

Smart technology facilitating patient-centered venous thromboembolism management : pilot study on the adherence

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Smart technology facilitating patient-centered venous thromboembolism management : pilot study on the adherence

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Abstract

Background: Mobile health (mHealth) technologies show promise in addressing suboptimal anticoagulation adherence among venous thromboembolism (VTE) patients

Objective: To evaluate the impact of a mobile VTE application (mVTEA) on thromboprophylaxis adherence in VTE or moderate-to-high-risk patients.

Methods: This single-center pilot study enrolled 88 patients at the Chinese PLA General Hospital (August–December 2023). Participants used mVTEA for automated medication reminders and self-management. Adherence was assessed using the Morisky Medication Adherence Scale-8 (MMAS-8) and Beliefs about Medicines Questionnaire-Specific (BMQ-Specific). Real-time adherence data were analyzed at 1 month (Trial registration: ChiCTR2200063206).

Results: Among 45 completers (age 60.8±15.2 years; 35.6% female), baseline adherence was suboptimal (good: 28.9%; moderate/poor: 71.1%). Primary non-adherence drivers included forgetfulness (Q2: 0.69±0.47) and premature discontinuation (Q6: 0.78±0.42). BMQ-Specific revealed higher necessity than concern scores (17.58±3.12 vs. 14.58±3.34, p<0.001). At 1-month follow-up, 100% achieved perfect adherence, with 80% completing mVTEA check-ins. Patients utilizing check-in features demonstrated superior necessity-concern differentials (NCD>0: 80.6% vs. 0%, p<0.001). No adverse events occurred.

Conclusions: mVTEA significantly improved short-term anticoagulation adherence through behavioral nudges and real-time monitoring. Individualized patient education may further optimize outcomes. Clinical Trial: ChiCTR2200063206

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Conclusions: mVTEA significantly improved short-term anticoagulation adherence through behavioral nudges and real-time monitoring. Individualized patient education may further optimize outcomes.

Keywords: venous thromboembolism; medication adherence; smart technology; patient-centered

Introduction

Venous thromboembolism (VTE) affects 75-140 per million annually, with 11% acute pulmonary embolism mortality within 30 days [1-3]. Despite direct oral anticoagulants (DOACs) revolutionizing treatment, adherence remains suboptimal (30-60% discontinuation by 6 months) [4,5]. Non-adherence correlates with 4.1-fold increased recurrence risk [6].

mHealth interventions demonstrate efficacy in chronic disease management through medication reminders, biometric tracking, and patient-provider connectivity [7]. However, existing VTE-focused apps lack comprehensive features addressing dynamic risk monitoring and longitudinal adherence support [8]. Building on the success of atrial fibrillation apps (e.g., mAFA) [9], we developed the mobile venous thromboembolism management app *mVTEA* integrating: Automated anticoagulation reminders, Dynamic thrombosis/bleeding risk assessment, Telemonitoring of coagulation parameters, Patient-provider communication portals. This pilot study evaluates *mVTEA*'s feasibility and preliminary efficacy in enhancing anticoagulation adherence.

Methods

Study Design and Participants

We conducted a pilot study to explore changes of medication adherence in VTE patients under the intervention of *mVTEA*. Participants were enrolled between August 25, 2023, and December 20, 2023 in the Sixth Medical Center of the Chinese People's Liberation Army General Hospital. Inclusion criteria were (1) over 18 years of age; (2) diagnosed with VTE or at moderate to high risk of VTE; (3) taking anticoagulant medication; (4) cognitively normal, without mental disorders; (5) proficient in the use of a smartphone; and (6) signing an informed consent form. Exclusion criteria included (1) mental impairment or comorbidity with other serious diseases without the ability to live autonomously, and (2) no smartphone.

The primary endpoint of the study was the adherence rate to the prescribed anticoagulant regimen (determined as the proportion of individuals who adhered fully to their prescribed anticoagulant regimen throughout the anticoagulant therapy cycle) at 1-month follow-up. The secondary endpoints included the interactive anticoagulant therapy reminder check-in rate via *mVTEA* (calculated as the ratio of the number of completed check-ins for prescribed anticoagulant doses to the total number of prescribed doses), VTE events, International Society on Thrombosis and Hemostasis (ISTH) defined major bleeding events, VTE-related hospitalizations, VTE-related rehospitalizations, all-cause deaths. Hospitalization due to the new-onset VTE will be documented as VTE-related hospitalizations, while rehospitalization due to VTE recurrence, progression, or complications arising from VTE treatment will be classified as VTE-related rehospitalizations. All-cause death refers to any death occurring during the study period, regardless of the cause.

Patients enrolled in the study were registered with *mVTEA* via smartphone. The registration process collected essential demographic and clinical information, including name, gender, age, height, weight, hospitalization department, use of anticoagulants and contact details. During the inpatient period, departmental healthcare staff provided VTE health education as part of the institution's standard protocol for VTE prevention and management. A tailored VTE prevention and treatment plan was formulated by the patient's supervising physician. Prior to discharge, patients were asked to complete the 8-item Morrissey Medication Adherence Scale (MMAS-8) and the Beliefs about Medication Questionnaire Specific (BMQ-Specific). Upon discharge, the *mVTEA* system commenced sending reminders for anticoagulant medication administration according to the prescribed regimen. Patients were instructed to log their medication adherence using *mVTEA* on the day of administration or on subsequent days for additional entries. The system also provided weekly feedback on adherence data. A follow-up assessment was conducted on the 30th day post-discharge,

either via telephone or in a clinical setting. The study flow chart is shown in Figure 1. This study protocol is registered with the China Clinical Trial Registry (ChiCTR2200063206).

Ethical Considerations

The Independent Ethics Committee of the sixth medical center of Chinese People liberation Army General Hospital approved the study (approval HZKY-PJ-2022-21). This study was registered on www.chictr.org.cn, no. ChiCTR2200063206.

Data collection

Patient demographic and clinical information will be extracted from the hospital information system. Data related to MMAS-8 and BMQ-Specific will be collected at the point of discharge. Information regarding anticoagulant adherence, logged via the digital punch card system in mVTEA, will be gathered during the follow-up visit on the 30th day after discharge. Additionally, an electronic questionnaire will be administered to obtain details regarding the patient's compliance with prescribed anticoagulant therapy. All patients will undergo follow-ups at 1-month post-discharge via outpatient clinic visits, telephone calls, or mVTEA-based online interviews.

The Chinese version of MMAS-8

Medication adherence was tested using the Chinese version of the validated eight-item self-report Morisky Medication Adherence Scale (MMAS-8) (Appendix 1). Response choices are “yes” or “no” for items 1 to 7 and Item 8 has a five-point Likert response scale. Each “no” response is rated as 1 and each “yes” response is rated as 0 except for item 5, in which each “yes” response is rated as 1 and each “no” response is rated as 0. For Item 8, the code (0-4) has to be standardized by dividing the result by 4 to calculate a summated score. Total scores on the MMAS-8 range from 0 to 8, with scores of 8 reflecting high adherence, 7 or 6 reflecting medium adherence, and <6 reflecting low adherence[10].

The simplified Chinese version of BMQ-Specific

The simplified Chinese version of BMQ-Specific was employed to evaluate individuals' perceptions of taking prescribed anticoagulants (Appendix 1). It consists of 10 items, 5 items on medication necessity, and 5 items on medication concern. A 5-point Likert scale was used for each item, ranging from 1 (strongly disagree) to 5 (strongly agree). The overall score ranges from 5 to 25, with higher values indicating stronger beliefs about necessity and concerns. Based on median scores, patients were categorized into High-BMQ and Low-BMQ. Additionally, a necessity-concerns differential (NCD) is derived by subtracting the concerns score from the necessity score, producing a range of -20 to 20. This metric serves as an indicator of the balance between perceived benefits and concerns, representing an individualized cost-benefit assessment of medication use[11].

mVTEA-Facilitated Patient-Centered VTE Management

When designing the mVTEA, we took into account the fact that the long-term management of VTE is multifaceted, requiring individualized patient assessment and a nuanced approach to therapy. Therefore, we have proposed the ABCDEF pathway for integrated management of VTE to complement mVTEA-assisted patient-centered management, thus minimizing the risk of VTE and its complications and ensuring patient safety and quality of life: (A) Appropriate antithrombotic management; (B) Bleeding risk management; (C) Complication monitoring; (D) Digital health management; (E) Exercise and rehabilitation; (F) Facilitate the management of risk factors and comorbidities.

The mVTEA is designed as a patient-side and physician-side interface. The core functions of the patient interface are four modules: thrombosis risk assessment; bleeding risk assessment; anticoagulation management; and home rehabilitation report (Figure 1).

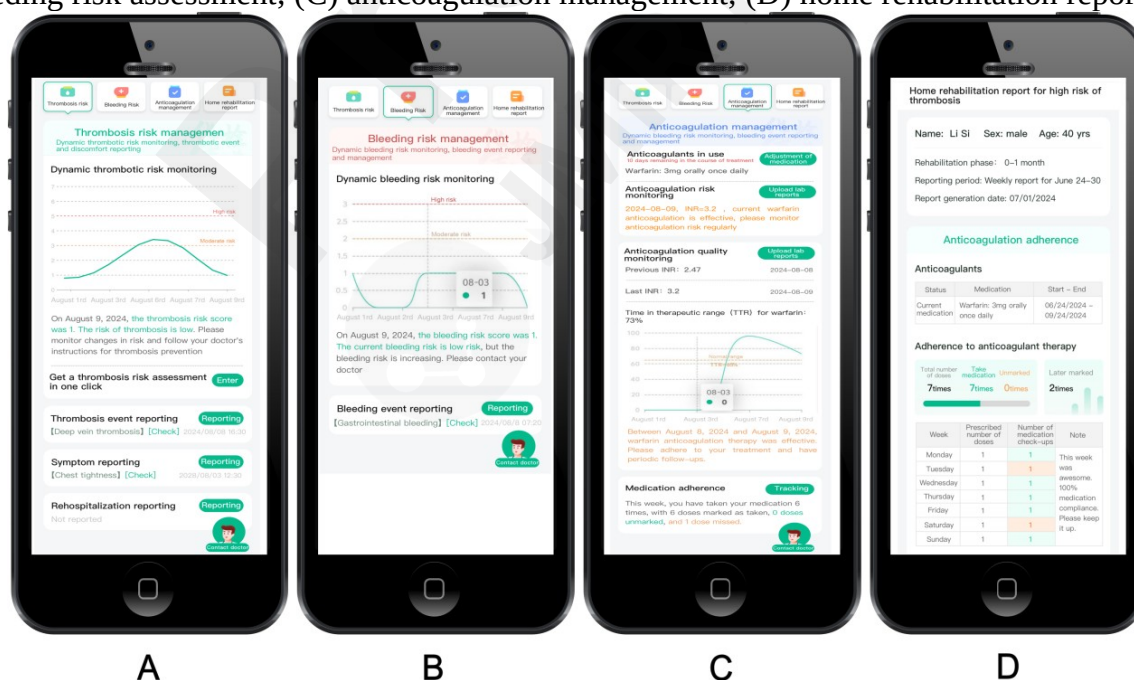
The Thrombosis and Bleeding Risk module provides dynamic monitoring of a patient's risk for thrombosis and bleeding. Automated risk assessments are initiated when patients report symptoms, adverse events, or upload relevant test results. Additionally, patients may complete a thrombosis risk self-assessment form. Based on the individualized risk profile, the mVTEA patient interface generates personalized recommendations for VTE prevention and treatment. These risk assessment outcomes are also transmitted to the mVTEA physician interface for further evaluation and feedback from thrombosis specialists.

The Anticoagulation Management module is structured into four key components: anticoagulants in use, anticoagulation risk monitoring, anticoagulation quality monitoring, and medication adherence. For anticoagulation risk and quality monitoring, patients can upload test results related to coagulation, liver, or kidney function. These results are synchronized with the physician interface, where thrombosis specialists perform additional evaluations and interventions as needed. The medication adherence feature allows patients to log anticoagulant administration through a digital "punch card" system, which tracks and displays their adherence history.

The Home Rehabilitation Report module outlines the patient's home-based rehabilitation plan, including the duration of anticoagulant therapy, historical anticoagulant usage, detailed adherence records, and VTE prevention and management recommendations. This report is automatically generated on a weekly and monthly basis for continuous monitoring and support.

Additionally, the mVTEA app offers daily medication reminders. At the end of each week, the app will provide feedback on the number of days the anticoagulant is taken as prescribed. The app also issues alerts when there are changes in thrombosis or bleeding risk assessments and monitors anticoagulation quality, such as the international normalized ratio for patients on warfarin. Patients can access their electronic health records at any time. When necessary, thrombosis specialists can deliver patient health education, including motivational interviewing, or conduct online consultations via the mVTEA doctor-patient communication module, which supports text, photo, and voice interactions. Outpatient appointments can also be arranged as needed through mVTEA.

Figure 1. The core functional interface of the mVTEA app: (A) thrombosis risk assessment; (B) bleeding risk assessment; (C) anticoagulation management; (D) home rehabilitation report.



Statistical Analysis

Continuous variables will be presented as mean and standard deviation, or as median and interquartile range for variables not following a normal distribution. Categorical variables will be

presented as counts and percentages. Continuous variables will be assessed using the Student's t-test or Mann-Whitney U test, depending on distributional assumptions. Categorical variables will be analyzed using the chi-square test or Fisher's exact test, as applicable. Statistical analysis was performed using SPSS, version 20.0 (IBM Corp).

Result

Participant Characteristics

A total of 45 patients were included from August 25 to December 20, 2023. The flow chart is shown in Figure 2. The mean patient age was 60.8 ± 15.2 years and 35.6% (16/45) of the patients were females. VTE was diagnosed in 86.7% (39/45) of these patients. Of the remaining 6 patients, 2 (4.4%) were at medium risk for VTE and 4 (8.9%) were at high risk for VTE. The detailed patient characteristics are illustrated in Table 1.

Figure 2. Flowchart of the patient analysis in this study.

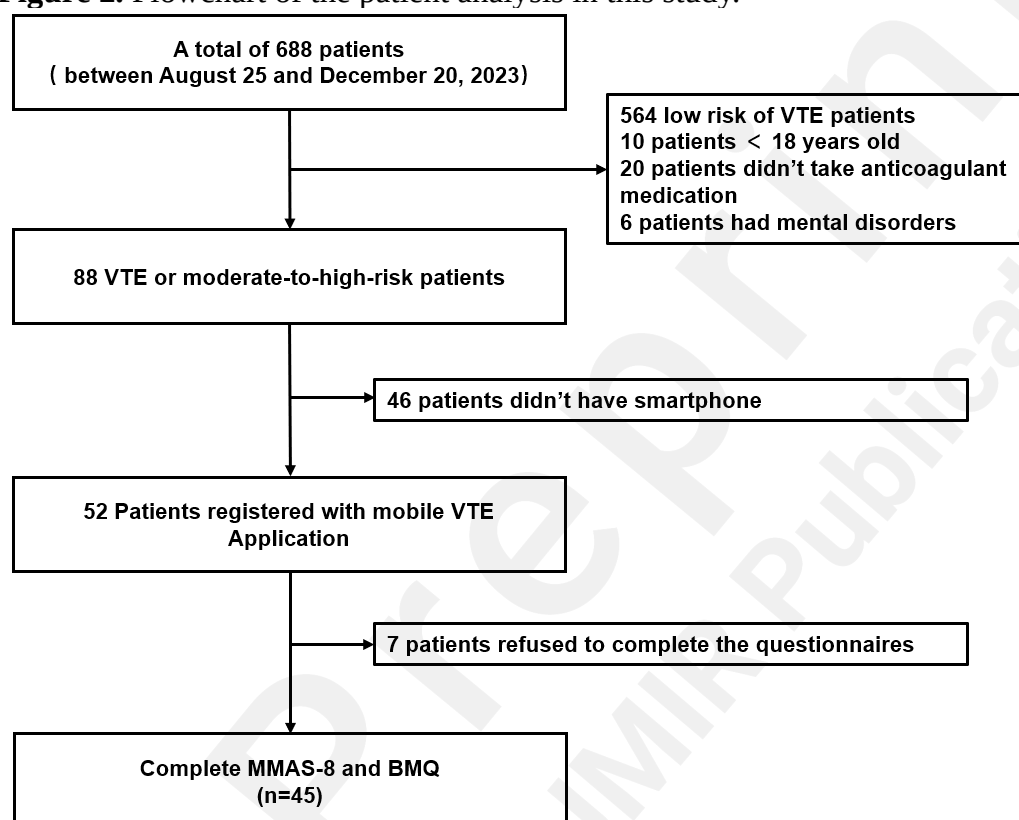


Table1. Characteristics of the patients in this study.

Item	Patients (n=45)
Age (years) Mean±SD	60.8±15.2
Female (n%)	16 (35.6)
Risk of VTE (n%)	
Medium	2 (4.4)
High	4 (8.9)
VTE patients (n%)	
DVT	18 (40.0)
PE	11 (24.4)
DVT and PE	10 (22.2)
Comorbidities (n%)	
Hypertension	19 (42.3)
History of Cancer	2 (4.4)
Diabetes	6 (13.3)
Previous stroke	2 (4.4)

Atrial fibrillation	3(6.7)
Valvular Heart Disease	1(2.2)
Others	12(26.7)

VTE: Venous thrombosis; **DVT:** Deep venous thrombosis; **PE:** pulmonary embolism

Medication adherence at baseline

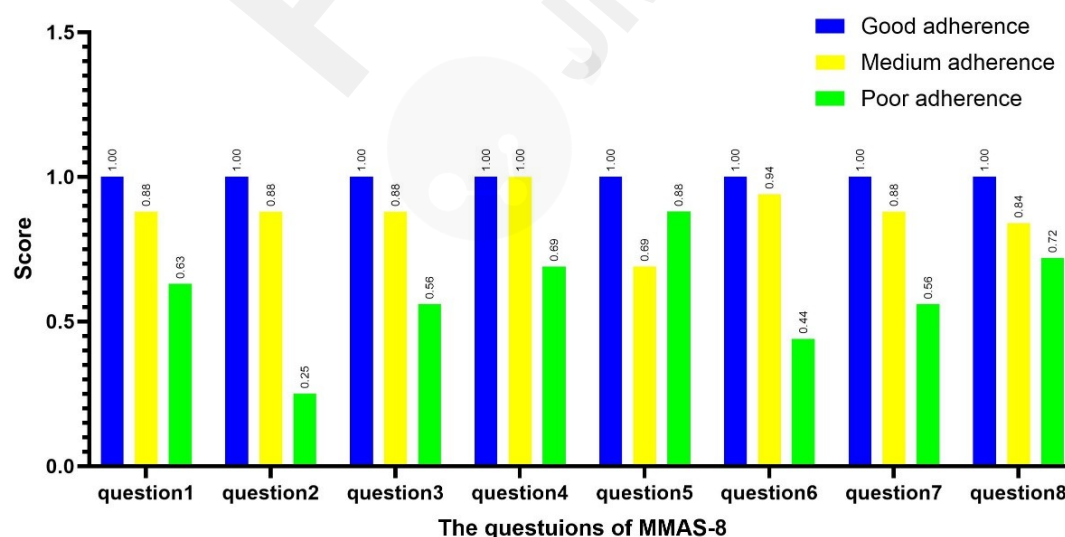
Table 2 shows the MMAS-8 scores for each question. Among the 45 patients who completed the MMAS-8 baseline survey, the mean MMAS-8 score was 6.28 ± 1.81 , with the lowest scores for Question 1 (0.62 ± 0.49) and Question 2 (0.69 ± 0.47). The proportions of those with good, moderate, and poor medication adherence were 28.9% (13/45), 35.5% (16/45), and 35.5% (16/45), respectively ($P = 0.741$). In patients with poor medication adherence, the main reasons for poor adherence were “Forget to take their medications for reasons other than forgetting” (Question 2) and “Sometimes stop taking your medication” (Question 6) (Figure 3).

Table 2. The MMAS-8 scores for each question.

MMAS-8 item	Scores, mean $\pm$ SD
Q1. Do you sometimes forget to take your medication?	0.62 $\pm$ 0.49
Q2. People sometimes forget to take their medications for reasons other than forgetting. Thinking over the past two weeks, were there any days when you did not take your medication?	0.69 $\pm$ 0.47
Q3. Have you ever cut back or stopped taking your medication without telling your doctor, because you felt worse when you took it?	0.80 $\pm$ 0.40
Q4. When you travel or leave home, do you sometimes forget to bring your medication?	0.89 $\pm$ 0.32
Q5. Did you take your medication the last time you were supposed to take it?	0.84 $\pm$ 0.37
Q6. When you feel like your symptoms are under control, do you sometimes stop taking your medication?	0.78 $\pm$ 0.42
Q7. Taking medication every day is a real inconvenience for some people. Do you ever feel hassled about sticking to your treatment plan?	0.80 $\pm$ 0.40
Q8. How often do you have difficulty remembering to take all your medications?	0.84 $\pm$ 0.22
Total scores	6.28$\pm$1.81

MMAS-8: 8-item Morisky Medication Adherence Scale

Figure 3. MMAS-8 scores of each question at different levels of medication adherence.



Brief about taking anticoagulants at baseline

Table 3 shows the BMQ-Specific scores for each question. Among the 45 patients who

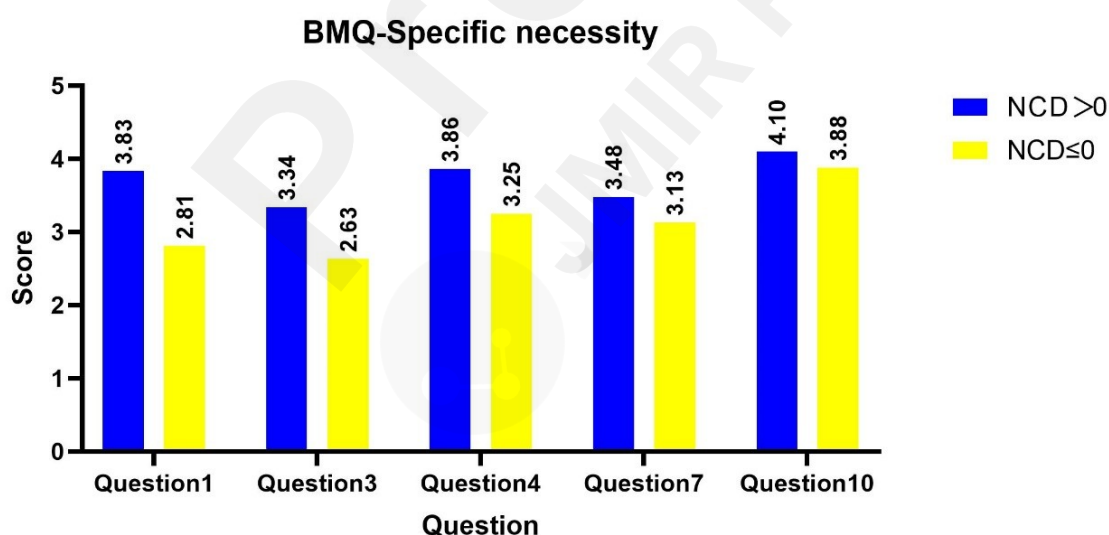
completed the BMQ-Specific baseline survey, the necessity score for taking anticoagulants was greater than the concern score (17.58 ± 3.12 vs. 14.58 ± 3.34 , $P < 0.001$). The main cause of insufficient belief in the necessity of taking anticoagulants was “Without my anticoagulants, I would be very ill” (Question 3). The main reason that cause concern was “I sometimes worry about the long-term effects of my anticoagulants” (Question 5). Among patients with Low-BMQ ($NCD \leq 0$), the main reasons for insufficient belief in the necessity of taking anticoagulants were “Currently, my health depends on anticoagulants” (Question 1) and “Without my anticoagulants, I would be very ill” (Question 3); all the concern-related questions scored high (score range: 3.00-3.69) (Figure 4).

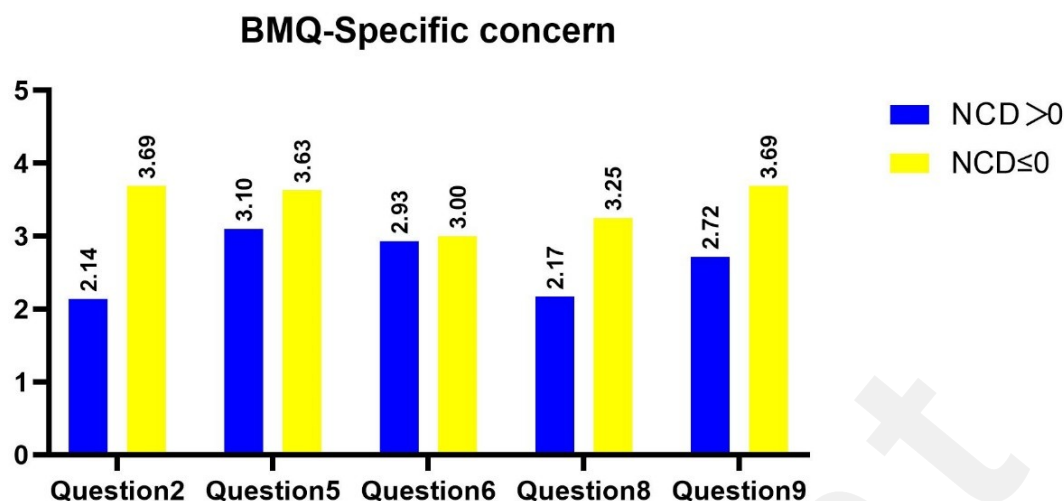
Table 3. The BMQ-Specific scores for each question

Characteristics classification	Scores, mean $\pm$ SD
BMQ-Specific necessity	17.58 $\pm$ 3.12
Q1. Currently, my health depends on anticoagulants.	3.47 $\pm$ 0.97
Q3. Without my anticoagulants, I would be very ill.	3.09 $\pm$ 0.90
Q4. My life would be impossible without my anticoagulants.	3.64 $\pm$ 0.77
Q7. My health in the future will depend on my anticoagulants.	3.36 $\pm$ 0.91
Q10. My anticoagulants prevent my condition from worsening.	4.02 $\pm$ 0.62
BMQ-Specific concern	14.56 $\pm$ 3.34
Q2. Having to take my anticoagulants worries me.	2.69 $\pm$ 1.22
Q5. I sometimes worry about the long-term effects of my anticoagulants.	3.29 $\pm$ 0.87
Q6. My anticoagulants are a mystery to me.	2.96 $\pm$ 0.83
Q8. My anticoagulants disrupt my life.	2.56 $\pm$ 0.89
Q9. I sometimes worry about being too dependent on my anticoagulants.	3.07 $\pm$ 1.03
BMQ-Specific NCD	3.02 $\pm$ 5.04

BMQ: Beliefs about Medicines Questionnaire; NCD: necessity-concerns differential.

Figure 4. BMQ-Specific scores for each question between the High-BMQ ($NCD > 0$) and Low-BMQ ($NCD \leq 0$). A: BMQ-Specific necessity; B: BMQ-Specific concern





The impact of mVTEA on anticoagulation adherence and adverse events

The results show that 100% adherence to the prescribed anticoagulants for all patients at the 1-month follow-up. And the check-in rate for interactive anticoagulant therapy reminders through mVTEA was 80% (36/45). Table 4 shows those participating in check-ins during 1-month follow-up (n=36) had significantly better medication adherence and beliefs about taking anticoagulants. All patients in the no-check-in group (n=9) had a negative NCD, compared to only 19.4% (7/36) patient in the check-in group. No adverse events occurred at 1-month follow-up.

Table 4. Comparison of medication adherence and beliefs between patients participating and not participating in check-ins during follow-up.

	Patients (n=45)		P value
	Check-in N=36(80)	No check-in N=9(20)	
MMAS-8, n (%)			
Good	13(36.1)	0(0)	0.092
Moderate	11(30.6)	5(55.6)	
Poor	12(33.3)	4(44.4)	
BMQ-Specific, n (%)			<0.001
NCD≥0	29(80.6)	0(0)	
NCD<0	7(19.4)	9(100)	

MMAS-8: 8-item Morisky Medication Adherence Scale; BMQ: Beliefs about Medicines Questionnaire; NCD: necessity-concerns differential.

Discussion

This pilot study demonstrates the feasibility and short-term effectiveness of a mobile venous thromboembolism management application (mVTEA) in enhancing adherence to anticoagulant therapy. Consistent with prior evidence suggesting 37% to 51% gains in adherence through digital health interventions [12], the present findings highlight the utility of a multifaceted mobile platform in addressing well-documented barriers to long-term anticoagulation adherence[13].

Three primary mechanisms likely contributed to the observed improvements.

1. Behavioral Nudging through Automated Reminders

The most immediate contributor was likely the app's reminder system, which functioned as a behavioral nudge to reduce forgetfulness—a leading cause of non-adherence reported both in this study and in the broader cardiovascular literature. Automated prompts may have increased patients' attentiveness to medication schedules and disrupted patterns of unintentional omission. This aligns with findings from Bae et al., who reported enhanced adherence and self-care behaviors in patients with coronary heart disease following a one-way text messaging intervention [14]. Similarly, Luong et al. demonstrated that reminder messages significantly improved medication refill rates [15]. These findings suggest that timely digital prompts can be an effective tool to modify adherence-related behaviors in chronic disease management.

2. Enhanced Connectivity and Real-Time Clinical Feedback

A second mechanism involved the facilitation of real-time communication and clinical monitoring via the mVTEA platform. Given the extended and sometimes indefinite duration of anticoagulation therapy in patients with VTE [16], ensuring sustained engagement with healthcare providers is critical. The app's capacity to enable remote monitoring of coagulation parameters and symptom reporting allowed for early identification of clinical changes and timely provider intervention. This is consistent with previous studies indicating superior therapeutic control—such as improved time in therapeutic range (TTR)—and reduced adverse events among patients using app-based warfarin management systems compared to conventional care [17]. Moreover, the role of telehealth was particularly emphasized during COVID-19 lockdowns, when mobile platforms facilitated continuity of anticoagulation monitoring despite limited in-person visits [18].

3. Risk Visualization and Patient Engagement

The third contributing factor may have been the app's ability to deliver personalized risk feedback through dynamic thrombosis and bleeding risk assessments [19]. By visualizing individual risk trajectories, patients may have developed a heightened awareness of the consequences of non-adherence, thereby increasing their perceived necessity for continued treatment. This mechanism aligns with behavioral models suggesting that the perceived relevance and urgency of therapy—rather than abstract knowledge alone—influence long-term adherence [20]. Patients with positive necessity-concern differentials (NCD) were significantly more likely to engage in app-based check-ins, further supporting this interpretation.

Notably, patients who engaged with the mVTEA check-in system were more likely to report higher medication adherence and stronger necessity beliefs. In contrast, all non-check-in users demonstrated negative NCD scores, suggesting persistent attitudinal or motivational barriers despite access to digital support. These findings are consistent with the Technology Acceptance Model, which posits that perceived system usability and usefulness jointly influence user engagement [21]. They also underscore the need for complementary human-delivered interventions, such as motivational interviewing, to address underlying belief-related obstacles to adherence.

The implications of these findings extend beyond VTE management. A growing body of evidence supports the role of smart technologies in improving adherence for other chronic conditions, including hypertension and diabetes, where mobile interventions have been shown to enhance self-care and treatment persistence [22,23]. Moreover, initiatives in Europe to develop online compliance repositories reflect an evolving healthcare paradigm in which digital tools serve as foundational elements in long-term, patient-centered care [24].

Importantly, this study reinforces the relevance of patient-centered care frameworks. Unlike traditional models that emphasize physician-directed decision-making, patient-centered approaches involve continuous education, bidirectional communication, and alignment of treatment with individual values and preferences [6,25,26,27]. Mobile platforms such as mVTEA may serve as enabling technologies for this paradigm, empowering patients to take an active role in managing their health while providing clinicians with actionable data to guide shared decision-making.

Future research should prioritize randomized controlled trials comparing mVTEA-assisted management with standard care to determine long-term effectiveness and clinical outcomes. Integration with wearable devices and artificial intelligence-based risk prediction models may further enhance the app's capacity to support personalized, anticipatory care.

Limitations

The present study has several limitations. First, the sample size used in the evaluation of the mVTEA app was limited, which may restrict the generalizability of the findings. A larger, more diverse patient population is necessary to assess the app's effectiveness across various demographic groups. Second, the study did not assess the long-term sustainability of using the app. While short-term engagement and adherence were monitored, further research is needed to evaluate whether the app maintains its effectiveness over extended periods of use. This is particularly important for chronic conditions like VTE, where long-term medication adherence is crucial for preventing recurrent thromboembolic events. Finally, Another limitation is the reliance on self-reported data for medication adherence. While the digital punch card system provides a useful tool for tracking adherence, it is susceptible to inaccuracies or intentional omissions by patients. Objective measures, such as biomarkers, could complement the app's tracking system to provide more reliable adherence data.

Conclusion

mVTEA shows promise in bridging the adherence gap through patient-centered digital interventions. Sustained benefits require addressing underlying belief barriers via blended mHealth-human support models.

Acknowledgments

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Conflicts of Interest

The authors declare no conflict of interest.

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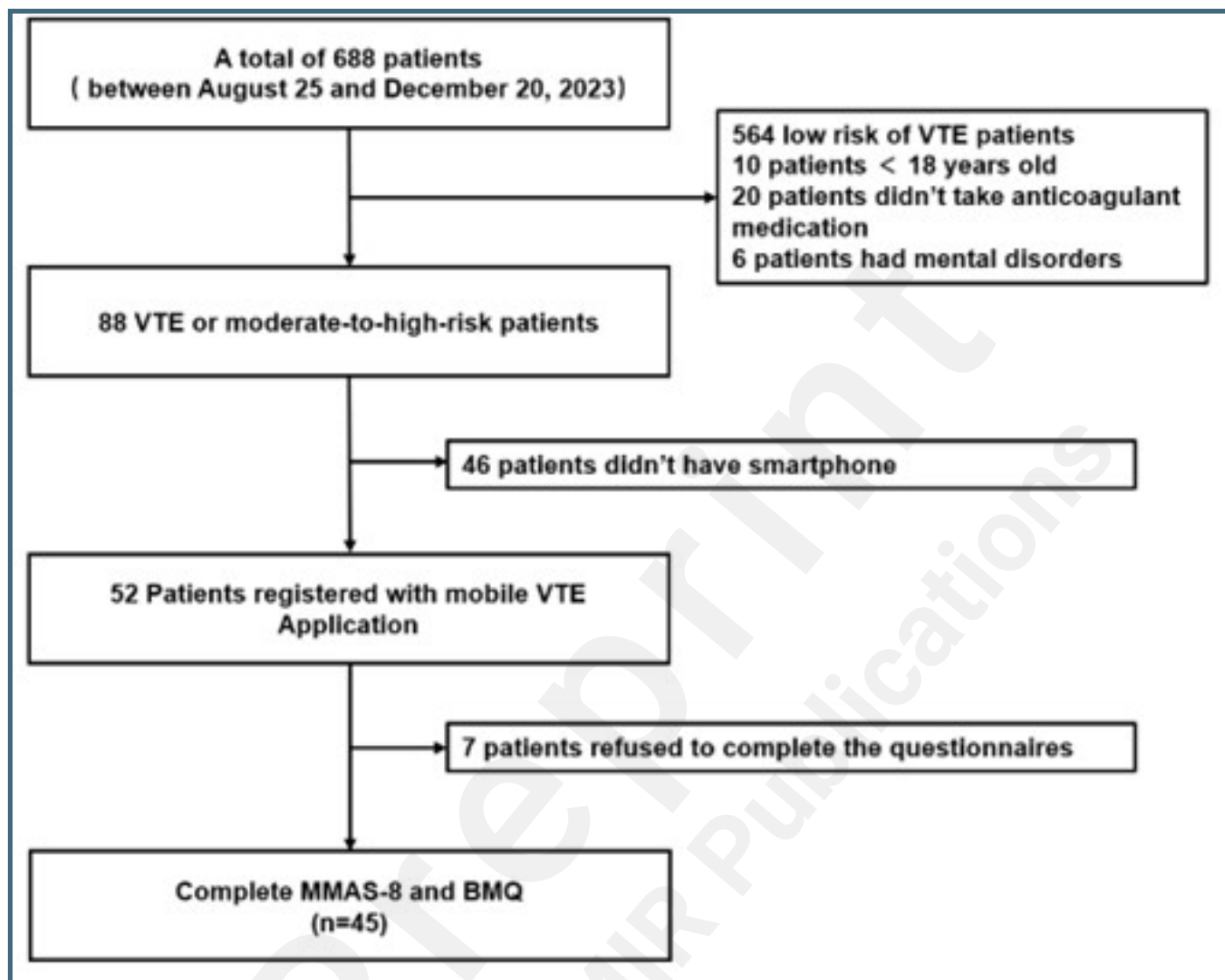
Supplementary Files

Figures

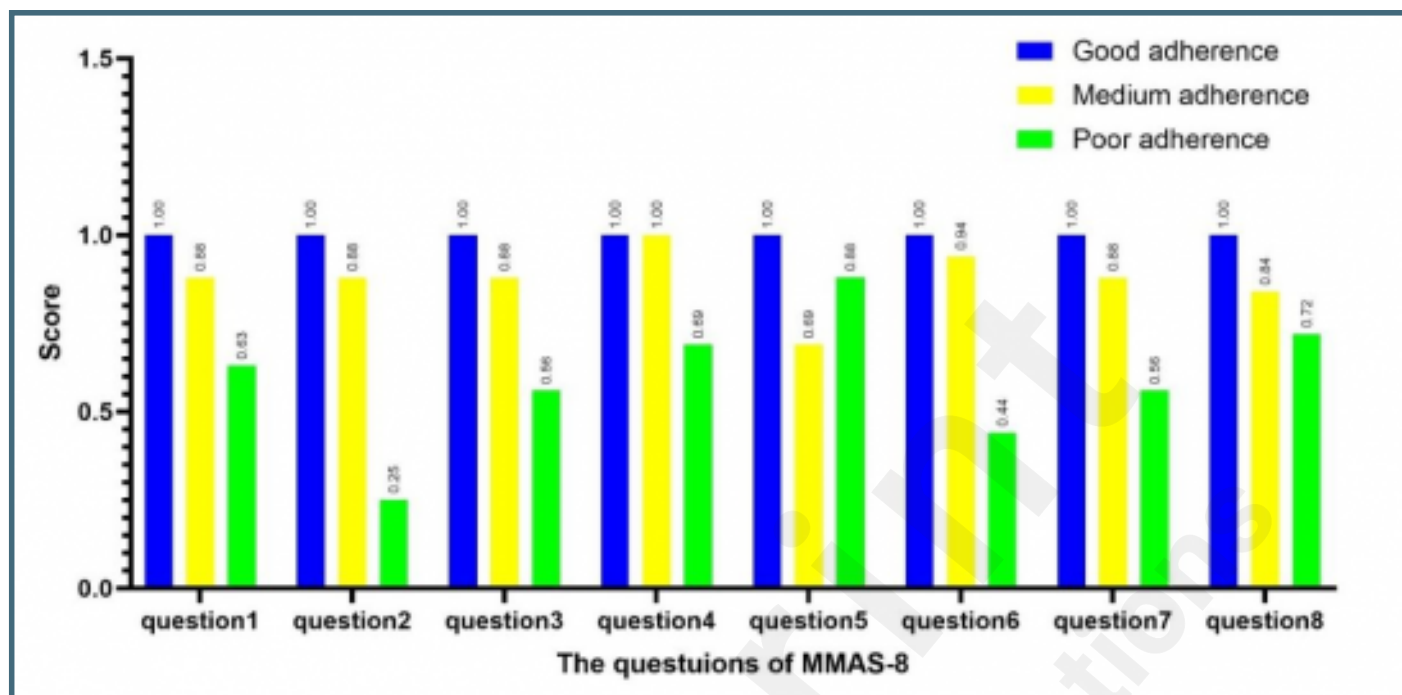
The core functional interface of the mVTEA app: (A) thrombosis risk assessment; (B) bleeding risk assessment; (C) anticoagulation management; (D) home rehabilitation report.



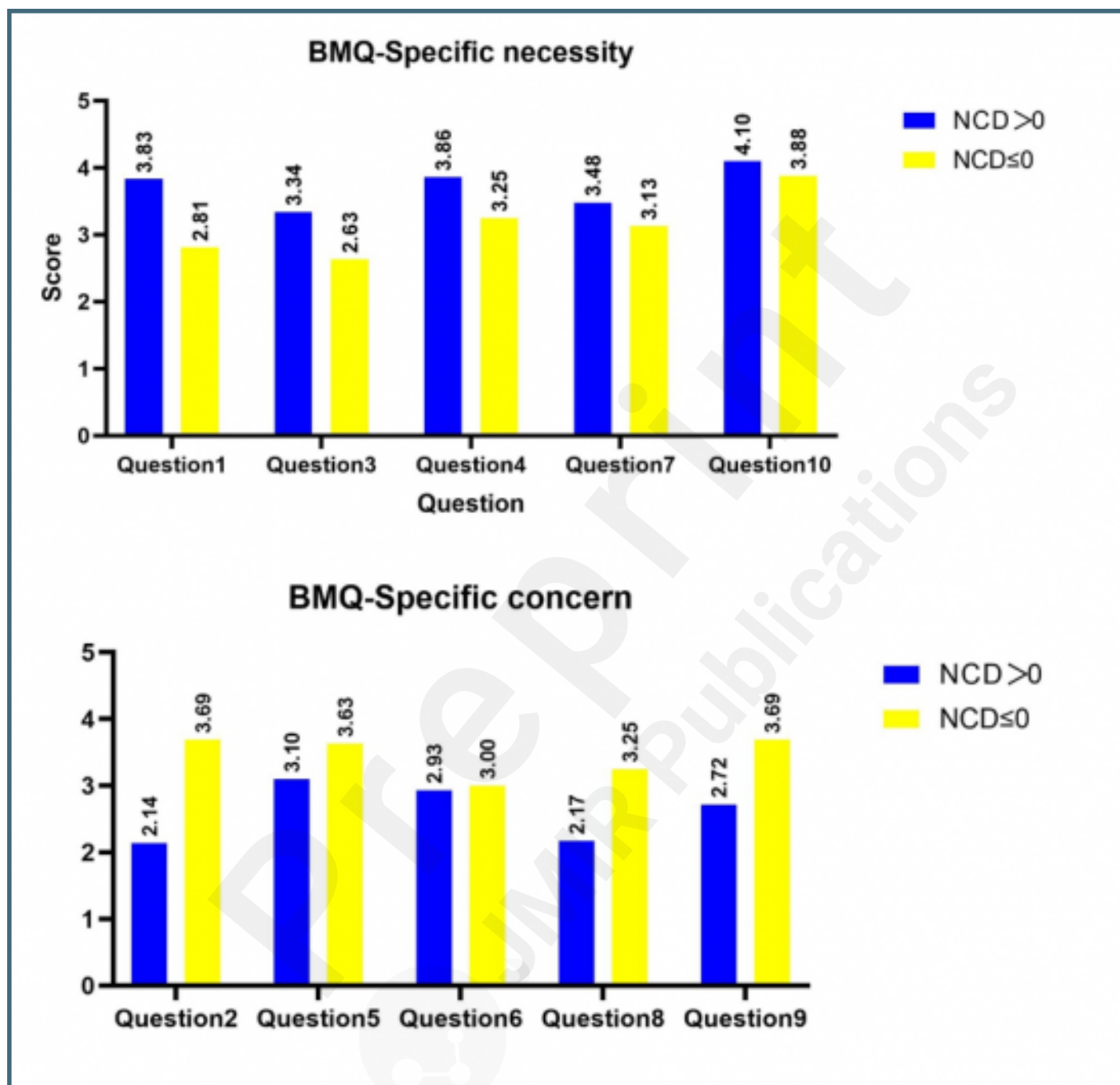
Flowchart of the patient analysis in this study.



MMAS-8 scores of each question at different levels of medication adherence.



BMQ-Specific scores for each question between the High-BMQ (NCD>0) and Low-BMQ (NCD≤0).A: BMQ-Specific necessity; B:BMQ-Specific concern.



Multimedia Appendixes

Characteristics of the patients, The MMAS-8 scores for each question, The BMQ-Specific scores for each question and Comparison of medication adherence, and beliefs between patients participating and not participating in check-ins during follow-up.

URL: <http://asset.jmir.pub/assets/e0c668e22a1f8396b9b3b7a4bdd2e985.docx>

Check-list.

URL: <http://asset.jmir.pub/assets/0f5933ee874ecc88233745b00ff9265d.docx>

MMAS-8 license agreement.

URL: <http://asset.jmir.pub/assets/1e1a1970179dc2c58de89130cc208766.pdf>

Cover letter.

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