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Evaluation of the effectiveness of a mobile application on the adherence of patients with atrial fibrillation

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Summary **Background.** To date, no research on the adherence of patients with atrial fibrillation (AF) within the territory of Kazakhstan and Central Asia has been conducted.

Objectives. The study aimed to investigate the effect of a mobile application on adherence in patients diagnosed with AF and treated in outpatient clinics. In addition, the reliability of a structured scale for assessing adherence in patients with atrial fibrillation was also validated.

Material and methods. A prospective one-centre study was conducted on 599 patients diagnosed with AF at the City Cardiology Centre (Almaty, Kazakhstan). Patients were sub-divided into control (CG) and intervention (IG) groups. Patients in the IG group used the MyTherapy mobile app. Treatment adherence was assessed using the 14-item Lebanese Drug Adherence Scale (LMAS-14). Data was collected before starting therapy (T1) and 3 months (T2), 6 months (T3) and 12 months (T4) after the start of treatment.

Results. In the T1 period, the adherence of patients in the CG and IG groups was average ($p = 0.547$). After 3 months (T2), adherence of participants in the IG group (39.1 ± 1.3) was significantly higher than in the CG group ($p \leq 0.05$). In the T3 period, patients of the IG group had a high adherence equal to 38.3 ± 1.6 ($p \leq 0.05$). After 12 months (T4), the respondents in the IG group retained high adherence rates equal to 38.9 ± 3.2 ($p = 0.001$). An estimate of the readmission rate within 12 months shows relatively low rates in the IG group (9.8%).

Conclusions. The results of the study showed the effectiveness of using the MyTherapy mobile app for increasing adherence in patients with AF. In addition, the use of the LMAS-14 facilitated and optimised the assessment of the level of adherence in patients with AF.

Key words: atrial fibrillation, cardiology, mobile applications, patients.

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Background

Chronic diseases, including cardiovascular disorders, are the most common causes of death and disability worldwide [1, 2]. It has been reported that adherence to long-term therapies in developed countries is approximately 50% 1 year after initiation of therapy [3]. The percentage of adherence is much lower in developing countries. For this reason, adherence to chronic disease management is highly critical for healthcare systems, resulting in an increase in quality of life and cost-effectiveness [4].

Atrial fibrillation (AF) is a type of chronic cardiac arrhythmia [5], with a negative prognosis of doubling prevalence rates by 2030 [6]. Among patients with AF, the most common cardiovascular complications are ischemic stroke, heart failure (HF) and sudden cardiac death [7]. AF is known to increase the risk of ischemic stroke due to thromboembolism fivefold [8], and the administration of oral anticoagulants in many cases is recommended as thromboprophylaxis [9]. According to the American Heart Association, more than 65% of people with AF due to a frequent occurence of mild or asymptomatic forms of this disease do not realise the severity level [10]. Therefore, low adherence to therapy hampers effective treatment and decreases the opportunity for positive outcomes [11].

It has been shown that comprehensive care and clinical monitoring of patients with chronic conditions are essential to maintaining adherence to treatment [12]. At present, one of the main emerging challenges relates to the potential negative impact of the coronavirus pandemic (COVID-19) on patients with chronic diseases [13]. As a result of quarantine measures and reduction in the number of doctors' visits, the access to drugs and adequate treatment has been significantly impaired [14].

Recently, a number of remote monitoring technologies have become more widely available to monitor patients with AF [15]. This includes implantable heart monitors, portable medical grade devices, direct consumer access devices and mobile applications [16]. In order to monitor the condition and adherence of patients, mobile applications are becoming very popular due to their accessibility and ease of functionality [17]. From the scientific point of view, mHealth tools have been intensively studied as an aid to optimise the decision-making process on

a treatment regimen, to provide telemonitoring feedback and improve adherence to drugs [18]. Previous studies demonstrated that there is some potential for mHealth tools to improve the adherence to chronic disease management, but the evidence to support their current effectiveness is still mixed and vague [19].

There is a number of reports on the efficacy and suboptimal adherence in AF patients (moderate to low adherence) [20, 21]. Nevertheless, an assessment of the adherence of patients with AF within the territory of Kazakhstan has not been conducted yet.

Study objectives

The purpose of this study is to assess the possibility of using the mobile application "My Therapy". The study has also evaluated treatment adherence in patients diagnosed with AF (treated at outpatient clinics).

Material and methods

Ethical issues

The study was approved by the High Ethics Committee of Kazakh Medical University of Continuing Education, Almaty, Kazakhstan (Local Ethics Commission Approval No. 3, dated 17.03.2020).

Setting

A prospective study was carried out at the Municipal Cardiology Centre in the city of Almaty (Republic of Kazakhstan). The City Cardiological Centre is a specialised hospital in the Republic of Kazakhstan, providing qualified assistance to patients with severe, difficult to diagnose cardiological and cardiac surgical diseases. To this centre cardiological patients from the city of Almaty as well as from all regions of Kazakhstans are admitted both in an urgent and planned hospitalization. For this reason, the data obtained from patients treated at the City Cardiological Centre can be extrapolated to the entire territory of the Republic of Kazakhstan.

Data collection

This prospective study involved 616 people with a verified diagnosis of AF who underwent inpatient treatment at the City Cardiological Centre (Almaty, Kazakhstan) in the period from 01.01.2017 to 31.12.2020. The dataset was carried out according to the CONSORT criteria [22]. The study was conducted in accordance with the Consolidated Reporting Standards for Testing Electronic and Mobile Applications for Health and Online Telemedicine [23].

This study used a matched pair design, taking into account the age and period of illness as potential factors influencing adherence and full use of the mobile app. Thus, in our study, we controlled two potential hidden variables – age and duration of AF.

Inclusion criteria: the presence of written voluntary informed consent to participate in the study, the presence of a verified diagnosis of AF, over 18 years of age, the presence of a smartphone and the ability to use a mobile application.

Exclusion criteria: < 18 years of age, inability to read and use a smartphone, severe visual or hearing impairment, any mental disorder.

The diagnosis of AF was made based on the determination of corresponding changes in the electrocardiogram (ECG) [8]: wrong rhythm; the absence of P waves; variability of the interval between two atrial excitations (if any) with an interval of less than 200 ms (more than 300 per minute); irregular RR intervals. According to severity, AF in the participants was classified into three forms: paroxysmal (spontaneous termination < 7 days and most often < 48 hours; persistent (not self-terminated; lasting > 48 hours); permanent (not terminated; terminated but relapsed; no cardioversion attempt) [24].

Demographic indicators such as age and gender were studied and analysed. In addition, indicators of an unhealthy lifestyle (overweight, smoking and alcohol consumption) were also assessed.

According to sources of official statistics, there is more than 130 nationalities with the territory of Kazakhstan [25]. Among all ethnic groups, Central Asians (Kazakhs, Uzbeks, Tatars, Kyrgyz, Uighurs, Tajiks, Turkmens, etc.) and Slavs (Russians, Ukrainians, Belarusians, etc.) make up the larger share. Other nationalities (Koreans, Germans, Azerbaijanis, Georgians, etc.) make up a small proportion of the population [25]. By ethnicity, the patients were sub-divided into three groups: Central Asians, Slavs and others.

The presence of concomitant diseases, such as arterial hypertension, ischemic heart disease (IHD), diabetes mellitus and degree of congestive heart failure (CHF) according to the New York Heart Association (NYHA) classification, was determined.

The diagnosis and treatment of AF was carried out using the following devices: 1) Pacemaker (ECS) Medtronic ADAPTA DR (USA); 2) Medtronic Sensia SESR 01 (USA); 3) Medtronic Sensia SEDR 01 (USA); 4) Medtronic Sphera DR (USA); 5) Biotronik Effecta SR (Germany); 6) Biotronik Effecta DR (Germany); 7) Biotronik Enticos 4 SR (Germany); 8) Biotronik Enticos 4 DR (Germany); X-ray angiographic system Philips Allura CV20 (Netherlands).

The treatment methods of patients were also studied (implantation of a one- and two-chamber pacemaker; conservative treatment), as well as the types of drugs used. It should be noted that, within the territory of the Republic of Kazakhstan and within the framework of the guaranteed volume of free medical care, patients with a verified diagnosis of AF are prescribed the necessary drugs free of charge.

Adherence assessment

Assessment of adherence to treatment was carried out using an indirect method: using the validated Lebanese Medication Adherence Scale-14 (LMAS-14) [26]. The purpose of this questionnaire was to determine the adherence rate to prescribed drugs. The LMAS-14 contains fourteen Likert scale questions with four options to answer each (coded from 0 (less adherence) to 3 (higher adherence)) [26]. A patient's score may range from 0 (lowest adherence) to 42 (highest adherence) [27].

To determine the internal consistency, Cronbach's alpha coefficient was calculated [28]. Values above 0.6 were considered satisfactory. In our study, a Cronbach's alpha value below 0.5 was considered unacceptable [28].

Table 1. Lebanese Medication Adherence Scale-14 (LMAS-14)

No	Question	Points
1	Do you forget to take your medication when you are busy (intensive work or travel)?	0–3
2	Do you forget to take your medication if you are invited to lunch or dinner?	0–3
3	Do you forget to take your medication?	0–3
4	Are you late when it comes to buying your medication packs when they become empty?	0–3
5	Do you stop taking your medication if it forbids you from eating certain foods that you love because of possible food-medication interactions?	0–3
6	Will you stop taking your medication without your doctor's consultation if your neighbour/relative took a prescription like yours for a long term and it caused side effects?	0–3
7	Do you stop taking your medication without consulting your doctor if the laboratory tests show improvement during the treatment period?	0–3
8	Do you stop taking your medication without consulting your doctor if you do not feel better during the treatment period?	0–3

Table 1. Lebanese Medication Adherence Scale-14 (LMAS-14)		
No	**Question**	**Points**
9	Do you stop taking your medication without consulting your doctor if you feel better during the treatment period?	0–3
10	Do you decide to stop some of your medications without consulting your doctor if you noticed that you are taking too many medications every day?	0–3
11	Do you stop your chronic treatment if you get bored of it?	0–3
12	Do you stop taking your medication in case of side effects?	0–3
13	Do you stop taking your medication if your insurance does not cover it?	0–3
14	Will you stop buying your medication packs if you considered them expensive?	0–3

The results of the 'Reliability test' are presented in Table 2. The reliability of individual questions was almost similar in all the subgroups. Cronbach's α was 0.620 for the total score.

Data was collected using user-completed SurveyMonkey© electronic questionnaires at standard time points or by telephone. Data was collected at baseline (T1), 3 months (T2), 6 months (T3) and 12 months (T4) after treatment. Patients who did not complete at least one time interval (T) were excluded from the adherence study in accordance with Figure 1.

Intervention

Study participants from the control group (CG) and intervention group (IG) received traditional (standard) medical care in accordance with the treatment protocols of the Ministry of Health of Kazakhstan (based on WHO recommendations) [29].

Table 2. Reliability test	
Items	**Cronbach's α**
Question 1	0.612
Question 2	0.598
Question 3	0.605
Question 4	0.608
Question 5	0.625
Question 6	0.603
Question 7	0.611
Question 8	0.624
Question 9	0.581
Question 10	0.623
Question 11	0.758
Question 12	0.501
Question 13	0.742
Question 14	0.602

Alpha reliability = 0.620.

Intervention group (IG) members were given access to the mobile phone application "MyTherapy" version 3.71.1 (Munich, Germany). The mobile application was installed on the patient's mobile device and made it possible to control the time of taking medications, notifying the patient in a convenient way (light signal, sound signal or vibration) [30]. The application allows one to create an individual medication schedule for each patient. The application is freely available and is easy to use (https://www.mytherapyapp.com/ru/download). In addition, to work with the application, all IG members underwent a short training on how to use the application and the text instructions.

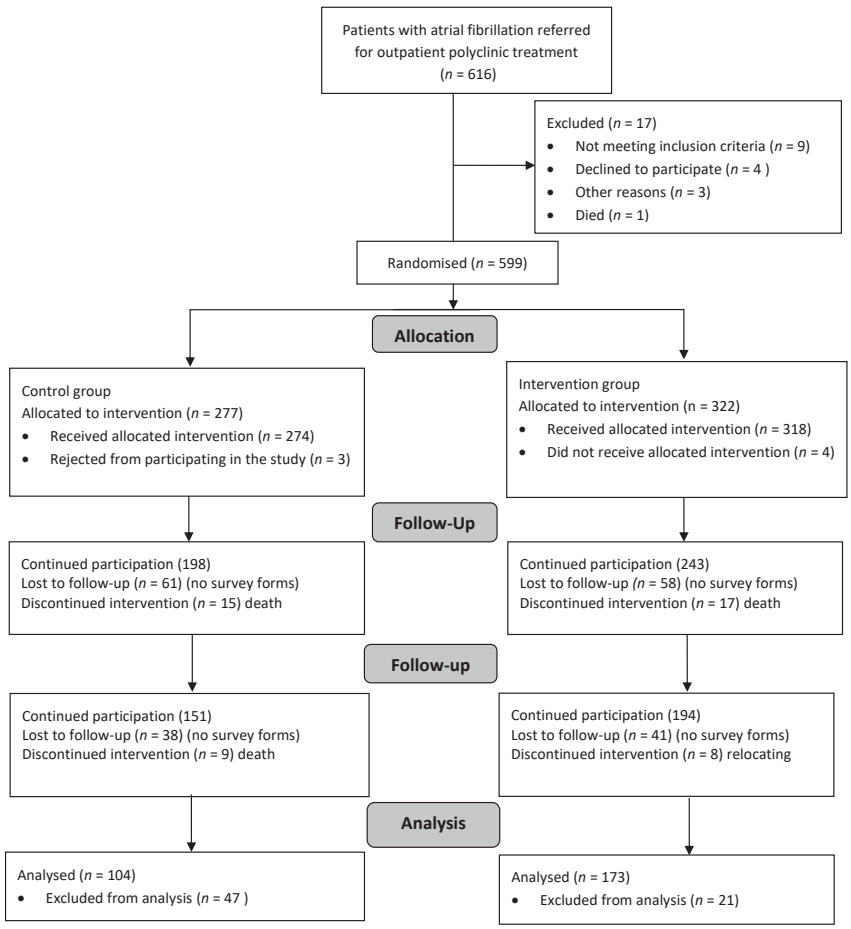

Figure 1. Block diagram of research participants

Outcomes

All patients were followed up on an outpatient basis after 6 and 12 months for clinical manifestations.

We have registered readmissions for any cause of AF, thromboembolism, major bleeding, HF, acute coronary syndrome and hospitalisations. Other cardiovascular outcomes included recurrent AF, which was defined as recurrent onset of AF in patients with paroxysmal AF.

Statistical analysis

Statistical analysis of the results was performed using IBM SPSS Statistics Base 22.0 for Windows. Arithmetic mean (M) and standard deviation (SD) were calculated for the quantitative variables. The data is presented as M ± SD. Qualitative attributes were described as absolute (*n*) and relative (%) values. Coefficients of variability have been calculated. The Kolmogorov-Smirnov method was used to test for normality. Student's *t*-Test was used to compare mean values. Treatment adherence, frequency, mean, median and standard deviation were calculated from the sum of the adherence scores. Differences between the studied parameters were considered statistically significant at $p \leq 0.05$.

For descriptive statistics, we used frequency, percentage, mean, median, standard deviation and interquartile range (IQR). For bipolar comparisons (adherent and non-adherent), we used the chi-square test for categorical variables, independent *t*-Test for continuous data if there was a normal distribution of variables and the Mann-Whitney U test in other cases.

We used a matched pairs design, considering age and period of illness as potential confounders. With pair matching, clusters are paired in terms of their potential confounders, and then within each pair, one cluster is randomised to receive one of the arms and the other cluster receives the opposite arm. Thus, in our study, we controlled for two potential hidden variables – age and duration of the disease. There were no divisions by gender since it was considered that gender does not matter in evaluating the use of a mobile application. A Cox proportional hazards model to account for the clustering effect, adjusted for baseline risk factors, was used to analyse readmission.

Results

A block diagram of study participants with AF (*n* = 616) is presented in Figure 1 (period 2017–2020). Among all patients with AF (*n* = 616), *n* = 17 (2.7%) patients were not included in the study. Such patients did not meet the inclusion/exclusion criteria (*n* = 9 or 52.9%), while 4 patients (23.5%) refused to participate. 3 patients (17.6%) refused for other reasons, and 1 patient died while being recruited into the study (5.8%).

97.2% (*n* = 599) of the patients were included in the study. The patients were sub-divided into 2 groups. Patients in the control group (CG) amounted to 46.2% (*n* = 277), while in the intervention group (IG), this was 53.8% (*n* = 322).

Sociodemographic and clinical characteristics

The general clinical and demographic characteristics of patients are presented in Table 3. By the nature of the treatment, implantation of a 1- and 2-chamber pacemaker was performed in almost an identical number of patients in the CG (*n* = 114) and IG (*n* = 122) groups, respectively. 59% (*n* = 163) of patients in the CG group and 62% (*n* = 200) in the IG group underwent conservative treatment.

According to BMI data, normal body weight (BMI < 25) was more often determined in the IG group in 34% (*n* = 110) of the cases compared with 21% (*n* = 58) ($p \leq 0.05$) of the patients in the CG group.

Overweight patients were found more often among the CG participants (67%; *n* = 186), in comparison with the IG group (42%; *n* = 135), which was statistically significant ($p \leq 0.05$). However, the number of obese patients (BMI > 30) in the IG group was found to be twice as much in 24% (*n* = 77) of the cases in comparison with the CG group (12%) ($p \leq 0.05$).

As for the AF type, "permanent" AF was more often determined in patients of the CG group (49%; *n* = 136) compared with 34% (*n* = 109) in the IG group ($p \leq 0.05$). However, "paroxysmal" AF was more common in 30% (*n* = 83) of the participants in the IG group in contrast to the respondents in the CG group (48%; *n* = 155) ($p \leq 0.05$).

By nationality, Central Asians prevailed at 54% (*n* = 325), among whom 58.2% (*n* = 188) were IG respondents compared to 49.6% (*n* = 137) of CG group members ($p \leq 0.05$). However, the number of Slavs prevailed in the CG group with 44.3% (*n* = 123), which was higher in contrast to the IG group (36.7%; *n* = 118) ($p \leq 0.05$).

There were more patients with concomitant diabetes mellitus in the CG group (21%; *n* = 58) in comparison with the IG group (13%; *n* = 42) ($p \leq 0.05$).

Table 3. General characteristics of patients in the study groups

General characteristics *n* = 599 (*n*, %)				
Characteristic	**CG (*n* = 277)**	**IG (*n* = 322)**	**Overall (*n* = 599)**	***p***
Age (mean + SD)	68.7 ± 11.9	67.9 ± 8.4	68.4 ± 10.8	–
Female (*n*, %)	58% (161)	62% (200)	60.3% (361)	–
Male (*n*, %)	42% (116)	38% (122)	39.7% (238)	–
Type of the treatment				
implantation of 1- and 2-chamber pacemaker	41% (114)	38% (122)	39,4% (236)	–
conservative treatment	59% (163)	62% (200)	60.6% (363)	–
BMI				
less than 25	21% (58)	34% (110)	28% (168)	**0.05**
25–29.9	67% (186)	42% (135)	54% (321)	**0.05**
more than 30	12% (33)	24% (77)	18% (110)	**0.05**
AH				–
yes	88% (244)	86% (277)	87% (521)	–
no	12% (33)	14% (45)	13% (78)	
AF				
constant (*n*, %)	49% (136)	34% (109)	41% (245)	**0.05**
paroxysmal (*n*, %)	30% (83)	48% (155)	40% (238)	**0.05**
persistent (*n*, %)	21% (58)	18% (58)	19% (116)	–
IHD				
yes	92% (255)	84% (270)	88% (525)	
no	8% (22)	16% (52)	12% (74)	

Table 3. General characteristics of patients in the study groups

General characteristics *n* = 599 (*n*, %)				
Characteristic	**CG (*n* = 277)**	**IG (*n* = 322)**	**Overall (*n* = 599)**	***p***
CHF NYHA				
I	9% (26)	31% (100)	21% (126)	
II	69% (191)	44% (142)	56% (333)	
III	19% (53)	19% (61)	19% (114)	
IV	3% (7)	6% (19)	4% (26)	
Nationality				
Central Asians	49,6% (137)	58,2% (188)	54% (325)	**0.05**
Slavs	44,3% (123)	36,7% (118)	40% (241)	**0.05**
other	6,1% (17)	5,1% (16)	6% (33)	–
Duration of AF (*n*, %)				
≥ 1 year	11% (30)	14% (45)	12% (75)	
≥ 3 years	25% (69)	21% (68)	23% (137)	
≥ 5 years	51% (142)	56% (180)	54% (322)	
≥ 10 years	13% (36)	9% (29)	11% (65)	
Diabetes (*n*, %)				
yes	21% (58)	13% (42)	17% (100)	**0.05**
no	79% (219)	87% (280)	83% (499)	**0.05**
Smoking status (*n*, %)				
no	84% (233)	74% (238)	79% (471)	*
ex	4% (11)	19% (61)	12% (72)	*
smokes	12% (33)	7% (23)	9% (56)	*
Alcohol consumption				
no	88% (244)	75% (242)	81% (486)	–
daily	1% (3)	2% (6)	2% (9)	–
once a week	3% (8)	8% (26)	6% (34)	**0.05**
once a month	8% (22)	15% (48)	11% (70)	**0.001**
AF heredity				
no	66% (183)	77% (248)	72% (431)	–
yes	21% (58)	7% (23)	14% (81)	–
do not know	13% (36)	16% (51)	14% (87)	–
CHA_2DS_2-VASc	3 (2–4)	3 (2–4)	3 (2–4)	–
HAS-BLED	1 (1–2)	1 (1–2)	1 (1–2)	–
SAMe-TT_2R_2	4 (3–4)	4 (3–4)	4 (3–4)	–

CG – control group; IG – intervention group; BMI – body mass index; CHF – chronic heart failure; AH – arterial hypertension; IHD – cardiac ischemia; NYHA – New York Heart Association; SAMe-TT_2R_2 = gender, age, medical history, treatment, tobacco use, race; CHA_2DS_2-VASc = chronic heart failure, hypertension, age > 75 years, diabetes, stroke, vascular disease, age 65–74 years, gender; HAS-BLED – hypertension, abnormal renal/liver function, stroke, bleeding history or predisposition, labile international normalised ratio, elderly, drugs/alcohol concomitantly.

According to smoking status, among all patients with AF included in the study, in 79% (*n* = 471) of the cases, the respondents did not smoke, which was more in the CG group (84%; *n* = 233) in comparison with the IG group (74%; *n* = 238) ($p \leq 0.05$). There were significantly more former smokers in the IG group (19%; *n* = 61) in comparison with the CG group (4%; *n* = 11) ($p \leq 0.05$). However, among all the subjects, there were almost twice as many smokers in the CG group (12%; *n* = 33) in comparison with the IG group (7%; *n* = 23) ($p \leq 0.05$).

In terms of alcohol consumption, the number of respondents who drink alcohol once a week was statistically significantly higher in the IG group (8%; *n* = 26) in comparison with the CG group (3%; *n* = 8) ($p \leq 0.05$). Moreover, the number of AF patients who consumed alcohol once a month was twice as high in the IG group (15%; *n* = 48) compared with the CG group (8%; *n* = 22) ($p = 0.001$).

The characteristics of the medications used in study participants with AF are presented in Table 4.

Among all the participants, 37% (*n* = 220 out of 599) of the patients did not use anticoagulant therapy. Patients in the CG (41%; *n* = 113) and IG (41%; *n* = 132) groups used NOACs in almost equal numbers of cases. Warfarin was used in the CG and IG groups in 24% (*n* = 66) and 21% (*n* = 68) of the cases, respectively.

In the group of patients who were prescribed warfarin, INR values were not monitored in 29% (*n* = 175) of the cases. An INR level of 2–3 was recorded in patients from the IG group (54%; *n* = 174) in comparison with the CG group (23%; *n* = 64) ($p = 0.001$). At the same time, labile INR was determined more often among the respondents from the CG group (50%; *n* = 138) in comparison with the IG group (15%; *n* = 48), which was regarded as a statistically significant difference ($p = 0.001$).

Sartans and ACE inhibitors were generally used by 77% (*n* = 464) of the patients, among whom 71% (*n* = 197) were from the CG group and 83% (*n* = 267) were from the IG group. In both groups, beta-blockers, calcium channel antagonists and other antiarrhythmics were used by 70% (*n* = 421), 77% (*n* = 460) and 61% (*n* = 365) of patients, respectively. However, among all patients (*n* = 599), statins and antiplatelet agents were not used by patients in 53% (*n* = 320) and 60% (*n* = 358) of the cases, respectively.

The results of assessing the adherence of patients with AF using the LMAS-14 scale are presented in Figure 2. According to the LMAS-14 questionnaire in the T1 period, the adherence rates of patients in the CG and IG groups were at an average level, amounting to 35.1 ± 4.9 and 34.6 ± 4.6, respectively, but without a statistically significant difference ($p = 0.547$). After 3 months, in the T2 period, the adherence of the participants in the IG group (39.1 ± 1.3) was statistically significantly higher than in the CG group (35.5 ± 3.9) ($p \leq 0.05$). In the T3 period (after 6 months), patients of the IG group had a high adherence

Table 4. Medicines used by patients in the study groups				
	CG (*n* = 277)	IG (*n* = 322)	Overall (*n* = 599)	*p*
Anticoagulant therapy				
no	35% (98)	38% (122)	37% (220)	–
NOAC	41% (113)	41% (132)	41% (245)	–
warfarin	24% (66)	21% (68)	22% (134)	–
If taking warfarin, INR control				
no	27% (75)	31% (100)	29% (175)	–
INR 2-3	23% (64)	54% (174)	40% (238)	**0.001**
/abile INR	50% (138)	15% (48)	31% (186)	**0.001**
Sartans and ACEI				
yes	71% (197)	83% (267)	77% (464)	–
no	29% (80)	17% (55)	23% (135)	–
β-blockers				
yes	66% (183)	74% (238)	70% (421)	–
no	34% (94)	26% (84)	30% (178)	–
Statins				
yes	38% (105)	54% (174)	47% (279)	–
no	62% (172)	46% (148)	53% (320)	–
Antiaggregant				
yes	42% (116)	39% (125)	40% (241)	–
no	58% (161)	61% (197)	60% (358)	–
Ca antagonists				
yes	72% (199)	81% (261)	77% (460)	–
no	28% (78)	19% (61)	23% (139)	–
Other antiarrhythmics				
yes	49% (136)	71% (229)	61% (365)	–
no	51% (141)	29% (93)	39% (234)	–

CG – control group; IG – intervention group; INR – International normalized ratio; NOAC – Novel oral anticoagulants; ACEI – angiotensin-converting enzyme inhibitors.

Table 5. Results of readmission of patients with AF in the IG and CG groups					
Hospitalisation	CG (*n* = 104)	IG (*n* = 173)	HR (CG vs IG)	95% CI	*p*
	24 (23.1)	17 (9.8)	0.41	0.19–0.59	< 0.05

CG – control group; IG – intervention group; HR – hospital readmission; values are *n* (%), readmissions included any cause of AF, heart failure, thromboembolism, major bleeding, coronary artery disease and other cardiovascular diseases.

equal to 38.3 ± 1.6, which was higher than the adherence of patients from the CG group (35.9 ± 2.9), with a statistically significant difference ($p \leq 0.05$). After 12 months in the T4 period, the respondents in the IG group retained high adherence rates equal to 38.9 ± 3.2, while the CG group had the lowest adherence level in comparison with all study periods, amounting to 33.0 ± 4.8 ($p = 0.001$).

The results of assessing the readmission rate over 12 months (Table 5) showed relatively low readmission rates in the IG group, with rates of 9.8% (*n* = 17) compared with the CG group, in which the number of readmissions was 23.1% (*n* = 24) (HR: 0.41; 95% CI: 0.19–0.59; $p = 0.024$).

Discussion

To the best of our knowledge, this is the first study to assess the adherence of patients with atrial fibrillation in Kazakhstan. Moreover, this the first attempt to investigate the possibility of using the mobile application "MyTherapy" and assess its impact on therapy adherence. In this study, the Lebanese Medication Adherence Scale-14, consisting of 14 questions, was used to evaluate patient adherence. Such a method allows for detailed assessment of the level of adherence. The results of the reliability test, of which Cronbach's $\alpha = 0.620$, showed the applicability of LMAS-14 to assess the adherence of patients with AF.

Taking into account the age and period of illness as potential factors in the study, the applied method of matched pairs allowed for two potential hidden variables, such as age and duration of AF, to be controlled throughout the study [31]. The use of a design with matched pairs made it possible to achieve completely identical conditions for using a mobile application in homogeneous age groups, since the key idea of the matched pairs method is that if two almost identical observations are combined into pairs before randomisation, the absence of a result from one unit is informative about the potential absence of a result from another unit [32].

Despite the fact that *n* = 322 patients participated in the initial T1 period, only 53.7% (*n* = 173) fully completed their participation in the study in the T4 period (after 12 months). This fact was associated with a relatively long period of continuation of the study (12 months) and, accordingly, any circumstances that arose, such as the death of patients, failure to fill out the survey forms, change of residence at the time of the study, since this hospital received patients from all over Kazakhstan for treatment. The results of previous studies based on CONSORT criteria with a certain duration indicate that the incompletion of study participation does not significantly affect the quality of analytics and results [33].

Previous studies have shown a significant relationship between the level of adherence to drug treatment and the age of patients [34], as patients with low adherence were significantly older than other patients with better adherence. The prevalence of AF increases with age, as AF affects 1% of people under the age of 60 and increases to 30% in people under the

age of 80 [35]. Previously published data indicates that 28% of high-risk patients (defined as CHA_2DS_2-VASc (cardiac failure, hypertension, age ≥ 75 (doubled), diabetes, stroke (doubled) – vascular disease, age 65–74 and gender category (female)) assessment ≥ 2) are not receiving anticoagulants, while 51% of very low-risk patients receive inadequate anticoagulants [36]. Non-adherence to recommendations for medical prescriptions, depending on territorial differences in patients with AF, can also range up to 50% in high-risk populations [37]. In this study, statistically significant differences in the age of AF patients and adherence were not found.

In addition to age, among other risk factors for the development of cardiovascular pathology, the presence of excess weight in patients has been identified as a significant risk factor for the progression of AF [38]. Perhaps for this reason, participants in the IG group, due to their higher adherence to treatment, had a statistically significant lower number of overweight patients compared to participants in the CG group. The statistically significant number of obese participants in the IG group compared to those in the CG group indicates the need for further research to determine the true relationship between changes in BMI of patients depending on their adherence to treatment. It has been thought that in cases of CVD, there is a paradox of obesity, where overweight (BMI from 25.0 to 29.9 kg/m^2) and persons with moderate obesity (BMI from 30.0 to 34.9 kg/m^2) have a better prognosis than underweight people (BMI up to 18.5 kg/m^2) and people with "normal" weight (BMI from 18.5 to 24.9 kg/m^2) [39, 40].

In fact, AF is the most common arrhythmia associated with chronic high alcohol consumption, and with more than 14 grams of alcohol per day, the relative risk increases by 10% for each additional standard drink (14 grams of ethanol) [41]. The findings indicate that there is a very small number of persons drinking alcohol on average once a week among patients with AF, with a variation in the rates in a range of 3–8%.

Smoking is one of the risk factors for death from AF and cardiovascular disease in general [40]. In Kazakhstan, the number of smokers is at a fairly high level [42]. In our study, a fairly low level of smokers was determined, both in the control group (12%) and in the intervention group (7%) ($p \leq 0.05$). In addition, the number of ex-smokers is also low and, on average in both groups, is 12% ($n = 72$) ($p \leq 0.05$). This finding could also be associated with an increase in the frequency of deaths from this disease [43]. Long manifestation of AF in patients, with a period of more than 5 years, could reduce the number of people who often drink alcohol, as well as the actual number of smokers in this cohort of patients.

According to a sample of patients from the control and intervention groups in our studies, more than 80% of cases of these patients with AF had concomitant cardiovascular diseases, which could certainly increase the frequency of deaths in patients with AF.

Patients with AF have an increased risk of stroke and, therefore, require preventive anticoagulant treatment, and according to some reports, the use of warfarin in this case can reduce the risk of thrombosis by 2/3 of cases [44]. The prophylactic use of anticoagulants can be challenging due to their narrow therapeutic range, as therapy must be closely monitored and maintained within a therapeutic INR of 2 to 3 [45]. In this regard, the need for periodic monitoring of INR and non-adherence to drug intake rules are well-documented obstacles to optimal INR control [46]. In the IG group, in comparison with patients from the CG group, an optimal INR level of 2–3 was recorded statistically significantly more often under control ($p = 0.001$); however, when the INR level was not monitored, there was no statistically significant difference between the groups in terms of the effect on the level of adherence. No association was also found between adherence in patients with AF and the type of medication used.

The study results showed that long-term use of the free, simple and easy-to-use mobile application "MyTherapy", in the Russian language, for 12 months had a positive effect on a sustained increase in patient adherence to therapy compared with the control group. This is consistent with a study conducted by Guo et al., where over 90% of AF patients using the mobile app for 95 days noted that the mobile AF App (mAF) mobile app was simple, user-friendly and accompanied by a significant improvement in knowledge over traditional care, and there was also an increase in adherence to treatment ($p < 0.05$) [17]. One of the factors that reduces adherence to therapy is forgetfulness [47], in particular in older people who are more likely to suffer from impaired cognitive functions [34]. There is evidence that in patients with AF, cognitive decline was found to be 16% higher, and the risk of dementia was 23% higher [48]. For this reason, the use of mobile applications with the function of reminding about and monitoring the medication process shows its optimality and applicability in increasing adherence to AF treatment for patients of different age groups [49]. Nonetheless, there are mobile applications with more complex functionality with additional devices for monitoring the condition of patients with AF, designed for both patients and medical personnel [50–52], but the lack of scientific validation of their applicability requires further research [53].

Patients with AF are often at a high risk of readmission to hospital within 6 months after discharge due to emerging cardiac and non-cardiac complications [54]. In this study, within 12 months after discharge, there was a relatively low rate of readmission to hospital in the IG group compared to the CG group ($p = 0.024$). This is consistent with a previous report on a decrease in hospital admissions in the group of patients using the mobile app [55]. This might be associated with improved adherence of patients with AF due to condition monitoring using a mobile application.

Limitations of the study

This study possesses several limitations. Despite the long period of monitoring patient adherence in this study, the single-centre nature of the study design could have influenced the occurrence of significant changes in some parameters of the sample (such as smoking, alcohol consumption), which requires further larger-scale studies. It should also be noted that patients with a direct indication for cryo-balloon and radiofrequency ablation were not included in the study, since these procedures are used in tertiary level hospitals.

Conclusions

Our findings indicate the effectiveness of using the MyTherapy mobile app to improve adherence in patients with AF. However, the positive effect of digital technologies requires further research to assess the clinical relevance and possibility of wider implementation in the healthcare system. In addition, the assessment of patients' adherence by using the LMAS-14 questionnaire demonstrated the possibility to optimise the assessment of the level of adherence in patients diagnosed with AF.

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Tables: 5
Figures: 2
References: 55

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