The usability and effect of an mHealth disease management platform on the quality of life of patients with paroxysmal atrial fibrillation – The emPOWERD-AF study

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Abstract
Atrial fibrillation (AF) is the most common arrhythmia. myAlgos is an mHealth disease management system consisting of physician-oriented platform and patient-oriented smartphone app. Our purpose was to assess the usability of myAlgos by physicians and patients and the effect of myAlgos on the quality of life (QoL) in patients with paroxysmal AF (PAF). Physicians rated the platform with the Post-Study System Usability Questionnaire (PSSUQ). Patients rated the app with the mHealth App Usability Questionnaire (MAUQ). The e-medicine Platform for Optimizing the Workflow in

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hEaRt Diseases (emPOWERD-AF) study investigated the effect of myAlgos in PAF patients randomized to full/control version. QoL was measured by the Atrial Fibrillation Effect on Quality-of-life (AFEQT) and 5-level EQ-5D (EQ-5D-5L) questionnaires. myAlgos got a PSSUQ score of 2.52 ± 0.36 by five physicians and a MAUQ score of 79.9% by 33 patients. In emPOWERD-AF, 80 patients were randomized 1:1 (58.1 ± 8.7 years, 66% male). The median AFEQT change at 6 months was +2.63% in full version users and −1.63% in controls (p < .001). The myAlgos platform and app were easy-to-use and improved QoL in patients.

**Keywords**
atrial fibrillation, mHealth, eHealth, telehealth

**Introduction**

Atrial fibrillation (AF) is the most common arrhythmia, affecting more than 30 million people globally.\(^1\) Aging, male sex, and cardiovascular comorbidities are the main risk factors for AF.\(^2\) In paroxysmal AF (PAF), AF episodes last less than 7 days before patients revert to sinus rhythm with or without medical intervention. AF in general conveys a nonhomogeneous risk of severe complications, most commonly due to thromboembolic events, which may affect patients’ health status and quality of life and in some cases prove fatal.\(^1\) However, AF need not incite life-threatening complications to severely impact patients’ quality of life – in most patients the arrhythmia itself elicits burdensome symptoms such as palpitations, exertional dyspnea, fatigue and lightheadedness.\(^3\)

The rapid rise in hospitalizations due to AF or AF complications indicate that there is significant room for early identification of the arrhythmia and improvement in the treatment of the disease.\(^4\) Notably, a high proportion of non-AF related hospitalizations can be observed in study populations (2196 out of 2614 hospitalizations observed in the 14171 patients in ROCKET-AF were not AF or bleeding related). This highlights the significance of enhancing structured and multidisciplinary care pathways in AF patients. Indeed, the integrated, patient-centered chronic care model put forward by Wagner et al. has been tested successfully in AF.\(^5,6\) All available evidence shows that such patient-centered approaches are powerful tools in improving outcomes in AF.\(^7\)

mHealth interventions in AF are equally promising since they enable a high degree of patient involvement in AF management and personalization depending on individual needs.\(^8,9\) The 2020 European Society of Cardiology guidelines for the management of AF acknowledged the utility of mHealth projects that enhance patient education and improve and streamline physician-patient communication.\(^11\) The ESC also launched “myAF”,\(^12\) a smartphone application that enhances patient education and self-engagement, while optimizing communication between physicians and patients. In terms of detecting AF, both Apple and Huawei have investigated the capability of their wearable devices to detect the arrhythmia.\(^13,14\)

myAlgos combines patient care with an mHealth component. It is an integrated, cloud-based, cooperative chronic disease management system which offers clinicians, patients, and caregivers an electronic environment where automated procedures address their own different perspectives for remote monitoring, supported self-management, personalized treatment plan, and enhanced communication as well as collaboration. The system’s philosophy of operation is based on precision medicine. myAlgos features patient education, in-app medical contact via messages, medication reminders and heart rate log. Any improvement of medication adherence is expected to benefit
patients, as declining adherence in anticoagulation medication in this patient group has been associated with increased risk of thromboembolic events. In terms of the AF Better Care pathway, the app supports patients and physicians in every step—aiding physicians optimize stroke prevention by highlighting high-risk patients, providing real-time feedback on symptom management efficacy, and in-app monitoring of risk factors for AF-related complications. Real depictions of the myAlgos platform for physicians and the myAlgos smartphone app for patients are presented in Figure 1, while a schematic representation of main functionalities is present in Figure 2.

The physician-side of the platform is a website (hence often referred to as the myAlgos web platform) with a layout optimized for use via any internet browser. Each physician has unique credentials that enable access to the files and data of patients they treat. Upon accessing the web platform, physicians are first notified of high- and mid-level alerts automatically generated by the platform upon detection of abnormal patient inputs (e.g., high heart rate, palpitations, high blood pressure etc.). Regarding patient files, a thorough but AF-focused patient history is always available, as is all clinical data from the previous patient visit and an overview of the reported medication adherence. Physicians also have access to a summary and detailed log of patient inputs on the app (arterial pressure, heart rate, palpitations, anxiety) as well as any messages the patient may have sent to the management team. Most importantly, the physician is able to direct treatment changes through the app or even instruct the patient to contact emergency services, upon which the patient is immediately notified. One of the main goals of the myAlgos physician platform was to streamline the workflow of PAF patients follow-up by giving treating physicians the ability to review a patient’s file, medications, recent disease course and potential urgent situations as well as give tailored medical advice in a safe and user-friendly digital environment.
The patient-side of the myAlgos platform is a smartphone app installed in patients’ smartphones. Inside the app, the patients have a detailed list of prescribed medications, including dosage and frequency, along with an extensive patient empowerment module that contains information about atrial fibrillation and relevant medications and interventions. Most of this information has been prepared by physicians and targeted for laypeople, although it is supplemented with physician-approved articles from allied health professionals and/or medical journalists. Medication reminders are also present and serve dual purpose as tools for monitoring medication adherence, since patients are kindly notified to confirm they took their prescribed doses. Patients can also inform the care team that they are experiencing an episode of palpitations or send unstructured messages. It should be pointed out that in the interest of patient safety, users are always reminded that the app does not offer urgent/emergency health services and should not be used in an emergency situation.

Our aim was to firstly investigate the usability of the physician-centered myAlgos platform and the patient-oriented myAlgos smartphone app through patient and physician usability studies. Subsequently, we sought to measure the effect of the use of the myAlgos app by patients with PAF on their quality of life through the e-medicine Platform for Optimizing the Workflow in hEaRt Disease (emPOWERD) study.

**Methods**

**Usability study of the myAlgos web platform**

Five physicians from our cardiology department, belonging to a Greek tertiary hospital, were asked to use the myAlgos platform to monitor patients and direct treatment. The treatment plan consisted of medications typically prescribed in atrial fibrillation, self-care behavior recommendations

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**Figure 2.** Schematic representation of the myAlgos platform main features and functionality. AF: atrial fibrillation.
(e.g., feeling the heart rhythm for irregularity, blood pressure measurement) and patient education material. After a tutorial session with technical personnel, users were free to use the platform.

After 4 weeks of using the platform, the participating physicians were asked to complete the Post-Study System Usability Questionnaire (PSSUQ). The PSSUQ is a 16-item questionnaire that measures users’ perceived satisfaction of a system. PSSUQ scores can range from 1 to 7, lower being better. Its questions can be divided in three subdomains: system usefulness, information quality and interface quality.

**Usability study of the myAlgos mHealth app**

Patients visiting our department’s outpatient arrhythmia clinic (belonging to a Greek tertiary hospital) were invited to participate in the usability study. Participants downloaded the myAlgos app on their smartphone, while researchers assumed the role of the care team, transposing patients’ treatment plan to the myAlgos platform. After an in-app tutorial, users were free to use the app at will. To simulate real-life conditions, patients were discouraged from contacting study personnel and physicians outside the app during the duration of the study, although tech support was available during working hours and patient appointments at the AF clinic continued as normal. After 4 weeks of using the app, participants were asked to complete the mHealth App Usability Questionnaire (MAUQ), specifically the version for interactive mHealth apps used by patients.

The MAUQ was created exclusively for usability testing of mHealth apps. Its performance and consistency in assessing mHealth apps during usability testing has been validated by comparing it to the PSSUQ and the System Usability Scale (SUS). The version for interactive mHealth apps used by patients consists of 21 questions divided into three categories: ease of use and satisfaction, system information arrangement, and usefulness. Each item is a Likert scale ranging from 1 to 7, higher the better.

**emPOWERD-AF study design**

The open, randomized, non-interventional, single-center cohort study recruited patients with PAF from June 2020 to November 2020. Patients visiting our department’s arrhythmia clinic (belonging to a Greek tertiary hospital) that fulfilled inclusion criteria were eligible to participate. Follow-up lasted 6 months. Inclusion criteria were age greater than 18 years old, thorough understanding of the Greek language, a history of PAF as well as owning and regularly operating a smartphone. Visual acuity lower than 40%, cognitive impairment defined as Montreal Cognitive Assessment test score <20, stroke within the previous 12 months and uncontrolled mental disorders comprised the study’s exclusion criteria. The study was designed and performed in accordance with the World Medical Association Declaration of Helsinki regarding ethical conduct of research involving human subjects and received approval from the institutional review board of our hospital. Written informed consent was obtained from all participants.

Patients were randomly divided into two groups using block randomization (researchers blinded to block size). The full version group received the full version of the myAlgos app, while the control group received a simplified version of the app. Patients randomized to the full version were signed on the myAlgos platform and received the full myAlgos smartphone app. The patient was encouraged to organize every aspect of self-care through the app. Physicians received all data that the patients logged in the app, including vital signs and other physiological parameters (blood pressure, heart rate, body weight, blood glucose levels, oxygen saturation) and medication adherence statistics, obtained by patients’ response rate to medication adherence notifications. They could also
instruct changes to patient medication. Patients could send messages to the care team at any point, although it was made clear that the app was not meant to replace contact with emergency health services. All communication between patients and members of the care team were asynchronous and text based. The control app version consisted of a heart pulse log only, which the patients and physicians could view at any time.

In total, three visits were performed at baseline, three and 6 months later. Patients used the app throughout this 6-month period. The baseline and 6-month visits demanded physical presence of the patient, whereas the 3-month visit was performed via phone call. Basic demographic characteristics, complete medical and AF-related history were collected at the baseline visit. Quality of life (QoL) was the study’s primary outcome, assessed with the Atrial Fibrillation Effect on Quality-of-life (AFEQT) Questionnaire at every visit and with the 5-level EQ-5D (EQ-5D-5L) health assessment tool at the baseline and the last 6-month visit.

The EQ-5D-5L questionnaire consists of five short questions and a visual analogue scale (VAS). Each question provides a 5-point scaled answer regarding five health subdomains including mobility, self-care, usual activities, discomfort/pain, and depression/anxiety. The VAS ranges from 0 to 100 (100 being best possible health).18 The AFEQT questionnaire quantifies AF-related QoL. AF related symptoms, daily activities, treatment concern and treatment satisfaction comprise the four sub-domains of the questionnaire, which consists of 20 items, with a 7-point Likert-type response scale. Each item and subdomain are transposed to a 0–100 scale with 100 describing the least severe condition. Domain-specific and total scores are calculated and assessed.19 Both questionnaires have been validated for the Greek population.20,21

To estimate the optimal sample size, we performed power analysis with an objective of to adequately recognize an increase in AFEQT score of 5 points or more as significant. This has been recently defined as the minimal clinically important change in AF.22 To his effect, AFEQT position and dispersion data were extracted from a study on European Heart Rhythm Association (EHRA) that reported AFEQT scores,23 while serial score correlation was extracted from the AFEQT Greek validation study.21 A Monte Carlo model simulating a 5-point increase with a paired sample correlation coefficient of 0.8 was designed to acquire a reliable estimate of the expected effect size. With an alpha of 0.05 and 80% power, the minimum sample size to reliably detect a 5-point increase in AFEQT between the full app group and the control app group with a Mann-Whitney U test24 was calculated at 100 (i.e., 50 for each group).

Statistical analysis

Power analysis was performed in Python (using modules from the numpy library)25 and R (using power analysis from the wmpow package).26 Data were tested regarding their normality of distribution via the Kolmogorov–Smirnov test. Normally and not normally distributed variables are presented as Mean ± SD and Median (IQR, Interquartile range), respectively. Categorical variables’ frequency distribution was compared with the Pearson Chi-square test, while normally distributed variables with the t-test and non-normally distributed parameters with the Mann-Whitney U test. p-values lower than 0.05 were considered as statistically significant. All statistical analyses were performed using IBM SPSS Statistics 25.0 (IBM Corp, Armonk, NY).
Results

Usability study of the myAlgos web platform

The myAlgos platform received a mean overall PSSUQ score of 2.52 ± 0.36 (Figure 3(a)). The highest score was noted in the system usefulness subdomain (2.27 ± 0.7). The platform was rated at 2.35 ± 0.51 in regard to interface quality and at 2.8 ± 0.4 for information quality. When it came to user satisfaction, the platform received a mean 75% satisfaction score by physicians.

Usability study of the myAlgos mHealth app

Thirty-three patients aged 57.1 ± 36 years (63% male) participated in the usability study. They gave the myAlgos app an average overall MAUQ score of 117 ± 17.7 out of a perfect 147 (79.9%, Figure 3(b)). In the subdomain of ease of use and satisfaction, the app received an average score of 16 ± 5.2 out of 21 (75% of perfect score). Regarding the arrangement of the app’s interface, users rated myAlgos at 56 ± 8.1 out of 70 (80%). Users rated the app’s predicted usefulness in the self-management of AF at 45 ± 6.3 out of 56 (81.5%). The aforementioned scores are graphically presented in Figure 3(b).

Figure 3. Bar charts of (a) PSSUQ overall score and subdomains in the myAlgos web platform usability study and (b) of MAUQ overall score and subdomains in the myAlgos smartphone app usability study. PSSUQ: Post-System Survey Usability Questionnaire; MAUQ: mHealth App Usability Questionnaire. *The presented results are inverted for ease of comprehension.
The emPOWERD-AF study

In the end, a total of 80 patients were randomly assigned to receive the control version (40 patients) or the full version of the MyAlgos app (40 patients). At baseline, no significant differences were observed between the control group and the full version group (Table 1). The patients that received the full version had a mean age of 57.5 ± 9.4 years and 35% were female. A sizeable proportion (31%) of patients were in EHRA classes III and IV. The median AFEQT total score was 72.1 and mean EQ-5D-5L visual analogue scale (VAS) was 74.6 ± 19.7 (Table 1).

### Table 1. Patient demographics at baseline.

| Parameter                          | Total (n = 80) | Control app group (n = 40) | Full version group (n = 40) | p-value |
|------------------------------------|---------------|---------------------------|-----------------------------|---------|
| Age (years)                        | 58.1 ± 8.7    | 58.8 ± 7.9                | 57.5 ± 9.4                  | .476    |
| Gender (male, %)                   | 53 (66)       | 27 (68)                   | 26 (65)                     | .813    |
| BMI (kg/m²)                        | 29.1 ± 3.9    | 29.2 ± 4.1                | 29 ± 3.8                    | .735    |
| CHADS2                             | 0.88 ± 0.8    | 0.93 ± 0.83               | 0.83 ± 0.78                 | .58     |
| CHA2DS2VASc                         | 1.70 ± 1.38   | 1.75 ± 1.41               | 1.65 ± 1.37                 | .748    |
| Comorbidities                      |               |                           |                             |         |
| Diabetes (%)                       | 7 (9)         | 4 (10)                    | 3 (8)                       | .692    |
| Stroke (%)                         | 7 (9)         | 3 (8)                     | 4 (10)                      | .692    |
| Hypertension (%)                   | 47 (59)       | 25 (63)                   | 22 (55)                     | .496    |
| Chronic kidney failure (%)         | 7 (9)         | 4 (10)                    | 3 (8)                       | .692    |
| Dyslipidemia (%)                   | 44 (55)       | 22 (55)                   | 22 (55)                     | 1.000   |
| Heart failure (%)                  | 7 (9)         | 4 (10)                    | 3 (8)                       | .692    |
| Coronary artery disease (%)        | 11 (14)       | 6 (15)                    | 5 (13)                      | .745    |
| Peripheral vascular disease (%)    | 6 (8)         | 3 (8)                     | 3 (8)                       | 1.000   |
| Treatment                          |               |                           |                             |         |
| Ablation (%)                       | 17 (21)       | 8 (20)                    | 9 (23)                      | .785    |
| Ic-antiarrhythmics (%)             | 18 (23)       | 7 (18)                    | 11 (28)                     | .284    |
| Beta-blockers (%)                  | 43 (54)       | 19 (48)                   | 24 (60)                     | .262    |
| NOACs (%)                          | 45 (56)       | 21 (53)                   | 24 (60)                     | .499    |
| EHRA class                         |               |                           |                             |         |
| I – ‘No symptoms’ (%)             | 36 (45)       | 17 (43)                   | 19 (48)                     | .39     |
| II – ‘Mild symptoms’ (%)          | 19 (24)       | 10 (25)                   | 9 (23)                      |         |
| III – ‘Severe symptoms’ (%)       | 14 (18)       | 7 (18)                    | 7 (18)                      |         |
| IV – ‘Disabling symptoms’ (%)     | 11 (14)       | 6 (15)                    | 5 (13)                      |         |
| AF-episodes                        |               |                           |                             |         |
| 0–no episodes (%)                  | 7 (9)         | 3 (8)                     | 4 (10)                      | .729    |
| 1–1 episode (%)                   | 30 (38)       | 13 (33)                   | 17 (43)                     |         |
| 2–2 to 5 episodes (%)             | 31 (39)       | 17 (43)                   | 14 (36)                     |         |
| 3–more than 5 episodes (%)        | 12 (15)       | 7 (18)                    | 5 (13)                      |         |
| QoL questionnaires                |               |                           |                             |         |
| AFEQT Total Score                 | 72.1 (20)     | 71.1 (20)                 | 72.5 (18)                   | .233    |
| EQ-5D-5L VAS                      | 74.6 ± 19.7   | 76.1 ± 18.6               | 73.1 ± 20.9                 | .496    |

BMI: body mass index; EHRA: European Heart Rhythm Association; NOACs: novel oral anticoagulants; QoL: quality of life; AFEQT: Atrial Fibrillation Effect on QualiTy-of-life; EQ-5D-5L VAS: 5-level EQ-5D visual analogue scale.
Over a follow-up of 6 months, no major cardiovascular events or deaths occurred in the study population. The control and full app version group experienced a similar number of AF-related hospitalizations (2 and 3 respectively, \( p = .644 \)) Patients experienced a median of 1 (IQR = 2) paroxysmal AF episode over the follow-up period. The median AFEQT score increase was 2.63 in the full version group and \(-1.63^3\) in the control group (\( p < .001 \), Figure 4). Regarding AFEQT subdomains, the difference between groups was highest in treatment satisfaction, which had a median increase of 7%\(^\text{13}\) in the full version group and a median decrease of 3%\(^\text{5}\) in the control group (\( p < .001 \)), followed by the treatment concern subdomain, which saw a median 5.5%\(^\text{11}\) increase in the full version group and simultaneous 1%\(^\text{7}\) drop in the control group over the follow-up period (\( p < .001 \)). The symptom burden and daily activities subdomains remained relatively stable in both groups (\( p = .46 \) and \( p = .118 \) for between-groups change, respectively). At the same time, mean EQ-5D-5L VAS results remained stable in the control group (+0.23 ± 7.4%) while exhibiting a minor increase in the full version group (+3.5 ± 9%, between-groups change \( p = .078 \)).

Overall, 16 patients (40%) in the full version group were classified as responders, having experienced an increase in AFEQT score of 5 points or more, recently defined as the clinically important change in AF.\(^\text{22}\) Responders did not significantly differ with non-responders in age nor sexual distribution (\( p = .405 \) and \( p = .599 \) respectively). In fact, among all recorded variables, responders differed significantly in that they interacted more with the app (73.9 ± 14.3% vs 40.5 ± 26.8% for non-responders, \( p < .001 \)) and that they handled all their AF episodes via the app, using the pill-in-the-pocket treatment approach (100% vs 60% in non-responders, \( p = .045 \)). Responders were also receiving more types of medication (2 vs 4, \( p = .044 \)).

Usage statistics were available for patients that used the full version of the app through app analytics coded in-app. Overall, patients fulfilled 53.9 ± 28% of all possible self-care interactions prescribed to them by physicians over a 6-month period. Compliance with the app decreased in the first 3 months before eventually stabilizing (Figure 5). Interestingly, patients using the full version used myAlgos to notify medical personnel of AF episodes in 85% of all episodes (such a feature was unavailable in the control group).

**Figure 4.** Bar chart of median AFEQT total scores for the control and full version group during follow-up. Note that the difference between medians (which can be inferred from this figure) rarely equals to the median difference in paired data (which is presented in-text).\(^\text{32}\) AFEQT: Atrial Fibrillation Effect on QualiTy-of-life.
Discussion

The main finding of the myAlgos physician-oriented web platform and patient-oriented smartphone app usability studies was that physicians and patients alike found them useful and easy to use. The platform’s interface assisted physicians in tracking their patients’ medication, heart rhythm and blood pressure, while patient-testers had little difficulty in navigating the menus necessary to fully access the app’s features.

Regarding the emPOWERD-AF study, the features of the app’s full version appear to have contributed significantly to conserving and even improving patients’ quality of life. Treatment-related QoL subdomains displayed the most prominent increase in the full version group, likely driven by the myAlgos’ medication tracking and ease of contact with the care team.

Indeed, 40% of patients using the full app version experienced a clinically significant increase in quality of life over the follow-up period. Based on app usage statistics, these patients appear to have made more frequent app use, and interestingly, handled all their PAF episodes through the app in the 6-month period of the emPOWERD-AF study. This fact indicates that although the myAlgos platform contains features that patients benefited from, helping them stay committed to their digital treatment plan is the primary challenge. It is probably no coincidence that the app deployed in the mAFA-II trial long-term extension, one of very few mHealth interventions in AF to achieve a hard composite endpoint (in this case lowering stroke, death and hospitalization risk), boasted a 91.7% adherence.27 Other self-care apps in cardiovascular disorders report similar app adherence rates to our 53.9% over a 6-month period,28 which shows that maximizing patient compliance remains an industry-wide concern.

Compared to apps like myAF, which was developed by the ESC,12 myAlgos has the main advantage of serving as a platform for telemedicine in addition to providing features such as medication reminders and educational articles about atrial fibrillation. Such innovations will be necessary as the state of the art regarding mHealth apps for AF patients evolves.

The COVID-19 pandemic may have affected the study’s results in two further ways. Firstly, a trend towards a decrease in quality of life was detected in the control version group, one that was averted in the full version group. This could be attributed to AF patients feeling a particular need to perform social distancing due to the disease, as well as the attested fact that care quality for
non-COVID diseases diminished significantly during peak months of the pandemic.\textsuperscript{29} Secondly, relatively few AF hospitalizations were observed in both treatment arms, suggesting that patients – and physicians – may have opted for a more conservative treatment approach to minimize patient exposure to the virus.

Regarding COVID-19 in general, this unprecedented crisis may accelerate the use of telehealth platforms such as myAlgos. In response to the pandemic, specialist societies now encourage telehealth provision in treating arrhythmias whenever possible.\textsuperscript{30} TeleCheck-AF, one of the largest integrated telehealth projects in AF, has the explicit purpose of enabling teleconsultations during the COVID-19 pandemic.\textsuperscript{31}

Our study had some limitations. First of all, emPOWERD-AF was a single-center, open-label study, which included patients that were already smartphone users and relatively free of visual/cognitive impairment. Thus, larger, multi-center studies with more expansive inclusion criteria will be needed to definitively assess the effect of mHealth apps on the quality of life of patients with PAF. The relatively young mean age of our sample indicates that our findings cannot be necessarily extrapolated to older AF patients, who may struggle with using mHealth applications. Additionally, the relatively low proportion of patients receiving NOAC therapy could suggest that patients in real-life AF cohorts may deal with more complex pharmacotherapy, with unsure effects of the efficacy of mHealth applications. The proportion of asymptomatic patients with a priori high QoL could have attenuated the beneficial effect of the myAlgos platform on patients’ QoL. Although the study was marginally underpowered to detect an increase in AFEQT-measured QoL, a significant result was nonetheless observed. This may be in part due to the smaller within-groups variation observed in the emPOWERD-AF study. The smaller variation is likely attributable to the fact that the relatively stringent inclusion led to an arguably more homogeneous sample (all had PAF, smartphone owners, no visual/cognitive impairment etc.). Finally, there was no patient group that received no intervention except for optimal treatment; this decision was made in order to eliminate any potential placebo effect derived by factors related to app installation and use.

Conclusions

The myAlgos platform was rated highly by physicians and patients alike regarding ease-of-use and presentation of available information. The use of the myAlgos app by patients with PAF significantly increased their disease-related quality of life, which was especially pronounced in patients that displayed adherence to the app’s integrative treatment approach. As such, a potential future objective lies in motivating patients to continue mHealth app use over sustained time periods. Furthermore, prolonged investigation of a larger population using the myAlgos app could yield further insights as to its effect on hard endpoints such as hospitalization risk, thromboembolic events, and mortality.

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References
1. Staerk L, Sherer JA, Ko D, et al. Atrial fibrillation: epidemiology, pathophysiology, and clinical outcomes. Circ Res 2017; 120: 1501–1517. DOI: 10.1161/CIRCRESAHA.117.309732
2. Andrade J, Khairy P, Dobrev D, et al. The clinical profile and pathophysiology of atrial fibrillation: relationships among clinical features, epidemiology, and mechanisms. Circ Res 2014; 114: 1453–1468. DOI: 10.1161/CIRCRESAHA.114.303211
3. Freeman JV, Simon DN, Go AS, et al. Association between atrial fibrillation symptoms, quality of life, and patient outcomes: results from the outcomes registry for better informed treatment of atrial fibrillation (ORBIT-AF). Circ Cardiovasc Qual Outcomes 2015; 8: 393–402. DOI: 10.1161/CIRCOUTCOMES.114.001303
4. Wong CX, Lau DH and Sanders P. Atrial fibrillation epidemic and hospitalizations how to turn the rising tide? Circulation 2014; 129: 2361–2363. DOI: 10.1161/CIRCULATIONAHA.114.010073
5. Hendriks JML, Vrijhoef HJM, Crijs HSJM, et al. The effect of a nurse-led integrated chronic care approach on quality of life in patients with atrial fibrillation. Eurospace 2014; 16: 491–499. DOI: 10.1093/europace/eut286
6. Carter L, Gardner M, Magee K, et al. An integrated management approach to atrial fibrillation. J Am Heart Assoc 2016; 5: e002950. DOI: 10.1161/JAHA.115.002950
7. Gallagher C, Elliott AD, Wong CX, et al. Integrated care in atrial fibrillation: a systematic review and meta-analysis. Heart 2017; 103: 1947–1953. DOI: 10.1136/heartjnl-2016-310952
8. Gomolin A, Lebouché B, Engler K, et al. Optimizing smartphone intervention features to improve chronic disease management: a rapid review. Health Inform J 2020; 26: 1795–1809. DOI: 10.1177/1460458219891377
9. Smahel D, Elavsky S and Machackova H. Functions of mHealth applications: a user’s perspective. Health Inform J 2019; 25: 1065–1075. DOI: 10.1177/1460458217740725
10. Chandrasekaran R, Katthula V and Moustakas E. Too old for technology? Use of wearable healthcare devices by older adults and their willingness to share health data with providers. Health Inform J 2021; 27: 1–14. DOI: 10.1177/14604582211058073
11. Hindricks G, Potpara T, Dagres N, et al. 2020 ESC Guidelines for the diagnosis and management of atrial fibrillation developed in collaboration with the European Association for Cardio-Thoracic Surgery (EACTS): The Task Force for the diagnosis and management of atrial fibrillation of the European Society of Cardiology (ESC) developed with the special contribution of the European Heart Rhythm Association (EHRA) of the ESC. Eur Heart J 2021; 42: 373–498. DOI: 10.1093/eurheartj/ehaa612
12. Kotecha D and Kirchhof P. ESC apps for atrial fibrillation. *Eur Heart J* 2017; 38: 2643–2645. DOI: 10.1093/eurheartj/ehx445

13. Turakhia MP, Desai M, Hedlin H, et al. Rationale and design of a large-scale, app-based study to identify cardiac arrhythmias using a smartwatch: The Apple Heart Study. *Am Heart J* 2019; 207: 66–75. DOI: 10.1016/j.ahj.2018.09.002

14. Guo Y, Wang H, Zhang H, et al. Mobile photoplethysmographic technology to detect atrial fibrillation. *J Am Coll Cardiol* 2019; 74: 2365–2375. DOI: 10.1016/j.jacc.2019.08.019

15. An J, Bider Z, Luong TQ, et al. Long-term medication adherence trajectories to direct oral anticoagulants and clinical outcomes in patients with atrial fibrillation. *J Am Heart Assoc* 2021; 10: e021601. DOI: 10.1161/JAHA.121.021601

16. Lewis JR. Psychometric evaluation of the post-study system usability questionnaire: The PSSUQ. *Proc Hum Factors Soc Annu Meet* 1992; 36: 1259–1260. DOI: 10.1177/154193129203601617

17. Zhou L, Bao J, Setiawan IMA, et al. The mhealth app usability questionnaire (MAUQ): development and validation study. *JMIR mHealth uHealth* 2019; 7: 1–15. DOI: 10.2196/11500

18. Herdman M, Gudex C, Lloyd A, et al. Development and preliminary testing of the new five-level version of EQ-5D (EQ-5D-5L). *Qual Life Res* 2011; 20: 1727–1736. DOI: 10.1007/s11136-011-9903-x

19. Spertus J, Dorian P, Bubien R, et al. Development and validation of the Atrial Fibrillation Effect on Quality-of-life (AFEQT) questionnaire in patients with atrial fibrillation. *Circ Arrhythmia Electrophysiol* 2011; 4: 15–25. DOI: 10.1161/CIRCEP.110.958033

20. Yfantopoulos JN and Chantzaras AE. Validation and comparison of the psychometric properties of the EQ-5D-3L and EQ-5D-5L instruments in Greece. *Eur J Heal Econ* 2017; 18: 519–531. DOI: 10.1007/s10198-016-0807-0

21. Tailachidis P, Tsimtsiou Z, Galanis P, et al. The atrial fibrillation effect on quality-of-life (AFEQT) questionnaire: cultural adaptation and validation of the greek version. *Hippokratia* 2016; 20: 264–267.

22. Holmes DN, Piccini JP, Allen LA, et al. Defining clinically important difference in the atrial fibrillation effect on quality-of-life score. *Circ Cardiovasc Qual Outcomes* 2019; 12: e005358. DOI: 10.1161/CIRCOUTCOMES.118.005358

23. Wynn GJ, Todd DM, Webber M, et al. The European Heart Rhythm Association symptom classification for atrial fibrillation: validation and improvement through a simple modification. *Europace* 2014; 16: 965–972. DOI: 10.1093/europace/eut395

24. Shieh G, Jan SL and Randles RH. On power and sample size determinations for the Wilcoxon-Mann-Whitney test. *J Nonparametr Stat* 2006; 18: 33–43. DOI: 10.1080/10485250500473099

25. Harris CR, Millman KJ, van der Walt SJ, et al. Array programming with NumPy. *Nature* 2020; 585: 357–362. DOI: 10.1038/s41586-020-2649-2

26. Mollan KR, Trumble IM, Reifeis SA, et al. Precise and accurate power of the rank-sum test for a continuous outcome. *J Biopharm Stat* 2020; 30: 639–648. DOI: 10.1080/10543406.2020.1730866

27. Guo Y, Guo J, Shi X, et al. Mobile health technology-supported atrial fibrillation screening and integrated care: a report from the mAFA-II trial Long-term Extension Cohort. *Eur J Intern Med* 2020; 82: 105–111. DOI: 10.1016/j.ejim.2020.09.024

28. Athilingam P and Jenkins B. Mobile phone apps to support heart failure self-care management: integrative review. *J Med Internet Res* 2018; 20: 1–16. DOI: 10.2196/10057

29. Moynihan R, Sanders S, Michaleff ZA, et al. Impact of COVID-19 pandemic on utilisation of healthcare services: a systematic review. *BMJ Open* 2021; 11: e045343. DOI: 10.1136/bmjopen-2020-045343

30. Lakkireddy DR, Chung MK, Gopinathnair R, et al. Guidance for cardiac electrophysiology during the COVID-19 pandemic from the Heart Rhythm Society COVID-19 Task Force; Electrophysiology Section of the American College of Cardiology; and the Electrocardiography and Arrhythmias Committee of the
Council on Clinical Cardiology, American Heart Association. *Hear Rhythm* 2020; 17: e233–e241. DOI: 10.1016/j.hrthm.2020.03.028

31. Linz D, Pluymaekers NAHA and Hendriks JM. TeleCheck-AF for COVID-19. *Eur Heart J* 2020; 41: 1954–1955. DOI: 10.1093/eurheartj/ehaa404

32. Wilcox RR. Comparing medians: an overview plus new results on dealing with heavy-tailed distributions. *J Exp Educ* 2005; 73: 249–263. DOI: 10.3200/JEXE.73.3.249-263