A virtual platform to deliver ambulatory care for patients with atrial fibrillation

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BACKGROUND There are little data on the use of virtual care for patients with arrhythmia. We evaluated a virtual clinic platform, in conjunction with specialist care, for patients with symptomatic atrial fibrillation (AF).

METHODS This was a prospective, observational cohort study evaluating an online educational and treatment platform, with a randomized sub-study examining the use of an ambulatory single-lead electrocardiogram heart monitor (AHM). Follow-up was 6 months. The main outcome was patients' platform use; success was defined as 90% of patients using the platform at least once, and 75% using it at least twice. The primary outcome in the AHM sub-study was Atrial Fibrillation Symptom Severity (AFSS) score. Other outcomes included patient satisfaction questionnaires, quality of life, emergency department visits, and hospitalizations for AF.

RESULTS We enrolled 94 patients between July 2018 and May 2019; 83% of patients logged in at least once and 54.3% more than once. Patients who were older, were male, or had new-onset

AF were more likely to log in to the platform. Satisfaction scores were high; 70%–94% of patients responded favorably. Quality-of-life scores improved at 3 and 6 months. In the AHM sub-study (n = 71), those who received an AHM had lower AFSS scores (least square mean difference -2.52, 95% CI -4.48 to -0.25, P = .03). There was no difference in emergency department visits or hospitalizations.

CONCLUSION The online platform did not reach our feasibility target but was well received. Allocation of an AHM was associated with improved quality of life. Virtual AF care shows promise and should be evaluated in further research.

KEYWORDS Atrial fibrillation; Online health care; Virtual clinic; Telemedicine

Introduction

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia, with a lifetime prevalence of 1 in 4 in those over 40 years of age.[1] The burden of AF is projected to exponentially increase in the coming decades worldwide: studies have estimated a doubling of prevalence of AF between 2010 and 2050 in the United States[2,3] and similarly in the European Union.[4] The current model of care for AF is through primary care, referral to specialists, with intercurrent emergency department (ED) visits and hospitalizations.

With the ubiquity of the internet in the modern era, many patients seek education regarding their own conditions from electronic sources.[5] There has also been an increasing use of online platforms by health care professionals to deliver patient education.[6] Virtual care has become of interest to clini-

cians as a potentially resource-efficient method to deliver timely and effective medical care.

Ambulatory AF care can be challenging without assessment of a patient's rate and rhythm. One-time electrocardiogram (ECG) readings in clinic and noninvasive ambulatory monitoring are the mainstays of assessing rate and rhythm control, but this lacks sensitivity to detect inadequate rate control and AF recurrence.[7,8] We investigated a device that allows patients to check their own heart rate and rhythm by pairing a single-lead ECG system with a smartphone. The rhythm strips can be stored and sent securely to the patient's treating team.

We created an online virtual patient-centered platform to deliver follow-up care for patients with AF, after evaluation by a specialist. In a subgroup of eligible patients, we provided ambulatory single-lead electrocardiogram heart monitor (AHM) monitoring in a randomized fashion. Our primary goal was to evaluate the feasibility of the platform and AHM and our secondary goal was to investigate the effect on outcomes, including patient satisfaction, quality of life, ED visits, and hospitalizations.

KEY FINDINGS

- Feasibility of the online virtual Kinduct AF platform (Kinduct Technologies, Halifax, Nova Scotia, Canada), measured as patient usage, did not reach our prespecified success threshold. We found that older, male patients, as well as those with new-diagnosis atrial fibrillation, were more likely to use it.

- The platform was well received by patients.

- Quality-of-life scores improved; the Canadian Cardiovascular Society Severity of Atrial Fibrillation scores were less severe at 3 and 6 months; the Atrial Fibrillation Symptom Severity (AFSS) scores were higher at 3 months but not at 6 months.

- The ambulatory heart monitor (AHM) was also well received by patients.

- Patients who received an AHM had improved AFSS scores compared to those who did not.

Methods

This was a single-center prospective observational study (Queen Elizabeth II Health Sciences Center, Halifax, Nova Scotia, Canada), with a randomized sub-study. The protocol was approved by the institutional research ethics board at the Queen Elizabeth II Health Sciences Center. The protocol was registered with Clinicaltrials.gov (NCT03080857) and adheres to CONSORT guidelines. We enrolled patients who were either referred for specialist evaluation for new-onset nonvalvular AF or under specialist care with symptomatic AF. Inclusion criteria were as follows: age 18 years or older, able to ambulate independently, able to provide informed consent, documented symptomatic AF, and English-speaking. Patients were excluded if they could not ambulate owing to physical limitations, did not have access to a computer and/or smartphone, were planning to move during the study follow-up period, or had a medical condition that made 1-year survival unlikely. Written consent was obtained for all patients. For the AHM sub-study, patients who owned a compatible smartphone were sequentially screened and randomized 1:1 to receiving an AHM, vs the online platform alone. Randomization was performed using random permuted blocks of 2 and 4, where the size of the next block was randomly chosen from the available block sizes. Follow-up was performed by telephone at 3 months and 6 months. Baseline demographics and clinical characteristics were obtained at time of the initial specialist visit. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

The platform (Kinduct AF) was designed by Kinduct Technologies (Halifax, Nova Scotia, Canada). The platform included a treatment plan as decided by the treating clinician. Content delivery was through both text-based and video-based media. The platform also contained an interactive

component, allowing for patients to send questions to be answered by a research nurse. Patients were allowed to log in at any time. Patients also received weekly e-mails with hyperlinks to the platform allowing entries into a diary of symptoms, without requiring login. The specific components of the platform are summarized in Table 1. The KardiaMobile Ambulatory Heart Monitor is manufactured by AliveCor Inc (Mountain View, CA). The device provides a 30-second single-lead ECG that is classified into "normal sinus," "indeterminate," and "possible AF" by the Kardia smartphone app. Patients were encouraged to routinely use the AHM once a week, as well as at any time at their own choosing. A PDF of the rhythm strip and corresponding analysis could then be sent to their research team by e-mail, at the patient's discretion, to a secure account, where the strip was analyzed by 2 independent investigators. The AHM system has been validated against cardiologist-interpreted ECGs[9] and has been used in the outpatient setting for detecting AF recurrence after catheter ablation with a sensitivity of 100% and specificity of 97%.[10]

The primary outcome of the study was feasibility of the platform, measured by the use of this platform. The threshold for success of platform usage was defined as 90% of the patients using the platform at least once and 75% of patients using it at least twice over the 6-month follow-up period. Other outcomes included patient reported quality of life and AF severity, ED visits, and hospitalizations related to AF. Quality-of-life estimates were obtained using the EQ-5D questionnaires and visual analogue score, and the disease-specific University of Toronto Atrial Fibrillation Symptom Severity (AFSS) score.[11] Severity of AF symptoms was also evaluated using the Canadian Cardiovascular Society Severity of Atrial Fibrillation (CCS-SAF) score.[12] Individual patient feedback regarding the platform was sought using questionnaires and dedicated patient focus groups. When feasible, modifications were made to the platform in response to patient feedback. Satisfaction with the platform was measured using a Likert scale (1–5) on the following statements: (1) I think the platform was user friendly; (2) I liked the overall presentation of the platform; (3) I was able to easily find my way around the platform; (4) The education modules were easy to understand; (5) The education modules contained information that was helpful and relevant to me; (6) The education material provided answers about the management of AF.

For the AHM, the main outcome was AF symptom burden, as measured by the AFSS score. We estimated *a priori* that a sample size of 58 patients (29 of whom would receive an AHM) was required to measure a reduction of mean AFSS score of 13 ± 8 to 7, with a power of 80%.[13] We also determined patient satisfaction; this was measured using the Likert scale (1–5), with the following 4 questions: (1) Do you find the AHM easy to use?; (2) Did you find it provided useful information on how to live with AF?; (3) Did the AHM help avoid a visit to the emergency department?; (4) Did the AHM reduce your anxiety regarding AF?

Table 1 Components of the Kinduct AF platform (Kinduct Technologies, Halifax, Nova Scotia, Canada)

Documentation of the treatment plan as prescribed by their physician

Goal-directed therapy individualized to patient: exercise ≥150 minutes/week, alcohol reduction to ≤2 drinks/day for men and ≤1 drink/day for women, weight loss of 10% of body weight over next 3–6 months

Aggressive risk factor management focusing on nutritional counseling and exercise

Advice on management of their AF, whether it is persistent or paroxysmal in nature, and when to proceed to seek medical attention, as well as the urgency of the attention

Personalized information on AF treatment plan

Frequently asked questions – video based

Detailed information on AF and its complications

Tracking of weight, exercise, diet

Messaging application with direct communication to the research personnel

AF = atrial fibrillation.

Statistical analysis was performed using SAS software 14.3 version 9.4 (SAS Institute, Cary, NC). For baseline variables, Student t tests were used to compare continuous variables, and χ^2 tests were used to compare categorical variables between baseline groups. Pearson correlation coefficient was used to correlate continuous variables. For platform usage, a negative binomial model was used to model number of login days against baseline characteristics and logistic regression model was used to model the dichotomized outcome of logging in yes/no. Incident rate ratios (IRR) and odds ratios (OR) were reported with 95% confidence intervals (CI). Multivariate analysis was performed including those variables significant at $P < .2$. Questionnaire responses were reported as a 1–5 Likert scale for individual questions. A summary score for patient satisfaction was created by adding patient responses on each individual question and treated as a continuous variable. A cumulative logit model with random effects to account for correlation between measurements on same subjects was used separately for ordinal repeated CCS-SAF and EQ-5D scores. Repeated measures ANOVA was used to model AFSS overall score with an autoregressive correlation structure to account for correlation between measurements on same subjects over time. An interaction term for time by baseline covariate was included in the model to investigate if the baseline variables were associated with change in measurements over time. Paired t tests were used to compare scores between baseline and follow-up.

In the AHM sub-study, independent sample t tests were used to compare scores between groups. Repeated measure analysis of variance with autoregressive correlation structure was used to model AFSS overall score over time and between AHM groups. Least square mean (LSM) difference estimates with standard error (SE) and 95% CI were reported. A P value of <.05 was considered statistically significant.

Results
Between July 2018 and May 2019, 239 patients were screened (Figure 1). A total of 94 patients were enrolled
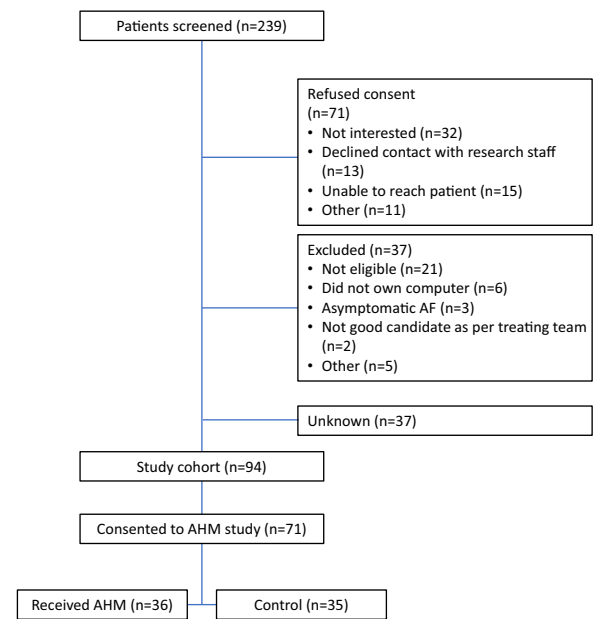

Figure 1 Patient enrollment flowsheet. AHM = ambulatory heart monitor.

into the study. Follow-up was completed for 99% (n = 93) of the patients at 6 months.

Baseline characteristics are shown in Table 2. The mean age was 62.6 ± 11.6 years; 41.5% were female. 68.1% had paroxysmal AF, and 14.9% had persistent AF. The average duration of AF was 70.2 ± 87.2 months; 66.0% had AF duration over 1 year. There were 38 (40.4%) patients who had an ED visit for AF in the prior 6 months.

Outcomes
A total of 78 (83.0%) patients logged into the online platform; 51 (54.3%) patients logged in at least twice. Weekly surveys were submitted by 74 (78.7%) patients at least twice. Among the 78 patients who logged in at least once, the median number of days logged in was 2.0 (interquartile range 1–5, max 34). Platform usage, as measured by number of days logged in, was associated with higher patient satisfaction, as measured by the summary satisfaction score, at 3 months (OR 1.21, 95% CI 1.03–1.43, $P = .02$); this association was not seen at 6 months (OR 1.11, 95% CI 0.89–1.38, $P = .34$). On univariate analysis, the number of login days was associated with a new diagnosis of AF (IRR 1.85, 95% CI 1.02–3.58, $P = .05$); patients with prior cardioversions (IRR 0.57, 95% CI 0.36–0.91, $P = .02$) or prior cardioversion or ablation in the past 6 months (IRR 0.45, 95% CI 0.21–0.99, $P = .04$) were less likely to log in to the platform. On multivariate analysis, male sex (IRR 1.64, 95% CI 1.03–2.64, $P = .04$), age (IRR 1.03, 95% CI 1.01–1.05, $P = .01$), and new AF (IRR 1.86, 95% CI 1.07–3.29, $P = .03$) were associated with higher usage. Prior cardioversion (IRR 0.49, 95% CI 0.32–0.75, $P = .0009$) and sleep apnea (IRR 0.60, 95% CI 0.38–0.94, $P = .03$) were associated with lower usage. There was no significant relationship between number

Table 2   Baseline characteristics in entire study cohort (N = 94)

Age (years)	62.6 ± 11.6
Female	39 (41.5)
AF type	
New	15 (16.0)
Existing	74 (78.7)
Baseline rhythm	
Sinus	64 (68.1)
AF	23 (24.5)
AF duration (months)	70.21 ± 87.21
AF type	
Paroxysmal	64 (68.1)
Persistent	14 (14.9)
Prior cardioversion in ED	57 (60.6)
Cardioversion or hospitalization for AF in past 6 months	10 (10.6)
ED visit for AF in past 6 months	38 (40.4)
Cardioversion or AF ablation in past 6 months	11 (15.0)
Average CCS-SAF score	
1	8 (8.5)
2	36 (38.3)
3	39 (41.5)
4	10 (10.6)
Number of rate control medications	
1	53 (56.4)
2	10 (10.6)
≥3	3 (3.2)
Type of rate control medications	
Beta blocker	55 (58.5)
Calcium channel blocker	10 (10.6)
Beta blocker plus calcium channel blocker	4 (4.3)
Referred for AF ablation	9 (9.6)
Prior AF ablation	24 (25.5)
HTN	46 (48.9)
CHF	8 (8.5)
CAD	2 (2.1)
Diabetes	14 (14.9)
Smoking	3 (3.2)
OSA	31 (33.0)
CHADS2	
0	33 (35.1)
1	40 (42.6)
2	13 (13.8)
3	6 (6.4)
4	2 (2.1)
CHA2DS2-VASc	
0	18 (19.1)
1	26 (27.7)
2	17 (18.1)
3	16 (17.0)
≥4	17 (18.1)
LVEF	
<30%	1 (3.0)
30%–40%	1 (3.0)
40%–50%	7 (21.2)
>50%	24 (72.7)
LVEF (mean, %)	54.6 ± 10.7
Systolic blood pressure (mm Hg)	130.96 ± 17.51
Diastolic blood pressure (mm Hg)	78.74 ± 10.76

Values are shown as n (%) or n ± SD where applicable.

AF = atrial fibrillation; AHM = ambulatory heart monitor; CHF = congestive heart failure; CAD = coronary artery disease; ED = emergency department; HTN = hypertension; LVEF = left ventricular ejection fraction; OSA = obstructive sleep apnea.

Table 3   Clinical outcomes for patients in the entire study, as well as in the Ambulatory Heart Monitor sub-study

	Entire cohort N = 94	AHM N = 36	No AHM N = 35	P value*
ED visit or hospitalization	20 (21.2)	7 (19.4)	6 (17.1)	1.00
ED visit	18 (19.1)	6 (16.7)	6 (7.1)	
Hospitalization	4 (4.3)	1 (3)	0	

Values are shown as n (%).

AHM = ambulatory heart monitor; ED = emergency department.

*Fisher exact test, between AHM and No AHM cohort.

of log-ins and baseline CCS-SAF. Over a follow-up period of 6 months, 4 (4.3%) patients were hospitalized for AF; 18 (19.1%) presented to the ED for AF (Table 3).

Quality of life

Compared to baseline, the CCS-SAF score improved at 3 months (OR 0.45, 95% CI 0.28–0.71, P = .0008) and 6 months (OR 0.34, 95% CI 0.21–0.55, P < .001, Table 4). Persistent AF (OR 16.08, 95% CI 5.32–48.60, P < .001) and prior cardioversion (OR 3.32, 95% CI 1.74–6.35, P = .0003) were associated with more severe CCS-SAF scores at 6 months. Higher left ventricular ejection fraction was associated with less severe CCS-SAF scores (estimate -0.048, 95% CI -0.089 to -0.0075, P = .02).

AFSS scores demonstrated improvement between baseline and 3 months (LSM difference 2.89, SE 1.14, P = .01), but this was not sustained at 6 months (LSM difference 0.20, SE 0.76, P = .79). All components of the EQ-5D score were similar between baseline and 6 months. There was no change in the EQ-5D visual analogue scale (71.6 ± 18.9 vs 72.7 ± 18.0, P = .94).

Evaluation of platform

The platform was well received by the majority of patients (Figure 2). At 3 months, 83% of patients agreed or strongly agreed the platform was user friendly, increasing to 92% at 6 months. The majority of patients were able to navigate the platform (79% at 3 months, 85% at 6 months), with similar findings for satisfaction with the overall presentation (79% at 3 months, 78% at 6 months). Comprehension of the educational material was 94% at 6 months, while 85% felt the modules were helpful and relevant. A total of 72% of the respondents felt that the platform provided answers regarding AF management. The overall summary score, calculated by adding up scores from each of the 6 individual questions, improved between 3 and 6 months (LSM difference 1.09, 95% CI 0.23–1.95, P = .01). Patients with new-diagnosis AF (LSM difference 2.84, SE 1.10, P = .01), patients of younger age (per each year decrease, LSM difference 0.066, SE 0.029, p=0.025), and those who had not had prior cardioversion (LSM difference 2.16, SE 0.71, P = .003) had greater improvement in scores. There was no association between questionnaire responses and baseline CCS-SAF

Table 4   Canadian Cardiovascular Society Severity of Atrial Fibrillation and Atrial Fibrillation Severity Scale scores at baseline and 6 months

	Baseline	6 Months	Odds ratio (95% CI)
CCS-SAF score			0.34 (0.21–0.55), $P < .0001$
1	8 (8.5%)	18 (19%)	
2	36 (38.3%)	33 (35%)	
3	39 (41.5%)	21 (22%)	
4	10 (10.6%)	0 (0%)	
AFSS score			

	Baseline	6 months	P value*
AF frequency	5.85 ± 3.23	5.22 ± 3.19	.62
AF duration	6.28 ± 2.76	5.88 ± 3.01	.58
AF severity	6.12 ± 2.63	6.54 ± 2.10	.35
Total AF burden	16.66 ± 6.03	16.45 ± 5.89	.75

Values are shown as n (%) or n ± SD.

AF = atrial fibrillation; AFSS = Atrial Fibrillation Symptom Severity; CCS-SAF = Canadian Cardiovascular Society Severity of Atrial Fibrillation.

*Between baseline and 6 months.

($P = .80$) or AFSS scores ($P = .31$). Narrative feedback comments solicited at 3 and 6 months are shown in Supplemental Table 1. The major themes of positive comments included the content being informative and appreciation for the videos. Negative comments were primarily regarding difficulty with using computer technology, specific suggestions on how to improve the platform, and lack of benefit owing to lack of AF symptoms.

AHM sub-study

A total of 71 patients were enrolled into the AHM sub-study (36 received an AHM); baseline characteristics are shown in Supplemental Table 2. There were no significant differences in baseline characteristics between the AHM and control group, including sex (33% vs 40% female, $P = .56$), age (61.3 vs 60.9 years, $P = .89$), and new diagnosis of AF (14.7% vs 15%, $P = .96$). Among those who received AHM, 7 patients (19%) submitted an average of 3.3 tracings at 3 months. Between 3 and 6 months, only 1 patient submitted tracings.

Over time, patients who received an AHM had a lower AFSS score (LSM difference -2.52, 95% CI -4.48 to -0.25, $P = .03$). There was also an improvement in several EQ-5D scores over time among patients who received an AHM: mobility (LSM difference -1.05, 95% CI -1.95 to -0.16, $P = .02$), usual activities (LSM difference -2.07, 95% CI -3.01 to -1.13, $P < .0001$), pain and discomfort (LSM difference -1.03, 95% CI -1.89 to -0.18, $P = .02$). There was no difference in the visual analogue scale ($P = .93$). There was no difference in CCS-SAF severity ($P = .51$).

At 6 months, there was no difference in composite of ED visits or hospitalization between the AHM and control cohort group (19% vs 17%, OR 1.13, 95% CI 0.27–2.89, $P = .84$). Among those who received an AHM, 6 had presented to the ED (17%) and 1 had been admitted. Among the control group, there were 6 who presented to the ED (17%) and no hospitalizations.

The AHM was well received, as shown in Figure 3. A total of 32 (88.9%) patients completed the satisfaction questionnaire at 3 months; 29 (80.6%) completed the questionnaire at 6 months.

The responses showed a numerical improvement between 3 and 6 months, but there was no statistically significant trend found in summary score. Several patients who were
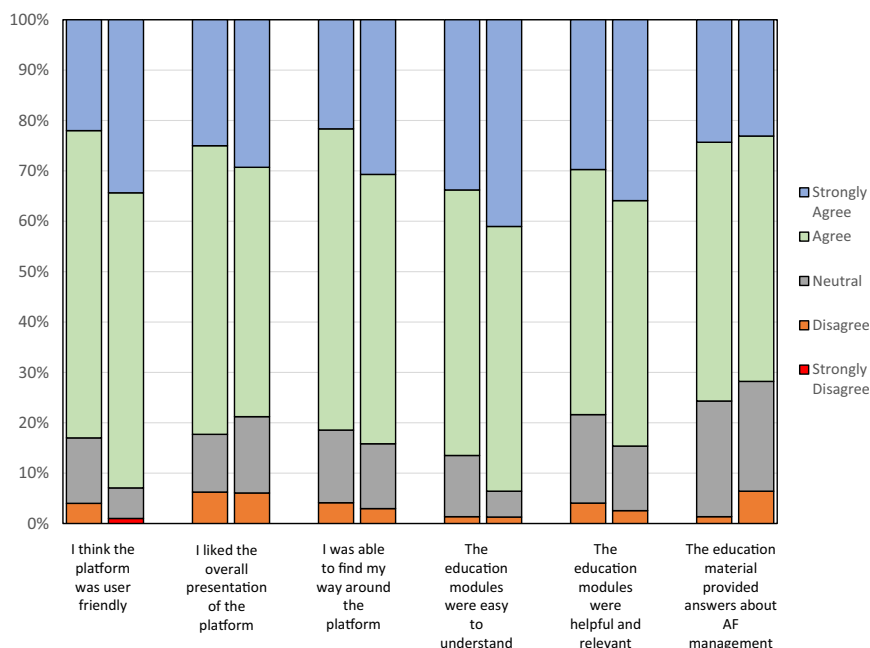

Figure 2   Results of satisfaction questionnaires for the online platform, at 3 months (left bar) and 6 months (right bar). A total of 80 patients completed the questionnaire at 3 months; 78 completed the questionnaires at 6 months. AF = atrial fibrillation.
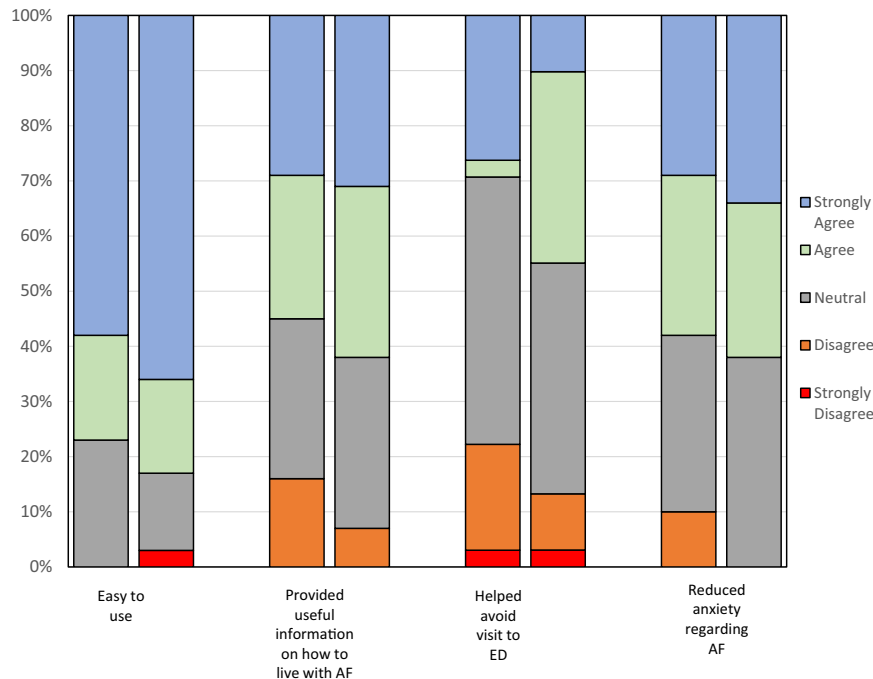
Figure 3 Results of satisfaction questionnaires for the ambulatory heart monitor, at 3 months (left bar) and 6 months (right bar). A total of 36 patients completed the questionnaire at 3 months; 29 completed the questionnaires at 6 months. AF = atrial fibrillation; ED = emergency department.

randomized to the control group indicated interest in getting the device at a later time.

Discussion

In this prospective study of an ambulatory cohort of patients with symptomatic AF, we investigated the implementation of a virtual web-based platform. Our prespecified threshold for feasibility was not met; however, the platform received high satisfaction scores. Although our target usage was not met, we did find that usage was higher in those with a new diagnosis of AF, and in older patients. We observed a higher response to weekly surveys using a link distributed by e-mail and did not require an active login. There was an improvement in AF symptom severity as measured by the CCS-SAF and AFSS scores at 3 months, with no change in EQ-5D scores. The AHM also received high satisfaction scores; patients reported that it helped them avoid AF-related ED visits. Patients in the AHM group demonstrated significantly improved quality of life on AFSS and several EQ-5D measures; there was no measurable effect on AF-related ED visits or hospitalizations.

Although the platform was well received by patients, usage rate of the platform did not reach our predefined target. We found that those with new-diagnosis AF had higher usage rates and also had higher satisfaction scores, while those with prior cardioversion/ablation had lower usage and were less likely to rate the platform positively. We also found that younger patients were more likely to rate the platform higher, even though older patients logged in to the platform more often. The population that was studied was heterogeneous

in that AF duration ranged from less than 1 month to 41 years. Our observations suggest that the type of platform offered in this study was of greater utility to those that were earlier in their diagnosis of AF. It is possible that patients with longer-standing AF did not find as much benefit as those who were less familiar. The idea of patient-centered interventions in earlier stages of chronic disease, such as chronic kidney disease,[14] rheumatoid arthritis,[15] and chronic obstructive pulmonary disease,[16] has been investigated, with limited but promising results.

Of interest, we had defined usage as logging in through the website. As part of the platform, weekly surveys were e-mailed out; entering responses only required following a hyperlink. While just over half of patients logged in at least twice, a significantly higher proportion (78.7%) submitted 2 or more weekly surveys. This disparity could be explained by the ease of clicking a link rather than logging on through a site; alternatively, the system-triggered reminder may have motivated patients to interact with the platform. This observation may help tailor future development and investigation of virtual interfaces.

In the AHM sub-study, a significant improvement in quality of life was observed on more than one scale, including the AF-specific AFSS, despite a relatively low rate of rhythm transmission (19%). The AHM was well received by patients and it is possible that patients used the AHM device more frequently, but did not send rhythm strips in for review. The questionnaire results indicated that the device was easy to use and useful. There is a signal by patient report that the AHM may have been beneficial in preventing ED visits. This suggests that the possibility of being able to

have home-based rhythm monitoring provided some measure of safety or comfort; there has only been 1 prospective study on the effect of AHM on quality of life, and there was a trend in improvement of AF-specific quality-of-life measures.[17]

There are very little published data on patient-centered virtual care for cardiac patients. Surveys of cardiac patients have shown an interest in having more internet-based tools available.[18,19] Most of the previous studies have been on delivery of virtual cardiac rehabilitation care.[20,21] In the field of arrhythmia, virtual care has mostly been related to implantable cardiac device monitoring[22] and wearable technology.[23] Studies investigating virtual care for arrhythmia patients have been small and limited. In the United Kingdom, a recent pilot study used a video-conferencing smartphone app in lieu of in-person visits with 39 post-AF ablation patients; this modality was well received.[24] Another preliminary report with 1 week follow-up from the United States paired a text-to-speech engine on a smartphone with an AliveCor AHM, to automatically provide predefined information and counseling, based on live rhythm tracings and user input.[25] Two novel platforms endorsed by the European Society of Cardiology are currently under investigation.[26] The strengths of our platform include the interactive elements of the platform, freedom for patients to log in at any time and receive the content at their own pace, and a relatively long follow-up period of 6 months. In addition, the treatment regimen for the patients was contained within the platform, resulting in personalization of the content for each patient.

Despite the relative paucity of data, there is significant interest in implementing virtual tools into routine clinical care.[27,28] Spurred by the COVID-19 pandemic, arrhythmia societies have called for implementation of digital health solutions, such as virtual clinics and contactless monitoring with wearable technology[29]; our study demonstrates a promising method of achieving this goal. Another digital platform, the TeleCheck-AF, is currently enrolling patients across Europe.[30]

Computerized decision aids have also been investigated for arrhythmia care, in efforts to integrate digital technology into a modern healthcare systems; there have been few randomized controlled trials. An outpatient decision aid for primary care providers was not found to reduce hospitalization or emergency room visits among patients with AF.[31] However, for high-risk inpatients with AF, a computerized aid built into the hospital electronic medical record did decrease rates of adverse cardiovascular outcomes.[32] A computerized decision support system for primary care providers improved guideline-based treatment of heart failure, but not AF or hyperlipidemia.[33] Although there may be a role for these physician-oriented interventions in high-risk patients, current literature has not found a consistent benefit in randomized controlled trials.

There are several limitations to our study. Although the follow-up period is the longest in comparison to similar prior studies, it was still relatively short; clinical outcomes (ED visits or hospitalizations) were not our primary outcome, so the study was not powered to detect differences in these

outcomes. This was the first iteration of our online platform; lack of some features in the platform may have deterred patients from regularly logging on. Many patient feedback comments were regarding features that they believed could be better implemented. As well, having to log in with credentials may have deterred users, compared to simply following a hyperlink. The lower-than-expected usage rate also may have led to underestimation of the effect of the platform. We did not collect data on the frequency of AHM use; thus we were unable to determine if low usage rates influenced the outcomes. This study used the virtual platform as an add-on to an in-clinic visit, and thus provides no data on its use in patients without a prior specialist assessment.

Conclusion
This pilot study demonstrated that an online virtual clinic for AF patients was well received by patients and led to improvement in some patient-reported AF-specific quality-of-life outcomes. Patient usage, the study's primary outcome, did not meet the prespecified target. Addition of an AHM was well received and also led to improvement in AF-specific quality-of-life measures. Overall, our virtual platform for AF patients has the potential to be beneficial to patients, particularly those with new-onset AF. Future studies should explore further innovative methods of incorporating this type of platform into clinical care for arrhythmia patients, as well as strategies to improve patient usage.

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Data sharing statement: Data will not be made available.

Appendix
Supplementary data
Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.cvdhj.2020.11.005.

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