of the app/m-health, duration, frequency, providers, target users, follow-up points); (vi) comparator(s) (usual care, description of usual care, no intervention); and (vii) outcomes (patients’ and/or HCP’s knowledge of AF, HCP behaviour (e.g. adherence to AF management guidelines), patient behaviour (e.g. medication adherence), patient quality-of-life, and user engagement and perspectives on acceptability).

**Risk of bias assessment**

Assessment of risk of bias in individual studies was undertaken independently by two reviewers (DL/JG) utilising the Cochrane risk of bias tool8 for randomised controlled trials and the Risk of bias tool for non-randomised studies,9 as appropriate.

**Data synthesis**

Given that the included studies varied widely in their design, interventions, comparators and outcomes, no synthesis was undertaken and we report a narrative review.

**RESULTS**

The searches identified 11,152 citations (see **Figure 1**). After removal of duplicates (n=2223), the titles and abstracts of 8929 articles were independently assessed by two reviewers. Of these, 52 were deemed to be potentially relevant and were assessed for eligibility in their full text; 43 were excluded and 2 studies were on-going.10, 11 A full list of the excluded studies and the reason for exclusion are provided in the Supplementary materials (see **Supplementary Table 2**). No relevant studies were identified via hand-searching. As a result, seven studies4-6, 12-15 were included (see **Table 1**).

**Characteristics of the included studies**

The included studies were published between 2017 and 2019 and comprised between 1013, 15 and 2096 participants, with a total of 466 patients4-6, 12-14 (mean age ranged from 5914 to 716 years; 50%13 to 67%5 male) and 10 HCPs (mean age 43.8 years; 30% men).15 Studies were conducted in Belgium (n=2),4, 5 China (n=1),6 Iran (n=1),15 Poland (n=1),12 and the USA (n=2).13, 14 Six studies were m-health apps aimed at patients4-6, 12-14 all of whom had AF (not exclusively AF in one study12), with one targeting HCPs.15 Only one study6 had m-health apps directed at both patients and HCPs, but this study only reported outcome data for patients. The studies varied widely in design with one cluster-randomised pilot study;6 one prospective, randomised controlled trial;4 two before-and-after studies;12, 15 and three exploratory/feasibility pilot studies.5, 13, 14 Most studies had short follow-up periods, between 4-weeks13, 14 and 3-months,4-6 with only two studies following participants for longer (6-months15 and 1-year12).

**Types of interventions**

The interventions varied markedly in their design, features of the m-health app, and method of delivery (see **Table 1**). Three were delivered via an app on a mobile phone only,6, 12, 13 and four via mobile phone or tablet.4, 5, 14, 15 Two studies were patient education interventions,4, 12 two were patient behaviour change interventions utilising support and adherence apps,13, 14 two supported HCP behaviour change6, 15 although one of the two6 did not report the outcome data related to the HCP app, and two were multi-faceted apps incorporating patient behaviour change and education interventions.5, 6

The one m-health app designed for HCPs (cardiologists) was a computerised decision-support system (CDSS) to help improve adherence to oral anticoagulation (OAC) guidelines, using an app to calculate the CHA2DS2-VASc, and HAS-BLED scores and to provide OAC treatment recommendations based on clinical guidelines.15

One study12 used oculus glasses (virtual reality headset) and a smartphone to deliver patient education on risk of stroke and use of OAC for stroke prevention via a 3D movie, while another, the miAfib app, assessed AF symptoms and mood throughout the day.13 The mAF app6 included a patient version and a doctor version, containing clinical decision-support tools (CHA2DS2-VASc, HAS-BLED, SAMe-TT2R2) linked to patient health records, patient educational materials (8 topics), and tools to engage and support patients in self-care (e.g., heart rate and blood pressure monitoring) and structured follow-up.

Hirschey and colleagues14 developed an app for patients’ use on smartphones or tablets, to provide information on AF and OAC via text and animated videos, with a log for patients to record AF episodes and related notes, triggers for AF, medication and appointment reminders, heart rate monitor, and health-related news feed.

The Health Buddies app5 teamed up AF patients and their grandchildren and recorded performance of ‘healthy’ daily tasks, such as intake of OAC (non-vitamin K antagonist OAC, NOAC) and heart rate monitoring for the AF patients (grandparents) and eating fruit or brushing teeth twice a day for the ‘buddies’ (grandchildren). The app rewarded performance of these daily tasks with access to educational quizzes for the patients and educational games for the grandchildren. Completion of daily tasks for a 3-month period was rewarded with a joint trip or fun activity for the grandparents and grandchildren. Another study by the same research group utilised an on-line tailored education platform on AF and procedure-related information for patients undergoing pulmonary vein isolation or electrical cardioversion, accessed using a unique log-in.4

**Types of comparators**

One study compared the intervention to usual care only;6 one compared the app to standard care with internet access but no structured intervention, and standard care with no internet access;4 two were before-and-after studies,12, 15 and three studies did not have a comparison group.5, 13, 14 Usual care consisted of information from a cardiologist and booklets4, and consultation with a cardiologist.6

**Types of outcomes**

Four studies reported on patient knowledge of AF,4-6, 12 with only one reporting patient knowledge of OAC.12 No study reported on the knowledge of HCPs. Only one study15 reported on HCP behaviour, focussing on adherence to OAC guidelines. Three of the four studies that examined the impact of m-health apps on patient knowledge demonstrated a significant improvement on knowledge of AF and/or OAC after the intervention12 or compared to usual care4, 6 (see **Table 1**). Desteghe et al5 reported a non-significant (p=0.09) increase in knowledge level from baseline to 3-months post-intervention. The only study that reported the effect of the m-health app on HCP behaviour showed a significant improvement in guideline-adherent OAC treatment following the intervention (48% pre-intervention vs. 65.5% post-intervention; p<0.0001).15

Two studies reported on patient adherence to medication.5, 6 One6 reported a significant increase in drug adherence at 1- and 3-months in the intervention group (both p<0.001) measured using the Pharmacy Quality Alliance adherence measure, while the other study5 showed a reduction in adherence from 88.6% (SD 15.4%) to 81.8% (SD 18.7%) measured using an electronic medication monitor.

Two studies reported on patient’s quality-of-life.4, 6 Guo et al6 measured quality-of-life using the visual analogue scale of the EQ-5D16 and reported a significant improvement from baseline to 1-month and 3-months in the intervention group compared to usual care (all p<0.05). Desteghe4 assessed quality-of-life using the AFEQT.17 This demonstrated significant improvements at 6- and 12-weeks post-procedure compared to baseline in the m-health app group and the comparator who had access to the internet, but not in the usual care group.

Five studies investigated user engagement with the m-health app,4-6, 13, 14 with three assessing perspectives on acceptability,4, 6, 14 five on usability,4-6, 13, 14 and one on feasibility.6 Generally, patients found the m-health apps acceptable and usable. The two studies by Desteghe and colleagues4, 5 employed the User Experience Questionnaire18 to assess patient engagement with the apps. The m-health app for tailored patient education rated positively on all aspects,4 whilst the Health Buddies app was rated positively only for clarity, novelty, stimulation and attractiveness.5 Three studies4, 5, 14 reported some negative aspects of their m-health apps: software bugs reported by 7/12 (58%);14 10% were unable to use the device;4 and 5/15 (33%) often encountered technical difficulties or problems.5

**Risk of bias assessment**

A summary of the risk of bias assessment is presented in **Table 2**, with more detailed explanation available in **Supplementary Table 3**. Overall, most of the included studies had high or unclear risk of bias in relation to participant selection due to highly selected and often small sample sizes,5, 13, 14 the observational nature of the majority of the studies5, 13-15 and the lack of detail on the randomisation procedure6 or incomplete randomisation.4 Due to the nature of the interventions it was not possible to blind the participants or personnel to the treatment allocation, and outcome assessors were only blinded in one study.6 All included studies, with the exception of Sheibani et al15 had a high or unclear risk of selective reporting bias. The degree of incomplete data reporting (attrition bias) varied and was low in three studies4, 5, 15 and unclear in two.12, 13 The main issues were related to not defining the primary outcome and/or the timing of the primary endpoint. In the mAF app randomised controlled trial,6 42/113 (37.2%) people in the intervention group did not provide 3-month follow-up data compared to complete follow-up data in the usual care group and 4/16 (25%) of people enrolled in the study by Hirschey et al14 did not provide follow-up data.

**Excluded studies**

Supplementary Table 2 summarises the 43 excluded studies. Most (27/43 (62.8%)) studies were excluded as they were not an m-health intervention, four (4/43) reported outcomes which were outside the scope of the review, one (1/43) focused on a population without AF, one (1/43) was a systematic review, one (1/43) was a narrative review, three (3/43) were editorials and one (1/43) was a protocol for a systematic review. Five (5/43) were abstracts, four with no full-text available and one with full-text which was one of the included studies.12

**On-going studies**

Two protocol papers for ongoing studies were identified (see **Table 3**). One study11 is testing an upgraded version of the mAF app,6 incorporating the ABC- (Avoid stroke, Better symptom management, and Cardiovascular and other comorbidities management) pathway compared to usual care in 3660 AF patients with CHA2DS2-VASc score≥2, in a cluster-randomised controlled trial in China. The second study, the Atrial Fibrillation health Literacy Information Technology Trial (AF-LITT)10 is a pilot RCT, exploring a 30-day smartphone intervention, based on an embodied conversational agent and the AliveCor Kardia device, compared to standard care (a symptom and adherence journal), in 180 AF patients receiving OAC, in the USA.

**DISCUSSION**

We have reported a systematic review of studies that have evaluated the impact of m-health apps for the management of AF on patient and HCP knowledge and behaviour, patient quality-of-life and user engagement with the app. Despite the abundance of m-health apps available for healthcare, and AF specifically, only seven studies were eligible for inclusion in our systematic review. Of these, six were patient m-health apps.4-6, 12-14 Although the study by Guo et al6 reported both a patient and HCP version, outcome data was only presented relating to patient knowledge, behaviour, quality-of-life and app experience. Notwithstanding the disparity in the design, features, and delivery of the m-health interventions, overall the various apps improved patient knowledge on AF and OAC compared to baseline12 or patients receiving usual care,4, 6 improved patient medication adherence6 and quality-of-life,4, 6 improved provider adherence to OAC guidelines15 and were positively rated for user engagement and acceptability.4-6, 13, 14

However, many of the studies had limitations including very small sample sizes (≤15),5, 13-15 lack of a comparator group,5, 13, 14 lack of blinding for outcome assessors,4, 5, 12-15 imprecision or lack of definition of, and timing of, primary (and secondary) outcomes,5, 12-14 short follow-up periods for outcome evaluation (4-weeks14 to 3-months4-6), and incomplete reporting of outcome data.6, 14 This review has highlighted the need for larger, more comprehensive primary data collection studies with appropriate control groups, in diverse and representative AF patients, with longer-term follow-up, strategies to reduce attrition and ensure as complete as possible follow-up data, and more studies formally assessing the impact of m-health interventions on HCP knowledge and guideline-adherent AF management.

A commentary on two European Society of Cardiology-endorsed apps, MyAF (Patient version) and AFManager (HCP version),19 was identified in our searches. However, these apps have yet to be formally tested for impact on patient and HCP knowledge and behaviour and were therefore not eligible for inclusion in this review. The rapid integration and upscaling of mobile and e-technology in healthcare and everyday life does not negate the necessity for future m-health apps to demonstrate evidence of positive impacts on the outcomes they claim to support, to enable confidence in the end-user in their effectiveness and applicability.

The promise of mobile health is to make health education and health-related resources accessible regardless of health literacy. Reading ability plays a vital part in health literacy. Therefore, it is mandatory to introduce health apps that are not only scientifically validated but also written at reading-grade levels not exceeding national standard recommendations.20

All included studies used essentially stand-alone m-health apps, rather than apps as part of an intervention package, although the complexity and content of the apps varied. Four studies4, 12, 13, 15 used the app to focus on delivery of one element (i.e., patient education,4, 12 patient self-monitoring and reporting of AF symptoms and mood,13 and stroke and bleeding risk assessment and OAC recommendation for physicians15 ) whereas the other three5, 6, 14 were more complex. The Health Buddies app5 was an interactive game, involving patients’ grandchildren, to support medication adherence; the mAF app6 patient-version focussed on education but also incorporated patient self-support items, self-monitoring of heart rate and blood pressure and feedback on treatment; while the AFib Connect app14 included education, plus self-monitoring of heart rate, AF episodes and triggers, medication and appointment reminders, and a heart health-related news feed. These apps, as part of an intervention package, may be more, or less, effective than when used as the sole intervention; however, it is important to identify the active component(s) of interventions.

Of the two on-going studies, one11 has reported the results of the ABC-pathway supported by the mAFA II app on the primary outcome of a composite of stroke/thromboembolism, all-cause mortality, and rehospitalisation.21 Among the 1646 patients receiving the mAFA II-supported intervention (mean age 67.0 years; 38% female), the rate of the composite endpoint was significantly lower (1.9% vs. 6.0%; hazard ratio (HR): 0.39; 95% confidence interval (CI): 0.22 to 0.67; p < 0.001) compared to those receiving usual care (n=1678; mean age 70.0 years; 38% female).21 However, the impact of the m-health supported intervention on patient and HCP behaviour, patient knowledge and quality-of-life, is yet to be reported. The other on-going study, the AF-LITT,10 a pilot RCT of 180 AF patients receiving OAC, examining the impact of an embodied conversational agent and the AliveCor Kardia device for 30 days on health-related quality of life and self-reported adherence to OAC and app experience (patient and physician), is also still to report its findings.

It is encouraging that several of the included studies involved contributions from patients and inter-disciplinary HCPs in the design and refinement of the patient apps;4, 5, 13, 14 co-designing interventions with end-users is beneficial and effective.22, 23 Since the main goal of m-health is to support and maintain (healthy) behaviour change, utilising interdisciplinary teams, including psychologists and social scientists with expertise in behavioural change intervention development and implementation is essential.

m-health apps that include gamification features such as prizes, rewards, feedback on performance, competition, and social connectivity, have been shown to foster patient engagement and support adoption of healthy behaviours.24-26 Of the studies included in this systematic review, only one5 included gamification strategies within their app, such as rewards and communication with HCPs. However, several of the apps included self-regulatory behaviour change techniques, such as feedback and monitoring (including self-monitoring),5, 13, 14 which are known to be effective for health promotion and secondary prevention.27, 28

**CONCLUSION**

Mobile health technology can be utilised to support the management of AF, and apps which have been formally evaluated demonstrate improvements in patient knowledge of AF and OAC, medication adherence, and quality-of-life, and greater guideline-adherent OAC management by cardiologists. However, there is a dearth of studies formally evaluating the impact of m-health on HCP behaviour. Larger-scale studies with representative patient cohorts, appropriate comparators and longer-term assessment of the impact (both potential benefits and harms) of m-health in this field are warranted.

**Acknowledgements:** None

**Funding:** None

**Conflicts of interest:**

DL has received investigator-initiated educational grants from Bristol-Myers Squibb (BMS); has been a speaker for Boehringer Ingelheim and BMS/Pfizer; and consulted for BMS, Boehringer Ingelheim and Daiichi-Sankyo. She is a co-author of one of the included studies (Guo et al 2017). MF has been a speaker/consultant for BMS/Pfizer, Medtronic, Abbott, Boston Scientific. E.G.C. has received honoraria as speaker/consultant from Medtronic International Trading Sarl, Merck & Co., Inc., and Novartis. PD has been a speaker for Abbott, Boehringer Ingelheim, Biotronik and Medtronic; and served in the advisory board for Boehringer Ingelheim. TP has served as a consultant for Bayer and Pfizer (no fees).

None to declare: NM, JG, JW, RL, CW.

**Figure 1: PRISMA flow diagram for study selection process**

Records identified through database searching (n=11152)

MEDLINE (n=3192)

EMBASE (n=5750)

CINAHL (n = 2123)

PsychInfo (n = 87)

## Screening

## Included

## Eligibility

## Identification

Additional unique records identified through hand-searching

(n=0)

Trials registers (n=0)

Open grey (n=)

Records screened on title  
(n=8929)

Records excluded  
(n=8877)

Full-text articles assessed for eligibility  
(n = 52)

Full-text records excluded   
(n=43)

Wrong intervention (n=27)

Wrong outcomes (n=4)

Wrong population (n=1)

Reviews/Editorials (n=6)

Abstracts only (n=5)

( = )

( = )

( = )

Articles included in synthesis

(n=7)

Ongoing studies (n=2)

Records after duplicates removed  
(n=8929)

**Table 1:** Summary of the included studies

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **First author, year, country, reference** | **Study aim** | **Study population** | **Study design** | **App** | **Features of the App** | **Outcomes** | **Results** | **Conclusion** |
| Balsam 2019, Poland12  OCULUS study  NCT03104231 | Effectiveness of 3D movie in teaching patients about consequences of AF and pharmacological stroke prevention | 100 consecutive, hospitalised pts  Mean (SD) age: 63y (15); 38% women, 62% history of AF | Prospective, single centre (hospital), before-&-after study  *Inclusion criteria*: aged >18 years  *Exclusion criteria*: dementia  Recruitment April 2016 to August 2016  Questionnaire at baseline, immediately after viewing movie, 1 week and 1 year later  Follow-up: immediate, 1-week, and 1-year | Oculus glasses and smartphone with 3D movie describing risk of AF  VR-3D movie available on Google Play and Appstore  Version for men  <https://www.youtube.com/watch?v=5WFxq_m88ds>  Version for women  <https://www.youtube.com/watch?v=S8i7LxBBv0g> | Virtual reality headset (oculus glasses) and smartphone with 3D movie  Information on risk of stroke and use of OAC to reduce stroke | **Patient knowledge**: (1) stroke consequence of AF; (2) drugs may reduce stroke risk; (3) OAC reduces stroke risk  **Usefulness of 3D movie** to deliver information | **Knowledge that stroke was consequence of AF**:  Before movie 22/100 (22.0%);  Immediately after movie 83/100 (93%);  7-days later 74/94 (78.7%)  1 year 64/90 (71.1%); all p<0.0001  **Knowledge that drugs may reduce stroke risk:**  Before: 83/94 (88.3%)  Immediately after:  1-week later: 94/94 (100%); p<0.0001  1 year: 87/90 (96.7%) (p=0.02)  **Knowledge that OAC reduces stroke risk:**  Before: 66/94 (70.2%)  1-week later: 90/94 (95.7%)  1-year later: 83/90 (92.2%); all p<0.0001  **Usefulness:** 99/100 (99%) stated useful tool to increase awareness of consequences of AF | 3D movie was an effective tool in transferring knowledge about the consequences of AF and role of OAC in stroke prevention  Negative aspects of m-health apps not reported |
| Hirschey 2018, USA14 | Perceived usability and usefulness of mobile app designed to support self-care and treatment adherence for AF patients prescribed NOACs | 12 AF pts    Mean age: 59y (range 37-67y);  7 (58.3%) men; 100% Caucasian  Mean AF duration: 6y (range 1-15y); 11/12 (92%) symptomatic; 11/12 had college or greater level education  n=16 enrolled; 12 completed study | Exploratory pilot study: naturalistic app use; surveys (in-person at baseline, then by post); 5 x 30 min semi-structured weekly interviews to examine patients’ perceptions and everyday use of the app  4-week study with 5 visits total  Recruitment September 2016 to April 2017  Purposive sampling of AF patients on NOACs, identified by clinician from 1 hospital  Participants reviewed app features at different time-points and rated usability and usefulness over last week  Patient satisfaction assessed on 5-point Likert scale, yes/no and open-ended questions  Follow-up: weekly for 4-weeks | AFib Connect mobile app (Android & iPhone iOS) platforms  App developed based on semi-structured interviews and usability data from clinicians (n=9) and patients  Developed by interdisciplinary team (clinicians, qualitative researchers, & user experience designers)  Usability testing conducted with clinicians and patients using first version of app. Feedback incorporated into design of version two, which was used for this study | **AFib guide:** introduction to AF through text & animated videos;  **Library:** detailed information on AF (medication, procedure options, medication adherence & stroke risk)  **AF Episode Tracker:** Patient-generated for physician review  **AF Trigger Tracker:** Patient-generated  **AF News Feed:** American Heart News, StopAFib.org, AHA  **Medication reminder & diary**  **Heart rate monitor:** using mobile phone camera  **Appointment reminder** | App usability, satisfaction, and usefulness | **Usability improvement**: app navigation (3 themes); clarity of app instructions and design intent; software bugs  12/12 (100%) agreed somewhat or strongly that app was easy to use; only 1/12 reported needing to ask for help when using App;  **App satisfaction:** 92% reported being satisfied/very satisfied with the app  **Perceptions of app usefulness** (3 variables): core needs of the patient segment; patient workflow while managing AFib; app’s ability to support the patient’s evolving needs  10/12 somewhat or strongly agreed that the AFib app acted and felt like other apps they had used before | Needs more research in larger, more diverse AF sample  App broadly useful and effective in supporting patient self-care and medication adherence  Software bugs reported by 7/12 (58%) |
| Desteghe 2018, Belgium4 | Effectiveness of an on-line tailored education platform to inform AF patients undergoing DCCV or PVI | 120 AF pts. requiring DCCV or PVI  Mean (SD) age: 68.0y (10.2); 78 (65%) male | Prospective, randomised controlled trial at 1 Belgian tertiary hospital  *Inclusion criteria*: consecutive AF patients undergoing planned DCCV or PVI  *Exclusion criteria*: <18 years, severe mental (i.e. dementia) or physical (i.e. deafness) impairment, inability to read Dutch and not able to provide written informed consent  Those with internet access allocated to: Group 1 **on-line education** (n=35); or Group 2 **standard care with on-line access** (n=36)  Those without computer/ tablet/smartphone (Group 3) received (3) **standard care** (n=49)  JAKQ completed 1-3 weeks prior to hospitalisation, at hospitalisation and 6 and/or 12-week post-procedure  Standard care included information from cardiologist and specific and general information booklets  Only those in Group 1 received access to the on-line tools  Follow-up: Groups 1 and 2 at baseline, at hospitalisation, 6- and 12-months later  Group 3: at hospitalisation and 3-months only | On-line patient education (general AF information, OAC & procedure-related information) developed by 3 experienced cardiologists/electro-physiologists based on hospital brochures & patient websites (AFA, EHRA, AHA, Alliance for Aging Research)  Education provided by text, images and movies. Fact boxes highlighted key educational messages | Patients had unique log-in and could visit site whenever they wanted  On-line platform recorded how many times each patient visited platform, length of time viewing content and which topics were viewed | **Patient knowledge:** measured by JAKQ  **Patient QoL:** measured by AFEQT  **Patient experience/ opinions:** measured by UEQ | **Patient knowledge:**  Group 1 on-line tailored education group: significantly improved knowledge by end of hospitalisation (75.0% IQR 66.7-85.0; p=0.001)  Knowledge persisted at 6-weeks (77.5% IQR 65.0-85.0; p=0.010) and 12-weeks (80.0% IQR 70.0-90.0; p<0.001) after procedure  Group 2 standard care with on-line access: No improvement in overall knowledge between baseline and time of hospitalisation (65.0% IQR 50.0-73.8; p=1.00). Significant improvement between baseline and 6-week post-procedure (p=0.010) and between hospitalisation and 6-week post-procedure (p=0.016)  Group 3 Standard care only: No knowledge improvement over course of study (p=0.248)  **Quality of life:** Significant increase in overall AFEQT score in both on-line groups 6- and 12-weeks post-procedure compared to baseline and at hospitalisation  Group 3: no significant difference in overall AFEQT score over time (p=0.082)  **Usability:** on-line platform rated positively on all aspects | Small study  Those without compatible device significantly older, had lower educational level and higher risk of stroke and bleeding  10% sample unable to use device |
| Sheibani 2017, Iran15 | Effect of computerised decision support system (CDSS) on improving adherence to anticoagulation guidelines for AF | 10 cardiologists managing n=373 newly diagnosed AF pts  10 cardiologists (7 (70%) female)  Mean age 43.8y (range 33-58y)  Mean length professional experience: 11.2y (range 3-32y) | Interrupted times series design (before-&-after design)  Setting: offices of 10 cardiologists  OAC guideline adherence assessed fortnightly from January 2016 to January 2017; 6-months before and 6-months after intervention  *Inclusion criteria*: newly diagnosed AF patients  *Exclusion criteria*: mechanical heart valve, severe mitral valve disease, any other reason for requiring anticoagulation (history of recent or recurrent venous thromboembolism)  Convenience sampling for cardiologists  Follow-up: 6-months post-intervention only | CDSS designed for anticoagulant management of AF installed on cardiologist smartphone/tablet | App calculated CHA2DS2-VASc score and HAS-BLED score, gave treatment recommendations based on latest AHA/ACC guidelines | Provider adherence to OAC guidelines for AF | Before intervention (Jan-June 2016): 48% (n=212; 21 excluded due to missing data)  Post-intervention (July 2016-Jan 2017): 65.5% (n=207; 25 excluded due to missing data)  Significant increase in guideline-adherent OAC prescription post-intervention (p<0.0001) | CDSS improved adherence to guidelines for OAC for AF by reducing guideline complexity, simplifying risk calculation, and providing interpretation of risk scores  Negative aspects of m-health apps not reported |
| Guo 2017, China6  ChiCTR-IOR-17010436 | Evaluation of patients’ knowledge, QoL, medication adherence, OAC satisfaction, and usability, feasibility and acceptability of mAFA app | n=209 pts  **mAFA:** n=113  Mean (SD) age 67.4; 57.5% male  **Usual care:** n=96  Mean (SD) age 70.9y; 55.2% male | Cluster randomised pilot study, 2 hospitals in China  Recruitment 1 January to 1 May 2017  *Inclusion criteria*: aged ≥18; confirmed AF (ECG or 24-hr Holter)  *Exclusion criteria*: <18y; valvular AF; unable to provide written informed consent  Follow-up: 1- and 3-months | Mobile Atrial Fibrillation App (mAFA)  Clinician version\*  Patient version | Clinical decision-support tools (CHA2DS2-VASc and HAS-BLED, SAMe-TT2R2), educational materials, patient involvement strategies with self-care protocols and structured follow-up  Included personal health record (PHR)  App calculated risk scores from PHR; OAC recommended based clinical guidelines; pts. with HAS-BLED ≥3 flagged for FU  Patient educational program: 8 components with additional patient self-support items | **Patient knowledge** (11-item AF knowledge questionnaire Hendriks et al, 2013);  **Quality-of-life** (EQ-5D-Y);  **Drug adherence** (Pharmacy Quality Alliance adherence measure);  **OAC satisfaction** (Anti-Clot Treatment Scale)  All assessed at baseline, 1- and 3-months.  **App experience:** Usability, feasibility and acceptability of mAFA assessed at 1-month | **Patient knowledge:** mAFA significantly improved knowledge vs. UC (all p<0.05)  **Quality of life:**  Significantly increased in mAFA arm vs. UC at baseline (86.5 vs. 71.3), 1- (87.6 vs. 70.1) and 3-months (87.2 vs. 69.9) (all p<0.05)  **Drug adherence**: mAFA vs. UC: baseline (4 (4-11) vs. 4 (4-11); p=0.870); 1 month (0 (0-4) vs. 4 (0-11); p<0.001); 3 months 2 (0-4) vs. 4 (0-11); p<0.001)  **Anticoagulation satisfaction:** UC expressed more OAC burden (all p<0.05); mAFA pts. reported significantly more OAC benefit at 1-month only (p=0.013)  **App usability:** 90% reported app was easy, user friendly, helpful | Significant improvements in patient knowledge, quality-of-life, drug adherence, and reduction in OAC burden with mAFA vs. UC  Most (90%) rated app as easy, user friendly, helpful  Negative aspects of m-health apps not reported |
| Ghanbari 2017, USA13 | Assess usability and feasibility of a mobile application to assess symptoms in patients with AF | n=10 pts with PAF or persistent AF  Age (NR)  5 (50%) women; PAF 50% | Pilot, feasibility study  *Inclusion criteria*: >21y; AF diagnosis; stable medical regime for ≥30 days prior to study  *Exclusion criteria*: asymptomatic AF; psychiatric or neurological disorders; dementia, cancer, drug/alcohol abuse; life expectancy <1 year; pregnancy; existing implantable cardiac rhythm devices and neuro-stimulators  Semi-structured phone interview at 4-week  Follow-up: 4 weeks | **miAfib**  Mobile app (iPhone only) to assess AF symptoms and positive/negative affect  [www.miAfib.com](http://www.miAfib.com) to assist mobile app set-up and for study details | Beta version of app tested extensively for user experience, data recording and transfer prior to release of final product to app store  Users prompted via notifications to complete symptoms and affect assessment 4 times per day every 3 hours | User engagement and perspectives on acceptability  Questionnaire on app usage and acceptance (5-point Likert scale) | Users found app easy to use (4.75±0.46, intended to use it in the future (4.37±1.06) and found it easy to integrate into daily routine (4.5±1.07) | Pts found app easy to use and would consider using app in the future  Need larger study to determine feasibility in a diverse group of AF patients  Small sample size  Negative aspects of m-health apps not reported |
| Desteghe 2017, Belgium5 | Pilot study to assess the feasibility and usability of the Health Buddies App in AF patients | n=15 AF pts and n=20 grandchildren aged 5-15y  AF pts.: Mean (SD) age 69.2y (3.7); 10 (67%) male; 6 (40%) had college or university education  Grandchildren: Mean (SD) age 9.5y (3.0)  Only 15/410 (3.7%) of NOAC population and 15/114 (13.2%) eligible participated | Prospective feasibility pilot study  1 hospital in Belgium, recruited as out-pt. or in-pt.  *Inclusion criteria*: AF, on a NOAC, grandchild aged 5-15 years, having a tablet, mobile phone or computer with internet access  *Exclusion criteria:* enrolled in other studies; non-Dutch speaking  Study conducted October 2015 to August 2016  Participants had to use the App for 3 months  Follow-up: 3-months | Health Buddies App | App co-developed with pts., grandchildren and parents in 2 workshops  Patient contract: take NOAC daily; other health challenges.  Grandchild contract: daily healthy challenge (eating fruit, brushing teeth twice daily)  Rewards to completing daily challenges (gaming).  Goal to complete as many challenges as possible in 3 months. Reward at end trip or fun activity  NOAC stock with a refill reminder and communication with HCP | **Patient knowledge on AF and treatment:** measured by JAKQ baseline and 3-months  **Medication adherence:** measured by MMAS-8 baseline and 3-months**.** MEMS and Helping Hand devices monitored medication adherence. Pill count at 3-months  **Motivation to use app:** measured by number of log-ins  **App experience:** measured by UEQ  **App satisfaction usability, content and effects of the Health Buddies app:** questionnaire designed by study team gathered | **Patient knowledge on AF and treatment:** JAKQ score improved but not significantly from 64.6% (SD 14.7) at baseline to 70.4% (SD 10.4) after 3 months (p=0.09)  **Medication adherence:** Mean (SD) MMAS-8: at baseline 7.7 (0.6) and 7.4 (0.9) at end of study  Electronic monitoring showed lower taking and regimen adherence than self-reported on app (taking adherence 88.6% (SD 15.4) and regime adherence 81.8% (SD 18.7). Pill count adherence 94.5% (SD 9.2)  **Motivation to use app:** App use significantly decreased towards end of study in both pts (p=0.009) and grandchildren (p<0.001). 13/15 (87%) completed the 90-day contract  Mean (SD) % of days using app significantly higher in pts vs. grandchildren (57.7% (SD 30.0) and 24.3% (SD 23.8), respectively; p=0.002)  **App experience:** Rated positively on clarity (1.500), novelty (0.942) and stimulation (0.923) and attractiveness (0.859). Efficiency (0.577) and dependability (0.481) received neutral rating | Small sample; selected sample (only 15 participated); no control group  Patients evaluated the educational aspect of this app as a capital gain  5/15 (33%) often had technical difficulties with app |

ACC, American College of Cardiology; AF, atrial fibrillation; AFA, Atrial Fibrillation Association; AFEQT, Atrial Fibrillation Evaluation of QualiTy of life questionnaire; AHA, American Heart Association; CDSS, computerised decision support system; DCCV, direct current cardioversion; ECG, electrocardiogram; EHRA, European Heart Rhythm Association; FU, follow-up; HCP, healthcare professional; IQR, interquartile range; JAKQ, Jessa Atrial Fibrillation Questionnaire; mAFA, Mobile Atrial Fibrillation App; NOAC, non-vitamin K antagonist oral anticoagulant; NR, not reported; OAC, oral anticoagulation; pts, patients; PAF, paroxysmal atrial fibrillation; PVI, pulmonary vein isolation; QoL, quality of life; SD, standard deviation, UC, usual care; UEQ, User Experience Questionnaire; y, years

\*Data on clinician version of the app not reported in this paper

**Table 2:** Risk of bias assessment for included studies

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Randomised controlled trials** (assessed by **Cochrane Risk of Bias** tool8) | | | | | | | |
| **Study** | **Selection bias** | | **Reporting bias** | **Performance bias** | **Detection bias** | **Attrition bias** | **Other bias** |
| Author (year) | Random sequence generation | Allocation concealment | Selective reporting | Blinding participants and personnel | Blinding outcome assessors | Incomplete outcome data | Other sources of bias |
| Desteghe (2018)4 | High | High | Unclear | High | Unclear | Low | Unclear |
| Guo (2017)6 | Unclear | Unclear | Unclear | High | Low | High | Unclear |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Observational studies** (assessed by **Risk of Bias for non-randomised studies (RoBANS)** tool9) | | | | | | |
| **Study** | **Selection bias** | **Confounding variables** | **Performance bias** | **Detection bias** | **Attrition bias** | **Reporting bias** |
| Author (year) |  | Inadequate confirmation and consideration of confounding variables | Inadequate measurements of exposure | Inadequate blinding of outcome assessments | Incomplete outcome data | Selective outcome reporting |
| Balsam 201912 | Low | Unclear | Low | High | Unclear | High |
| Hirschey 201814 | High | High | High | Unclear | High | High |
| Sheibani 201715 | Unclear | Low | Low | High | Low | Low |
| Ghanbari 201713 | High | High | Low | Unclear | Unclear | Unclear |
| Desteghe 20175 | High | High | Low | Unclear | Low | Unclear |

**Table 3:** Summary of on-going studies of mobile health interventions for atrial fibrillation management

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **First author, year, country, reference, trial registration number** | **Study aim** | **Study design** | **Study population** | **App** | **Features of the App** | **Outcomes** |
| Guo 2019, China11  ChiCTR-OOC-17014138 | To investigate the effectiveness of an integrated care approach to AF management, supported by mobile health technology | Prospective cluster-RCT (40 sites)  Intervention vs. usual care  Follow-up: 1 -year | Adult AF patients with CHA2DS2-VASc score≥2  N=3660 | Mobile Atrial Fibrillation App (mAFA) II | Smartphone app  Upgraded version of mAF app6  Clinical decision-support tools (CHA2DS2-VASc and HAS-BLED, SAMe-TT2R2), guideline-based treatment recommendations, educational materials, patient involvement strategies with self-care protocols and structured follow-up, to support implementation of ABC pathway | **Primary:** composite of stroke and thromboembolism, ACM, and rehospitalisation  **Secondary:** incidence of AF in 2 weeks; change in proportion continuing OAC; cost-effectiveness; QALY |
| Guhl 2017, USA10  NCT03093558 | To evaluate the efficacy of the ECA/Kardia intervention to improve HRQoL and OAC adherence and implementation into a larger multi-centre RCT | Pilot RCT  Novel smartphone-based intervention to address patient experience of AF  Intervention: 30-day smartphone-based ECA and Kardia  Standard care: symptom and adherence journal | N=180 AF patients receiving OAC | Atrial Fibrillation health Literacy Information Technology Trial (AF-LITT) | Embodied Conversational Agent and AliveCor Kardia monitor | **Primary:** HRQoL  Self-reported adherence to OAC  **Secondary:** patient acceptability, usage levels, and acceptability to referring physicians |

ABC, Avoid stroke, Better symptom management, and Cardiovascular and other comorbidities management; AF, atrial fibrillation; AF-LITT, Atrial Fibrillation health Literacy Information Technology Trial; ECA, Embodied Conversational Agent; HRQoL, health-related quality of life; mAFA, Mobile Atrial Fibrillation App; OAC, oral anticoagulation; PPG, photoplethysmography; QALY, quality-adjusted life years; RCT, randomised controlled trial

**REFERENCES**

1. Kumar S, Nilsen WJ, Abernethy A, Atienza A, Patrick K, Pavel M, Riley WT, Shar A, Spring B, Spruijt-Metz D, Hedeker D, Honavar V, Kravitz R, Lefebvre RC, Mohr DC, Murphy SA, Quinn C, Shusterman V, Swendeman D. Mobile health technology evaluation: the mHealth evidence workshop. Am J Prev Med 2013;**45**(2):228-36.

2. Steinhubl SR, Muse ED, Topol EJ. The emerging field of mobile health. Sci Transl Med 2015;**7**(283):283rv3.

3. Statista. *Number of mHealthapp downloads worldwide from 2013 to 2017 (in billions).* <https://www.statista.com/statistics/625034/mobile-health-app-downloads/>.

4. Desteghe L, Germeys J, Vijgen J, Koopman P, Dilling-Boer D, Schurmans J, Delesie M, Dendale P, Heidbuchel H. Effectiveness and usability of an online tailored education platform for atrial fibrillation patients undergoing a direct current cardioversion or pulmonary vein isolation. Int J Cardiol 2018;**272**:123-129.

5. Desteghe L, Kluts K, Vijgen J, Koopman P, Dilling-Boer D, Schurmans J, Dendale P, Heidbuchel H. The Health Buddies App as a Novel Tool to Improve Adherence and Knowledge in Atrial Fibrillation Patients: A Pilot Study. JMIR Mhealth Uhealth 2017;**5**(7):e98.

6. Guo Y, Chen Y, Lane DA, Liu L, Wang Y, Lip GYH. Mobile Health Technology for Atrial Fibrillation Management Integrating Decision Support, Education, and Patient Involvement: mAF App Trial. Am J Med 2017;**130**(12):1388-1396.e6.

7. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA Statement. Open Med 2009;**3**(3):e123-30.

8. Higgins JP, Altman DG, Gotzsche PC, Juni P, Moher D, Oxman AD, Savovic J, Schulz KF, Weeks L, Sterne JA. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. Bmj 2011;**343**:d5928.

9. Kim SY, Park JE, Lee YJ, Seo HJ, Sheen SS, Hahn S, Jang BH, Son HJ. Testing a tool for assessing the risk of bias for nonrandomized studies showed moderate reliability and promising validity. J Clin Epidemiol 2013;**66**(4):408-14.

10. Guhl EN, Schlusser CL, Henault LE, Bickmore TW, Kimani E, Paasche-Orlow MK, Magnani JW. Rationale and design of the Atrial Fibrillation health Literacy Information Technology Trial: (AF-LITT). Contemp Clin Trials 2017;**62**:153-158.

11. Guo Y, Lane DA, Wang L, Chen Y, Lip GYH. Mobile Health (mHealth) technology for improved screening, patient involvement and optimising integrated care in atrial fibrillation: The mAFA (mAF-App) II randomised trial. Int J Clin Pract 2019;**73**(7):e13352.

12. Balsam P, Borodzicz S, Malesa K, Puchta D, Tyminska A, Ozieranski K, Koltowski L, Peller M, Grabowski M, Filipiak KJ, Opolski G. OCULUS study: Virtual reality-based education in daily clinical practice. Cardiol J 2019;**26**(3):260-264.

13. Ghanbari H, Ansari S, Ghannam M, Lathkar-Pradhan S, Kratz A, Oral H, Najarian K, Clauw D, Nallamothu B. Feasibility and Usability of a Mobile Application to Assess Symptoms and Affect in Patients with Atrial Fibrillation: A Pilot Study. J Atr Fibrillation 2017;**10**(2):1672.

14. Hirschey J, Bane S, Mansour M, Sperber J, Agboola S, Kvedar J, Jethwani K. Evaluating the Usability and Usefulness of a Mobile App for Atrial Fibrillation Using Qualitative Methods: Exploratory Pilot Study. JMIR Hum Factors 2018;**5**(1):e13.

15. Sheibani R, Sheibani M, Heidari-Bakavoli A, Abu-Hanna A, Eslami S. The Effect of a Clinical Decision Support System on Improving Adherence to Guideline in the Treatment of Atrial Fibrillation: An Interrupted Time Series Study. J Med Syst 2017;**42**(2):26.

16. Rabin R, de Charro F. EQ-5D: a measure of health status from the EuroQol Group. Ann Med 2001;**33**(5):337-43.

17. Spertus J, Dorian P, Bubien R, Lewis S, Godejohn D, Reynolds MR, Lakkireddy DR, Wimmer AP, Bhandari A, Burk C. Development and validation of the Atrial Fibrillation Effect on QualiTy-of-Life (AFEQT) Questionnaire in patients with atrial fibrillation. Circ Arrhythm Electrophysiol 2011;**4**(1):15-25.

18. Laugwitz B HT, Schrepp M. Construction and evaluation of a User Experience Questionnaire. In: A H, (ed). *HCI and Usability for Education and Work*. Berlin, Heidelberg: Springer; 2008.

19. Kotecha D, Kirchhof P. ESC Apps for Atrial Fibrillation. Eur Heart J 2017;**38**(35):2643-2645.

20. Ayyaswami V, Padmanabhan DL, Crihalmeanu T, Thelmo F, Prabhu AV, Magnani JW. Mobile health applications for atrial fibrillation: A readability and quality assessment. Int J Cardiol 2019;**293**:288-293.

21. Guo Y, Lane DA, Wang L, Zhang H, Wang H, Zhang W, Wen J, Xing Y, Wu F, Xia Y, Liu T, Wu F, Liang Z, Liu F, Zhao Y, Li R, Li X, Zhang L, Guo J, Burnside G, Chen Y, Lip GYH. Mobile Health Technology to Improve Care for Patients With Atrial Fibrillation. J Am Coll Cardiol 2020;**75**(13):1523-1534.

22. Boyd H, McKernon S, Mullin B, Old A. Improving healthcare through the use of co-design. N Z Med J 2012;**125**(1357):76-87.

23. Sabater-Hernandez D, Tudball J, Ferguson C, Franco-Trigo L, Hossain LN, Benrimoj SI. A stakeholder co-design approach for developing a community pharmacy service to enhance screening and management of atrial fibrillation. BMC Health Serv Res 2018;**18**(1):145.

24. Edwards EA, Lumsden J, Rivas C, Steed L, Edwards LA, Thiyagarajan A, Sohanpal R, Caton H, Griffiths CJ, Munafo MR, Taylor S, Walton RT. Gamification for health promotion: systematic review of behaviour change techniques in smartphone apps. BMJ Open 2016;**6**(10):e012447.

25. Johnson D, Deterding S, Kuhn KA, Staneva A, Stoyanov S, Hides L. Gamification for health and wellbeing: A systematic review of the literature. Internet Interv 2016;**6**:89-106.

26. Sardi L, Idri A, Fernandez-Aleman JL. A systematic review of gamification in e-Health. J Biomed Inform 2017;**71**:31-48.

27. Conroy DE, Yang CH, Maher JP. Behavior change techniques in top-ranked mobile apps for physical activity. Am J Prev Med 2014;**46**(6):649-52.

28. Direito A, Dale LP, Shields E, Dobson R, Whittaker R, Maddison R. Do physical activity and dietary smartphone applications incorporate evidence-based behaviour change techniques? BMC Public Health 2014;**14**:646.

**Supplementary Table 1:** Search strategy for Ovid MEDLINE

1 exp Atrial Fibrillation/ (51406)

2 (atrial adj3 fibrillat\*).ti,ab. (64727)

3 exp Atrial Flutter/ (5678)

4 atrial flutter.ti,ab. (5405)

5 (auricular adj3 fibrillat\*).ti,ab. (975)

6 (supraventricul\* adj3 arrhythmi\*).ti,ab. (2562)

7 1 or 2 or 3 or 4 or 5 or 6 (81038)

8 \*Internet/ (36349)

9 \*Online systems/ (3566)

10 exp Information Services/ (958012)

11 exp Decision Making, Computer-Assisted/ (137569)

12 exp Wireless Technology/ (3176)

13 exp Educational Technology/ (107093)

14 \*Computers, handheld/ (2348)

15 exp Microcomputers/ (20726)

16 exp Mobile Applications/ (4482)

17 mobile application\*.mp. (6019)

18 mobile app\*.mp. (7027)

19 app.ti,ab. (22608)

20 exp Cell Phone/ (9685)

21 (cellphone or cell phone).ti,ab. (1908)

22 (mobile or mobile phone).mp. (96184)

23 telephone.mp. (58946)

24 exp Smartphone/ (3237)

25 (smartphone or smart phone).mp. (8904)

26 android.mp. (2247)

27 (iphone or i-phone or ipad or i-pad or ipod or i-pod or tablet).mp. (26811)

28 (personal digital assistant or PDA).mp. (11129)

29 exp Remote Consultation/ (4612)

30 (remote consultation or remote monitoring).mp. (6531)

31 exp Telemedicine/ (25787)

32 (telemedicine or telehealth or telehealthcare).mp. (26029)

33 (telemonitor\* or telepsych\* or teletherap\*).mp. (7770)

34 (ehealth or e-health or electronic health).mp. (30825)

35 (emedicine or e-medicine or electronic medicine).mp. (108)

36 (mhealth or m-health or mobile health).mp. (9266)

37 (etherap\* or e-therap\*).mp. (721)

38 (cyber or forum or chat or blog or messaging or social network\* or social media or multimedia or multi-media or software or podcast or virtual or health messages).mp. (334012)

39 exp Text Messaging/ (2369)

40 text messag\*.mp. (4562)

41 (portal or e-portal or eportal).mp. (86044)

42 (audio\* or dvd or email or e-mail).mp. (105954)

43 (elibrary or e library).ti,ab. (56)

44 (digital adj3 (library or libraries)).ti,ab. (609)

45 ((electronic or online or on-line or internet or web\* or intranet) adj3 (library or libraries)).ti,ab. (4523)

46 ((electronic or online or on-line or internet or web\* or intranet) adj3 information).ti,ab. (11631)

47 ((electronic or online or on-line or internet or web\* or intranet) adj3 resource\*).ti,ab. (6680)

48 ((electronic or online or on line or internet or web\* or intranet) adj3 database\*).ti,ab. (40008)

49 ((computer\* or electronic or online or on-line or internet or web\* or digital) adj3 guideline\*).ti,ab. (1526)

50 exp artificial intelligence/ (86475)

51 (artificial intelligence or AI).mp. (50510)

52 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 (2050668)

53 7 and 52 (3700)

54 limit 53 to yr="2005 -Current" (3192)

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

**Supplementary Table 2:** Excluded studies and reason(s) for exclusion

|  |  |
| --- | --- |
| **Author, year, reference** | **Reason for exclusion** |
| Wilson 20191 | Wrong intervention (not a mobile app for AF management) |
| Risom 20192 | Wrong intervention (not a mobile app for AF management) |
| Richardson 20193 | Wrong intervention (not a mobile app for AF management) |
| Rakhshan 20194 | Wrong intervention (not a mobile app for AF management) |
| Orchard 20195 | Wrong intervention (not a mobile app for AF management) |
| Orchard 20196 | Wrong intervention (not a mobile app for AF management) |
| Montalescot 20197 | Wrong intervention (not a mobile app for AF management) |
| Goldenthal 20198 | Wrong intervention (not a mobile app for AF management) |
| Chaturvedi 20199 | Wrong intervention (not a mobile app for AF management) |
| Ferguson 201910 | Wrong outcomes |
| Ayyaswami 201911 | Systematic review |
| Al-Arkee 201912 | Systematic review protocol |
| Peleg 201813 | Wrong outcomesa |
| Orchard 201814 | Wrong intervention (not a mobile app for AF management) |
| Malm 201815 | Wrong intervention (not a mobile app for AF management) |
| Kotecha 201816 | Review |
| Eckman 201817 | Wrong intervention (not a mobile app for AF management) |
| Desteghe 201818 | Wrong intervention (not a mobile app for AF management) |
| Aljuaid 201819 | Wrong intervention (not a mobile app for AF management) |
| Ahuja 201820 | Wrong intervention (not a mobile app for AF management) |
| Talboom-Kamp 201721 | Wrong population and wrong outcomes |
| Roebuck 201722 | Abstract only – no full text available |
| Peleg 201723 | Wrong outcomesb |
| Maikranz 201724 | Wrong intervention (not a mobile app for AF management) |
| Hickey 201725 | Protocol paper for on-going study. Results reported in Goldenthal 2019. Wrong intervention (not a mobile app for AF management) |
| Kotecha 201726 | Editorial/comment |
| Hendriks 201627 | Editorial/comment |
| Cutting 201728 | Abstract only – no full text available |
| Borodzicz 201729 | Abstract for a full text of an included study (Balsam, 2019)30 |
| Arts 201731 | Wrong intervention (not a mobile app for AF management) |
| Parimbelli 201632 | Wrong outcomesc |
| Nieuwlaat 201633 | Editorial/comment |
| Millman 201634 | Wrong intervention (not a mobile app for AF management) |
| Hickey 201635 | Protocol paper for on-going study. Results reported in Goldenthal 2019. Wrong intervention (not a mobile app for AF management) |
| Chelu 201636 | Wrong intervention (not a mobile app for AF management) |
| Chalmers 201637 | Wrong intervention (not a mobile app for AF management) |
| Carlson 201638 | Abstract only no full text available |
| Abidi 201639 | Abstract only no full text available |
| Hendriks 201440 | Wrong intervention (not a mobile app for AF management) |
| Proclemer 201341 | Wrong intervention (not a mobile app for AF management) |
| Shacham 201242 | Wrong intervention (not a mobile app for AF management) |
| Hendriks 201043 | Wrong intervention (not a mobile app for AF management) |
| Amara 200944 | Wrong intervention (not a mobile app for AF management) |

aDescribes the generic architecture of the Motivational Patient Assistant and a preliminary assessment of the proof-of concept prototype

bDescribes the evaluation of MobiGuide’s capability for supporting distributed decision-making and its’ use by clinicians and patients but no outcomes of interest for this review

cPaper focuses on the nurses’ time and tasks setting up the system and enrolling the patients but not outcome data relevant to the outcomes of interest

**Supplementary Table 3:** Risk of bias assessment with detailed explanation of decision for each domain rating

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Randomised controlled trials** (assessed by **Cochrane Risk of Bias** tool45) | | | | | | | |
| **Study** | **Selection bias** | | **Reporting bias** | **Performance bias** | **Detection bias** | **Attrition bias** | **Other bias** |
| Author (year) | Random sequence generation | Allocation concealment | Selective reporting | Blinding participants and personnel | Blinding outcome assessors | Incomplete outcome data | Other sources of bias |
| Desteghe (2018)46 | High | High | Unclear | High | Unclear | Low | Unclear |
|  | Patients were only randomised to Group 1 or 2 (Group 1 was the intervention and Group 2 was those with internet connection). Group 3 were self-selected (those without a PC/tablet or smartphone or unable to use the device | People without a smartphone or tablet could not be allocated to Group 1 or 2 | No primary outcome or timing of this outcome specified. Several outcomes reported at several time-points | Due to nature of the intervention not possible to blind patients and personnel to treatment allocation | No information given | 34/35 in Group 1 had complete outcome data (4 time-points) and 32/36 in Group 2. Group 3: 47/49 had baseline and follow-up data  Group 3 did not have questionnaire data for as many time-points; Group 3 only completed questionnaires when attending hospital (no data at 1-3 weeks prior to the procedure or post-procedurally | Possible the Group 1 and 2 could have looked up the answers to the AF knowledge questionnaire or asked family/caregivers as this was completed on-line at home (although access to the m-health education was temporarily blocked when Group 1 filled in the questionnaire) |
| Guo (2017)47 | Unclear | Unclear | Unclear | High | Low | High | Unclear |
|  | No detail on randomisation procedure  Cluster design with only 2 sites; no individual randomisation | No detail on randomisation procedure | No primary outcome or timing of this outcome specified. Several outcomes reported at several time-points  Only reports on patient version of the mAF app | Due to nature of the intervention not possible to blind patients and personnel to treatment allocation | Data input performed by 2 individuals blinded to treatment allocation. Independently double-checked by third investigator | Zero attrition at 3 months in usual care group; 37% in intervention group | Some outcome measures were self-report and it is possible that patients in the intervention group reported better improvements because they were in intervention group |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Observational studies** (assessed by **Risk of Bias for non-randomised studies (RoBANS)** tool48) | | | | | | |
| **Study** | **Selection bias** | **Confounding variables** | **Performance bias** | **Detection bias** | **Attrition bias** | **Reporting bias** |
| Author (year) |  | Inadequate confirmation and consideration of confounding variables | Inadequate measurements of exposure | Inadequate blinding of outcome assessments | Incomplete outcome data | Selective outcome reporting |
| Balsam 201930 | Low | Unclear | Low | High | Unclear | High |
|  | Before and after study. Patients were recruited consecutively and data collected prospectively | No information given; unlikely for immediate recall but could be issue for long term outcomes | Hospitalised patients so exposure controlled | Blinding of outcome not completed | Numbers of drop-outs reported at all time-points (90% at 1 year) but data not complete at all time-points for all outcomes. No analysis reported for baseline between those who completed follow-up and those who did not | Timing of primary outcome not clear. No experimental protocol available. |
| Hirschey 201849 | High | High | High | Unclear | High | High |
|  | Purposeful sample via clinician referral; highly selected, N=12 | Given potential selection bias the participants may be more tech-aware | Asked to explore predetermined app features but no verification of actual exposure | No information given | N=16 enrolled but only 12 participated. Two ineligible due to mobile phone incompatibility; 1 lost-to-follow-up; 1 dropped out after 1 week due to lack of interest | Primary outcome not explicit |
| Sheibani 201750 | Unclear | Low | Low | High | Low | Low |
|  | Before and after study. Cardiologists (n=10) are participants and they utilised the CDSS on 373 patients. Cardiologists selected using convenience sampling. Not clear if patients were enrolled consecutively.  Data collected retrospectively | Interrupted time series design reduces risk of bias. Possible factors such as seasonal variation considered | CDSS was used for 88% of patients in post-intervention phase (remainder had incomplete baseline data) | Blinding of outcome not completed. Paper reports were completed by clinicians (no electronic records in place) | Pre-post data reported fully | Primary outcome defined and reported fully |
| Ghanbari 201751 | High | High | Low | Unclear | Unclear | Unclear |
|  | Recruitment via physician referral. No control group. N=10; highly selected | Given potential selection bias the participants may be more tech-aware | Number of assessments performed/day is reported clearly | No information given | No data given on drop-out rate | Feasibility study – primary outcome not clear |
| Desteghe 201752 | High | High | Low | Unclear | Low | Unclear |
|  | Participants not recruited consecutively. Only 15/114 (13.2%) eligible patients participated | Given potential selection bias the participants may be more tech-aware | App use is reported clearly across the study period | No information given | High rate of outcome data reporting. Only 1 patient did not complete 3-month study | Feasibility study – primary outcome not clear |

**REFERENCES**

[1] Wilson G, Davis A, Urbanczyk J, Banchs J, Erwin J, Michel J, Widmer R. Web-based patient portals are associated with higher readmission rates in atrial fibrillation. *Journal of the American College of Cardiology* 2019; **73**: 1845.

[2] Risom SS, Lind J, Dickson VV, Berg SK. Exploring the Mechanism of Effectiveness of a Psychoeducational Intervention in a Rehabilitation Program (CopenHeartRFA) for Patients Treated With Ablation for Atrial Fibrillation: A Mixed Methods Study. *The Journal of cardiovascular nursing* 2019; **34**: 336-343.

[3] Richardson CL, White S, Chapman S. A virtual patient educational programme to teach counselling to clinical pharmacists development adn proof of concept. *Pharmacoepidemiology and Drug Safety* 2019; **28**: 14-15.

[4] Rakhshan M, Najafi H, Valizadeh GA. Lifestyle of Patients with Atrial Fibrillation Following Self-Management Interventions: a Randomized Clinical Trial. *Journal of caring sciences* 2019; **8**: 83-88.

[5] Orchard J, Neubeck L, Freedman B, Li J, Webster R, Zwar N, et al. eHealth Tools to Provide Structured Assistance for Atrial Fibrillation Screening, Management, and Guideline-Recommended Therapy in Metropolitan General Practice: The AF - SMART Study. *Journal of the American Heart Association* 2019; **8**: e010959.

[6] Orchard J, Li J, Gallagher R, Freedman B, Lowres N, Neubeck L. Uptake of a primary care atrial fibrillation screening program (AF-SMART): a realist evaluation of implementation in metropolitan and rural general practice. *BMC family practice* 2019; **20**: 170.

[7] Montalescot G, Brotons C, Cosyns B, Crijns HJ, D'Angelo A, Drouet L, et al. Educational Impact on Apixaban Adherence in Atrial Fibrillation (the AEGEAN STUDY): A Randomized Clinical Trial. *American journal of cardiovascular drugs : drugs, devices, and other interventions* 2020; **20**: 61-71.

[8] Goldenthal IL, Sciacca RR, Riga T, Bakken S, Baumeister M, Biviano AB, et al. Recurrent atrial fibrillation/flutter detection after ablation or cardioversion using the AliveCor KardiaMobile device: iHEART results. *Journal of cardiovascular electrophysiology* 2019; **30**: 2220-2228.

[9] Chaturvedi S, Kelly AG, Prabhakaran S, Saposnik G, Lee L, Malik A, et al. Electronic Decision support for Improvement of Contemporary Therapy for Stroke Prevention. *Journal of stroke and cerebrovascular diseases : the official journal of National Stroke Association* 2019; **28**: 569-573.

[10] Ferguson C, Hickman LD, Phillips J, Newton PJ, Inglis SC, Lam L, et al. An mHealth intervention to improve nurses' atrial fibrillation and anticoagulation knowledge and practice: the EVICOAG study. *European journal of cardiovascular nursing : journal of the Working Group on Cardiovascular Nursing of the European Society of Cardiology* 2019; **18**: 7-15.

[11] Ayyaswami V, Padmanabhan DL, Crihalmeanu T, Thelmo F, Prabhu AV, Magnani JW. Mobile health applications for atrial fibrillation: A readability and quality assessment. *International journal of cardiology* 2019; **293**: 288-293.

[12] Al-Arkee S, Mason J, Lane DA, Fabritz L, Chu W, Yahyouche A, Singh K, Jalal Z. Mobile apps, cardiovascular disease and medication adherence: A systematic review. *International Journal of Pharmacy Practice* 2019; **27**: 35-36.

[13] 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**: 234.

[14] Orchard JJ, Neubeck L, Freedman B, Webster R, Patel A, Gallagher R, et al. Atrial Fibrillation Screen, Management And Guideline Recommended Therapy (AF SMART II) in the rural primary care setting: an implementation study protocol. *BMJ open* 2018; **8**: e023130.

[15] Malm D, Fridlund B, Ekblad H, Karlstrom P, Hag E, Pakpour AH. Effects of brief mindfulness-based cognitive behavioural therapy on health-related quality of life and sense of coherence in atrial fibrillation patients. *European journal of cardiovascular nursing : journal of the Working Group on Cardiovascular Nursing of the European Society of Cardiology* 2018; **17**: 589-597.

[16] Kotecha D, Chua WWL, Fabritz L, Hendriks J, Casadei B, Schotten U, et al. European Society of Cardiology smartphone and tablet applications for patients with atrial fibrillation and their health care providers. *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**: 225-233.

[17] Eckman MH, Costea A, Attari M, Munjal J, Wise RE, Knochelmann C, et al. Shared decision-making tool for thromboprophylaxis in atrial fibrillation - A feasibility study. *American heart journal* 2018; **199**: 13-21.

[18] Desteghe L, Vijgen J, Koopman P, Dilling-Boer D, Schurmans J, Dendale P, et al. Telemonitoring-based feedback improves adherence to non-vitamin K antagonist oral anticoagulants intake in patients with atrial fibrillation. *European heart journal* 2018; **39**: 1394-1403.

[19] Aljuaid M, Marashly Q, AlDanaf J, Tawhari I, Barakat M, Barakat R, et al. Smartphone ECG Monitoring System Helps Lower Emergency Room and Clinic Visits in Post-Atrial Fibrillation Ablation Patients. *Clinical Medicine Insights Cardiology* 2020; **14**: 1179546820901508.

[20] Ahuja T, Raco V, Papadopoulos J, Green D. Antithrombotic Stewardship: Assessing Use of Computerized Clinical Decision Support Tools to Enhance Safe Prescribing of Direct Oral Anticoagulants in Hospitalized Patients. *Journal of patient safety* 2018.

[21] Talboom-Kamp EP, Verdijk NA, Talboom IJ, Harmans LM, Numans ME, Chavannes NH. PORTALS: design of an innovative approach to anticoagulation management through eHealth. *BMC health services research* 2017; **17**: 213.

[22] Roebuck AR, Wagner SW, Skaggs CS, Ahmed RA, Rohani Ghahari RRG, Toscos TT, Mirro MM. "I don't know how you can be the decision maker when you don't understand": Designing tailored E-health intervention to empower patients living with nonvalvular 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* 2017; **19**: i47.

[23] Peleg M, Shahar Y, Quaglini S, Fux A, Garcia-Saez G, Goldstein A, Hernando ME, Klimov D, Martinez-Sarriegui I, Napolitano C, Parimbelli E, Rigla M, Sacchi L, Shalom E, Soffer P. MobiGuide: A personalized and patient-centric decision-support system and its evaluation in the atrial fibrillation adn gestational diabetes domains. *User Modeling and User-Adapted Interaction* 2017; **27**: 159-213.

[24] Maikranz V, Siebenhofer A, Ulrich LR, Mergenthal K, Schulz-Rothe S, Kemperdick B, et al. Does a complex intervention increase patient knowledge about oral anticoagulation? - a cluster-randomised controlled trial. *BMC family practice* 2017; **18**: 15.

[25] Hickey KT, Biviano A, Garan H, Sciacca RR, Riga T, Warren K, Frulla AP, Hauser NR, Wang DY, Whang W. Evaluating the utility of mHealth ECG heart monitoring for the detection and management of atrial fibrillation in clinical practice. *Journal of atrial fibrillation* 2017; **9**: 1546.

[26] Kotecha D, Kirchhof P. ESC Apps for Atrial Fibrillation. *European heart journal* 2017; **38**: 2643-2645.

[27] Hendriks JM, Walfridsson U, Johansson P, Stromberg A. E-health in patients with atrial fibrillation. *European journal of cardiovascular nursing : journal of the Working Group on Cardiovascular Nursing of the European Society of Cardiology* 2016; **15**: 200-202.

[28] Cutting H, Edwards F. Pan London atrial fibrillation (AF) toolkit for the prevention of stroke. *Internation Journal of Stroke* 2017; **12**: 56.

[29] Borodzicz S, Balsam P, Malesa K, Puchta D, Koltowski L, Peller M, Grabowski M, Opolski G. OCULUS study: Three-dimensional movie as a new weapon against poor compliance. *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; **2017**: Supplement 3.

[30] Balsam P, Borodzicz S, Malesa K, Puchta D, Tyminska A, Ozieranski K, et al. OCULUS study: Virtual reality-based education in daily clinical practice. *Cardiology journal* 2019; **26**: 260-264.

[31] Arts DL, Abu-Hanna A, Medlock SK, van Weert HC. Effectiveness and usage of a decision support system to improve stroke prevention in general practice: A cluster randomized controlled trial. *PloS one* 2017; **12**: e0170974.

[32] Parimbelli E, Sacchi L, Budasu R, Napolitano C, Peleg M, Quaglini S. The Role of Nurses in E-Health: The MobiGuide Project Experience. *Studies in health technology and informatics* 2016; **225**: 153-157.

[33] Nieuwlaat R, Mistry N, Haynes RB. Mobile Text Messaging and Adherence of Patients to Medication Prescriptions: A txt a dA keeps da doctR awA? *JAMA internal medicine* 2016; **176**: 350-351.

[34] Millman MD, Den Hartog KS. Optimizing Adherence Through Provider and Patient Messaging. *Population health management* 2016; **19**: 264-271.

[35] 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.

[36] Chelu MG, Margetts H, Kaur G, Tang W, Marrouche NF. Smartphone ECG in managing atrial fibrillation patients: Saving ER visits and changing paradigm. *Heart Rhythm* 2016; **1**: S263.

[37] Chalmers L BL, Prasad R, Hancock N, MacIntyre PD, McKenzie DS, Boland CM, Frain BE, Buttfield-Addison P. SMART-AF: Development of a decision support smartphone app to improve antithrombotic prescribing in atrial fibrillation. *Research in Social and Administrative Pharmacy* 2016; **12**: e22-e23.

[38] Carlson S, Berkley J, Luke D, Porterfield J, Huntsinger M, Doshi R, Saxon L. Smartphone application for AF surveillance and asynchronous communication post-ablation. *Journal of cardiovascular electrophysiology* 2016; **27**: 648.

[39] Abidi SS AS, Abusharekh A, Hashemian N. A decision support framework integrating medical knowledge with live patient data for proactive chronic patient management. *European Journal of Epidemiology* 2016; **31**: S8.

[40] Hendriks JM, Vrijhoef HJ, Crijns HJ, Brunner-La Rocca HP. The effect of a nurse-led integrated chronic care approach on quality of life in patients with 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**: 491-499.

[41] Proclemer A, Zoppo F, Molon G, Zanotto G, Gasparini G, Catanzariti D, Baccillieri MS, Menard C, Gentili A, Grammatico A. Improving atrial fibrillation detection and stroke prevention capability by a web-based application: A multicenter Italian research on AFinder application. *European heart journal* 2013; **1**: 737.

[42] Shacham J, Birati EY, Malov N, Yanay Y, Steinberg DM, Tamari M, et al. Telemedicine for diagnosing and managing paroxysmal atrial fibrillation in outpatients. The phone in the pocket. *International journal of cardiology* 2012; **157**: 91-95.

[43] Hendriks JL, Nieuwlaat R, Vrijhoef HJ, de Wit R, Crijns HJ, Tieleman RG. Improving guideline adherence in the treatment of atrial fibrillation by implementing an integrated chronic care program. *Netherlands heart journal : monthly journal of the Netherlands Society of Cardiology and the Netherlands Heart Foundation* 2010; **18**: 471-477.

[44] Amara W. [Management of atrial fibrillation in patients with cardiac stimulators or defibrillators: the possibilities of telemonitoring]. *Annales de cardiologie et d'angeiologie* 2009; **58**: 226-229.

[45] Higgins JP, Altman DG, Gotzsche PC, Juni P, Moher D, Oxman AD, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ (Clinical research ed)* 2011; **343**: d5928.

[46] Desteghe L, Germeys J, Vijgen J, Koopman P, Dilling-Boer D, Schurmans J, et al. Effectiveness and usability of an online tailored education platform for atrial fibrillation patients undergoing a direct current cardioversion or pulmonary vein isolation. *International journal of cardiology* 2018; **272**: 123-129.

[47] Guo Y, Chen Y, Lane DA, Liu L, Wang Y, Lip GYH. Mobile Health Technology for Atrial Fibrillation Management Integrating Decision Support, Education, and Patient Involvement: mAF App Trial. *The American journal of medicine* 2017; **130**: 1388-1396.e1386.

[48] Kim SY, Park JE, Lee YJ, Seo HJ, Sheen SS, Hahn S, et al. Testing a tool for assessing the risk of bias for nonrandomized studies showed moderate reliability and promising validity. *Journal of clinical epidemiology* 2013; **66**: 408-414.

[49] Hirschey J, Bane S, Mansour M, Sperber J, Agboola S, Kvedar J, et al. Evaluating the Usability and Usefulness of a Mobile App for Atrial Fibrillation Using Qualitative Methods: Exploratory Pilot Study. *JMIR human factors* 2018; **5**: e13.

[50] Sheibani R, Sheibani M, Heidari-Bakavoli A, Abu-Hanna A, Eslami S. The Effect of a Clinical Decision Support System on Improving Adherence to Guideline in the Treatment of Atrial Fibrillation: An Interrupted Time Series Study. *Journal of medical systems* 2017; **42**: 26.

[51] Ghanbari H, Ansari S, Ghannam M, Lathkar-Pradhan S, Kratz A, Oral H, et al. Feasibility and Usability of a Mobile Application to Assess Symptoms and Affect in Patients with Atrial Fibrillation: A Pilot Study. *Journal of atrial fibrillation* 2017; **10**: 1672.

[52] Desteghe L, Kluts K, Vijgen J, Koopman P, Dilling-Boer D, Schurmans J, et al. The Health Buddies App as a Novel Tool to Improve Adherence and Knowledge in Atrial Fibrillation Patients: A Pilot Study. *JMIR mHealth and uHealth* 2017; **5**: e98.