Original article

Development of the DoseProof system for medication monitoring with video confirmation and family support

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Volume 1 · Issue 1 · 2026 | Received: July 2026 | Published: 29 September 2026

Abstract

Introduction. Suboptimal adherence to long-term pharmacotherapy remains a significant problem, highlighting the need to develop digital tools that support adherence to medication regimens and enable the timely identification of unconfirmed medication-taking events.

Aim. To develop and describe the architecture of DoseProof, a medication monitoring system that integrates medication schedules, video confirmation of medication-taking events, and the involvement of a trusted person.

Materials and methods. The study followed an applied software system design approach. The methods included a targeted analysis of scientific publications, user scenario modelling, functional requirements decomposition, and client-server architecture design. A scheduled medication-taking event linked to the patient, medication, time, and digital confirmation was defined as the unit of recording. The mobile component was developed for Android using Kotlin and Jetpack Compose; the server-side component was implemented using NestJS and MySQL.

Results. An architectural and functional model of the DoseProof prototype was developed, comprising modules for therapy management, notifications, short video storage, identification of unconfirmed events, and interaction with a trusted person. The PENDING, TAKEN, and MISSED event states were formalized, and their transition conditions and measures of digital confirmation completeness were defined. A family monitoring mechanism was proposed whereby the absence of confirmation within a specified time window triggers a notification to the trusted person. The recording of digital confirmation was distinguished from actual medication intake.

Conclusion. The DoseProof prototype establishes a unified event-based framework linking therapy schedules, media data, event status, and the mechanism for notifying a trusted person. The system can provide a basis for subsequent evaluation of usability, event-recording reliability, and its impact on medication adherence. The clinical effectiveness of the system and the accuracy of automated biometric verification were not assessed in this study.

Keywords: medication adherence, drug therapy, mobile applications, medication therapy management, DoseProof, video recording, social support.

To cite this article: Shvets S.V., Ibragimov R.Z. Development of the DoseProof system for medication monitoring with video confirmation and family support. Pharmaceutical Sciences and Health Products. 2026;1(1):e0002.

Introduction

Adherence to prescribed medication is one of the factors determining whether the intended therapeutic outcome can be achieved. A 2003 World Health Organization report noted that adherence to long-term treatment for chronic diseases averaged approximately 50% in developed countries [1]. This historical estimate illustrates the scale of the problem but is not a universal contemporary estimate for all diseases and populations. Nonadherence includes missed doses, deviations from the prescribed regimen and premature treatment discontinuation. Self-report, pill counts, electronic monitoring and direct observation are used to detect these events, each with specific limitations [2].

The determinants of nonadherence are heterogeneous. Gast and Mathes identified possible associations of adherence with socioeconomic status and social support; evidence for many other factors was inconsistent or insufficiently certain [3]. A digital tool must therefore account for the specific reasons for a patient's difficulties rather than assume that every missed dose results from forgetfulness.

Mobile applications are considered one means of supporting regular medication use. The meta-analysis by Armitage et al. found an advantage of app-based interventions in adherence outcomes [4]. The 2025 review by Lanke et al. included 14 randomized trials, 10 of which reported statistically significant improvements in adherence. However, effect size depended on the measurement method and study characteristics [5]. In the systematic review by Shrivastava et al. involving patients with type 2 diabetes, statistically significant improvements were observed in only three of seven studies; heterogeneous designs and limitations in objective outcome assessment made it difficult to identify the most effective app features [6].

Reviews of app functionality describe reminders, medication logs, user-data recording and information-sharing tools [7, 8]. Involving close contacts is a distinct form of support: Shahin et al. found a positive association between social support and medication adherence in several studies of patients with hypertension [9]. These findings justify investigating the involvement of a trusted person but do not establish the effectiveness of any specific family-notification algorithm.

Remote observation of medication intake is also of interest. In the randomized trial by Burzynski et al., electronic observation during tuberculosis treatment met the noninferiority criterion for the proportion of observed doses compared with in-person observation [10]. Positive changes in digital measures do not necessarily improve clinical outcomes: in MedISAFE-BP, an app produced a small improvement in self-reported adherence without an additional significant reduction in blood pressure [11]. In the cluster-randomized trial by Liu et al., a digital medication monitor did not reduce unfavourable tuberculosis treatment outcomes [12]. Four pragmatic cluster-randomized trials by Jerene et al. likewise found no reduction in the risk of an unfavourable treatment outcome with digital adherence technologies [13]. These findings underscore the need to assess the clinical benefit of each intervention separately.

Developing a digital intervention also requires assessment of acceptability, potential harms, feasibility, resource constraints and equity of access, as specified in the WHO approach [14]. Backes et al. showed that insufficient transparency in data processing and storage may substantially limit the quality of medication-support apps [15]. The meta-analysis by Peng et al. confirms the potential of mobile interventions while highlighting the need for cautious interpretation of the evidence [16].

The WHO Global Strategy on Digital Health 2020-2025 calls for coordinated development of financial, organizational, human and technological resources [17]. DoseProof implementation therefore requires planning for user support as well as software functionality. Tangari et al. identified substantial privacy problems and discrepancies between stated and actual data-handling practices in mobile apps [18]. Rezaee et al. proposed criteria for assessing app security and privacy that can inform subsequent technical evaluation of DoseProof [19].

There is therefore a need for a system in which the schedule, digital confirmation and trusted-person involvement are linked to a single identifiable medication-taking event. Approaches that combine these components in one event model and automate the response to missing confirmation remain insufficiently studied. This approach is implemented in the project “Family digital monitoring and biometric verification of pharmaceutical product intake”, named DoseProof. The present work addresses the development of a prototype with video confirmation; automated biometric verification is part of the project's future development.

The aim was to develop and describe the architecture and event model of DoseProof for medication monitoring with video confirmation and family support.

Materials and methods

Study design and materials

This was an applied study of digital-system design. The object was the recording of adherence to medication prescriptions at home; the subject was software methods for linking schedules, user confirmation, media data and trusted-person notifications. Materials comprised functional and technical descriptions of DoseProof. A targeted descriptive analysis of publications on medication adherence, mobile interventions, social support and remote observation informed the design decisions. Published findings were not statistically re-pooled.

Design included defining user roles and use cases, identifying domain entities, distributing functions between the mobile client and server, and formalizing event-state transitions. Results are presented as an architectural and functional prototype model. Evaluation of effectiveness in patients, clinical sample-size calculation and statistical hypothesis testing were outside the scope of this stage.

There were no study participants at this stage; the system was not clinically tested in patients. Participant inclusion and exclusion criteria therefore did not apply.

User roles and functional requirements

Two main roles were defined: patient and trusted person. The patient maintains the medication list, enters the prescribed regimen, receives reminders and records confirmation. A trusted person joins by patient invitation and accesses information authorized by the patient. Core requirements include authentication, medication and schedule management, event creation, short video recording, processing of missing confirmations and summary measures. The app records the entered schedule; clinical prescribing and treatment changes are outside the software algorithm described here.

The unit of recording was an event linked to a particular patient, medication and scheduled time. The time window is defined relative to the scheduled moment and sets the permitted confirmation period. Its duration is a scenario parameter rather than a universal clinical allowance for all medicines. For future testing, window boundaries and rules for late confirmations must be specified in advance with regard to the treatment regimen.

Software architecture

DoseProof follows a client-server model. The Android mobile client uses Kotlin and Jetpack Compose and communicates with the server through a REST API using Ktor Client. Server logic is implemented with Node.js and NestJS; structured data are stored in MySQL using TypeORM. The main components are listed in Table 1. Video media are logically separate from structured records and linked to the event identifier.

The logical architecture is shown in Figure 1. The server processes schedules and event states, accesses storage and initiates messages through Firebase Cloud Messaging. The database stores records and does not independently send notifications. This design defines component responsibilities; scalability and fault tolerance require separate evaluation.

Approach to outcome assessment

At this stage, outcomes were assessed in terms of the completeness of the functional framework: user actions, generated records and state transitions were compared. The architectural description is not evidence of successful functional, load or clinical testing. Measures of the proportion of confirmed events, the proportion without confirmation and trusted-person notification coverage were defined for subsequent monitoring. Definitions and interpretative limitations are provided in the Results section.

No statistical analysis was performed at this stage because no clinical or experimental quantitative data were collected and no statistical hypotheses were tested. Specialized statistical software was therefore not used.

The stage described did not involve patients, human interventions or personal medical data. No clinical testing of the system is reported in this article. Subsequent patient studies must follow an approved protocol and ethics-approval conditions, with informed consent obtained from participants.

Results

Functional prototype model

The prototype combines therapy management, notifications, media confirmation, handling of unconfirmed events and interaction with a trusted person. The main modules and their outputs are summarized in Table 2. Medication, schedule and individual event are represented as related entities, allowing multiple doses of the same medication to be recorded without duplicating its main attributes.

Medication-taking events and state transitions

At the scheduled time, a PENDING event is created and a patient notification is generated. Receipt of confirmation with video within the defined window changes the event to TAKEN. If the window ends without confirmation, the event becomes MISSED and the specified trusted-person notification scenario is initiated. State meanings are presented in Table 3 and the overall sequence in Figure 2.

Video confirmation and trusted-person involvement

The video module saves a short recording at the time of confirmation and links it to the event. The technical scenario described uses a clip lasting 2-3 seconds.

Family monitoring is implemented through an authorized link between the patient and a trusted person. In the proposed model, missing confirmation triggers a notification; the trusted person can contact the patient to establish the reason. The interaction is shown in Figure 3.

Digital monitoring indicators

Calculations should include only events in the reporting period whose permitted windows have ended by the time of analysis. Let their number be N_e; N_t is the number of these events with TAKEN status and N_m the number with MISSED status. Once processing is complete, $N_e = N_t + N_m$. Future events and those with open windows are excluded from the denominator. An event that remains PENDING after its window has ended indicates incomplete processing: the final period indicator is not calculated until this has been resolved.

The proportion of events with recorded confirmation is calculated using equation (1), and the proportion without confirmation using equation (2):

$$C = (N_t / N_e) \times 100\ \% \quad (1)$$

$$M = (N_m / N_e) \times 100\ \% \quad (2)$$

When $N_e > 0$ and final states are mutually exclusive, C and M sum to 100%. When $N_e = 0$, the indicators are undefined. C describes digital-confirmation completeness and is not a direct estimate of the proportion of doses actually taken. Because TAKEN is assigned only within the window in this model, a separate “timely adherence” indicator would equal C. Its independent use would require a separate, verified system for recording late confirmations.

To assess notification, let N_a be the number of MISSED events with an active authorized link to a trusted person, and N_s the number of these events for which successful submission to the messaging service was recorded. Notification coverage is defined by equation (3):

$$E = (N_s / N_a) \times 100\ \% \quad (3)$$

When $N_a = 0$, E is undefined. Each event is counted once regardless of repeated messages or the number of recipients. Submission to the messaging service does not equal delivery to a device, reading or subsequent action by the trusted person. These stages can be assessed separately if necessary. The proposed indicators are summarized in Table 4.

The server model provides for aggregation of TAKEN and MISSED events. The denominator specifications and E indicator described here define requirements for subsequent analytical verification; their implementation must be confirmed by separate tests.

Discussion

Comparison with existing approaches

Reminders, logs and data sharing have already been described in studies of mobile apps [7, 8]. DoseProof's contribution therefore lies in formalizing component interaction around a single event rather than assuming that each component is unique. Table 5 provides a conceptual comparison with a reference model consisting of a schedule, reminder and manual tick. This model explains the architecture and does not represent a review of the entire app market.

The proposed integration may make the interaction history more informative by retaining time, status and media in a common record. However, more information does not necessarily mean greater reliability. Additional patient actions may reduce usability, while video recording may affect willingness to continue using the app. Reviews of mobile-intervention effectiveness [5, 16] support evaluation of the complete user scenario rather than the presence of individual features alone.

Data protection and study limitations

The architecture includes authentication, access tokens, password hashing and verification of authorized user relationships. These components do not demonstrate comprehensive system security. Before pilot testing, video transmission and storage, access segregation, data-access logs, retention and deletion periods, and consent withdrawal must be examined. The importance of these issues is consistent with WHO recommendations and app-quality assessments [14, 15].

The main limitation is the design-stage nature of the work: a prototype model is presented, but there are no clinical-testing data, video-verification accuracy measures, load-test results or quantitative usability assessments. Rates of false confirmation and false missed-dose alerts have not been established. Recording reliability under limited connectivity, trusted-person burden and the acceptability of video recording across user groups have not been assessed. It cannot therefore be concluded that

DoseProof has already improved adherence or clinical outcomes.

The next stage should include functional testing of critical scenarios, assessment of video suitability and a user study. Subsequent clinical testing requires a prespecified protocol, ethics review and participant informed consent. Digital-recording completeness, an independent adherence measure, technical failures and user burden should be assessed separately. The contributions of video and trusted-person involvement require a comparative design that distinguishes these components from the effect of reminders.

Methodological interpretation of the findings

The DoseProof model combines medication reminders, video confirmation and trusted-person involvement within a common event framework. This combination provides a basis for subsequently testing the potential benefit of integrating digital reminders, media confirmation and social support. However, previously published systematic reviews of mobile apps [4, 5, 16] do not permit effectiveness established elsewhere to be extrapolated directly to DoseProof. Its effect on medication adherence must be evaluated in a dedicated study.

Interpretation of TAKEN and MISSED is an important methodological issue. These labels describe technical event states and should not be treated as direct evidence of actual medication intake or omission. A patient may take a medicine without recording it, while a video and TAKEN status alone do not establish that the correct prescribed medicine and dose were taken. Missing digital confirmation may similarly reflect technical problems, including connectivity interruptions, camera failure or transmission delays, as well as nonadherence. Future clinical testing must distinguish technically unconfirmed events from actual missed doses. The need to validate digital records against an independent criterion is consistent with the focus of Zary et al.'s systematic review of the accuracy of digital adherence technologies in tuberculosis [20]. These characteristics must be established separately for DoseProof.

Event-model reliability also depends on unambiguous rules for boundary and exceptional scenarios. These include repeated confirmation submissions, simultaneous receipt of confirmation and window expiry, changes to the therapy schedule and time-zone changes. UTC-based server recording standardizes timestamps but does not remove the need for correct conversion and display of local time for users. These scenarios, including prevention of duplicate events and notifications, must be checked during subsequent functional testing.

Video confirmation requires separate interpretation. The prototype's 2-3-second recording provides a technical record of the event, but this study did not establish whether that duration is sufficient for reliable observation of user actions. At this stage, video should therefore be regarded as media-supported self-report rather than objectively confirmed medication intake. Improving reliability will require development and validation of additional mechanisms, including identity matching, liveness detection and recognition of the medication-taking action.

This approach is fundamentally different from organized electronic directly observed therapy. Burzynski et al. [10] assessed tuberculosis medication intake within a specifically organized observation procedure. Uploading a short video to DoseProof is not equivalent to that method. To use video as a more objective information source, requirements for video content, suitability criteria and an independent means of confirming actual intake must be defined in advance. Research on electronic directly observed therapy therefore supports the promise of this direction but does not validate DoseProof's video module.

Trusted-person involvement is intended to provide an additional social-support mechanism. An unconfirmed-event notification allows the trusted person to contact the patient promptly and clarify why no record was made. This approach is consistent with evidence of a possible association between social support and medication adherence [9]. However, its effects on actual adherence, patient anxiety and the additional burden on relatives or other trusted persons require separate empirical evaluation.

Voluntary participation and differentiated data access are particularly important in family monitoring. Adding a trusted person must not automatically grant access to all patient information, including videos. Before patient use, procedures for granting and withdrawing access, the data available and notification content must be defined. A missing-confirmation message must be interpreted solely as a prompt to clarify the situation and must neither contain nor imply medical advice to change the dose or take another dose.

The proposed digital indicators primarily describe event-recording completeness and notification-system operation, rather than actual medication adherence. Future studies must compare DoseProof data with an independent method and analyse them alongside user and clinical outcomes. This need is illustrated by MedISAFE-BP [11], which showed that improved self-reported adherence does not necessarily translate into improved clinical outcomes.

Conclusion

An architectural and functional model of the DoseProof prototype was developed, combining medication schedules, notifications, short video confirmation and authorized interaction with a trusted person. Medication-taking events with PENDING, TAKEN and MISSED states were formalized, and conditions for notification when confirmation is missing were defined.

Indicators of digital-confirmation completeness and notification-system operation were proposed with explicit consideration of completed time windows. Recorded confirmation was distinguished from actual medication intake, avoiding unsupported interpretation of software states as clinically verified adherence.

The scientific contribution is the formalization of a common event framework linking schedules, media, status and trusted-person involvement. Practical applicability, effects on adherence and the potential for automated biometric verification must be established in subsequent technical and clinical studies.

Conflict of interest

The authors declare no conflict of interest.

Author contributions

Shvets S. V.: study conception, development of the methodology and DoseProof software architecture, investigation, literature analysis, interpretation of results, visualization, manuscript drafting and editing.

Ibragimov R. Z.: assistance with literature searching and systematization, preparation of illustrations and manuscript formatting.

All authors have read and agreed to the final version of the manuscript. The authors state that this material has not been published previously and is not under consideration by other publishers.

Funding

The study received no funding.

Data availability statement

No clinical or experimental quantitative data were collected in this study. The architectural and functional DoseProof model, definitions of event states and calculated indicators are presented in this article.

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Table 1. Main software components of DoseProof.

Component	Technology	Purpose
Mobile client	Kotlin, Jetpack Compose	Patient and trusted-person interface
Network communication	Ktor Client, REST API	Structured-data exchange and video transfer
Server	Node.js, NestJS	Processing schedules, events and permissions
Database	MySQL, TypeORM	Accounts, medications, schedules, events and user relationships
Notifications	Firebase Cloud Messaging	Sending reminders and trusted-person notifications
Deployment	Docker, Docker Compose	Containerization of server components
Authentication	JWT, bcrypt	Access tokens and password hashing
Media data	multipart/form-data transfer	Video upload and linkage to an event

Figure 1. Logical architecture of the DoseProof system.

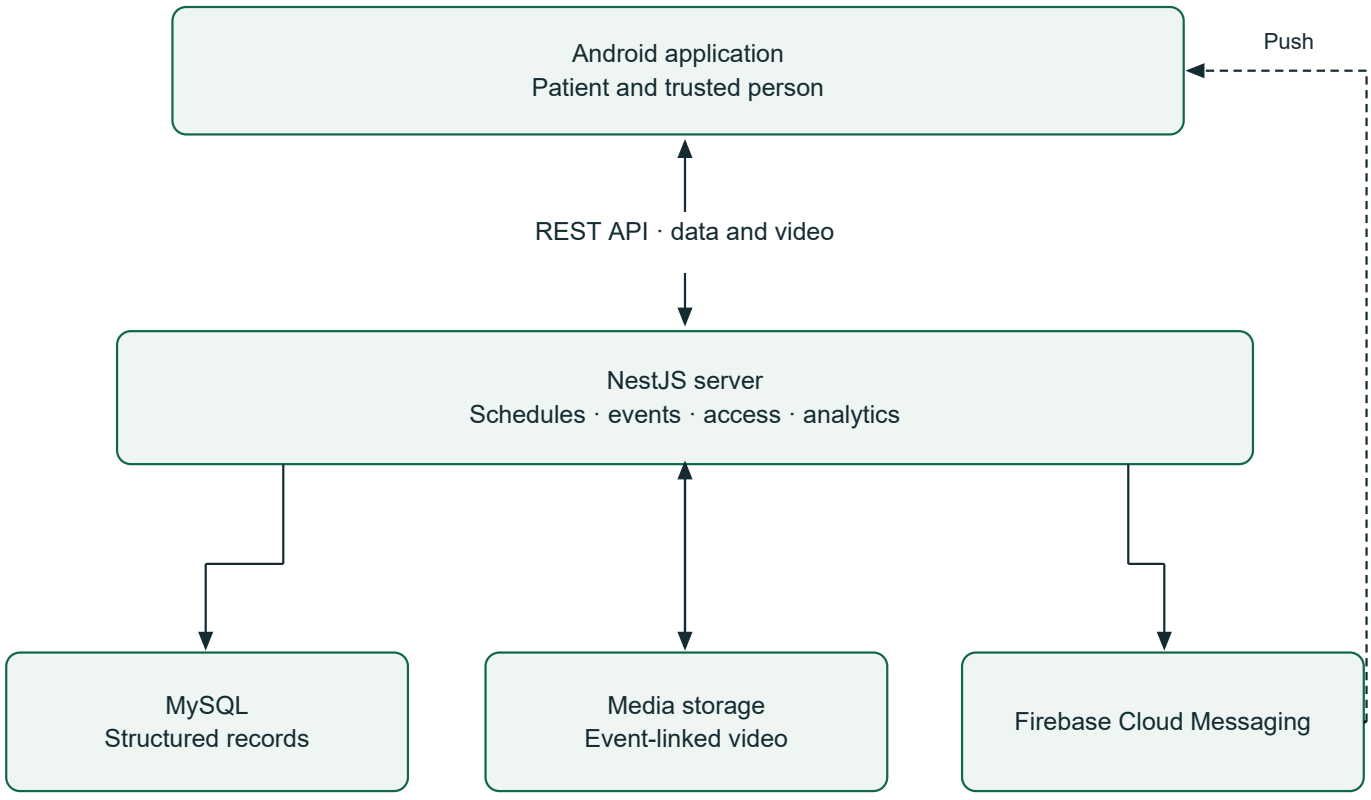


Table 2. Functional modules of DoseProof.

Module	Main action	Output
Therapy management	Entering medication and schedule	Medication record and scheduled dose times
Event recording	Creating and updating an event	Identifier, scheduled time and status
Reminders	Sending a message to the patient	Scheduled-dose notification
Video confirmation	Uploading a short video	Media linked to the event
Family monitoring	Linking users and notifying	Authorized relationship and unconfirmed-event notification
Analytics	Aggregating states over a period	TAKEN and MISSED counts; daily and overall summaries

Table 3. Event states and rules for interpretation.

Status	Meaning	Transition condition	Interpretation
PENDING	Awaiting confirmation	Scheduled time reached; window remains open	The event outcome is not yet determined
TAKEN	Confirmation recorded	Confirmation with video received within the window	Digital patient report recorded; intake is not automatically proven
MISSED	No confirmation	Window ended without confirmation	Possible missed dose or absence of recording for another reason

Figure 2. Algorithm for processing a scheduled event.

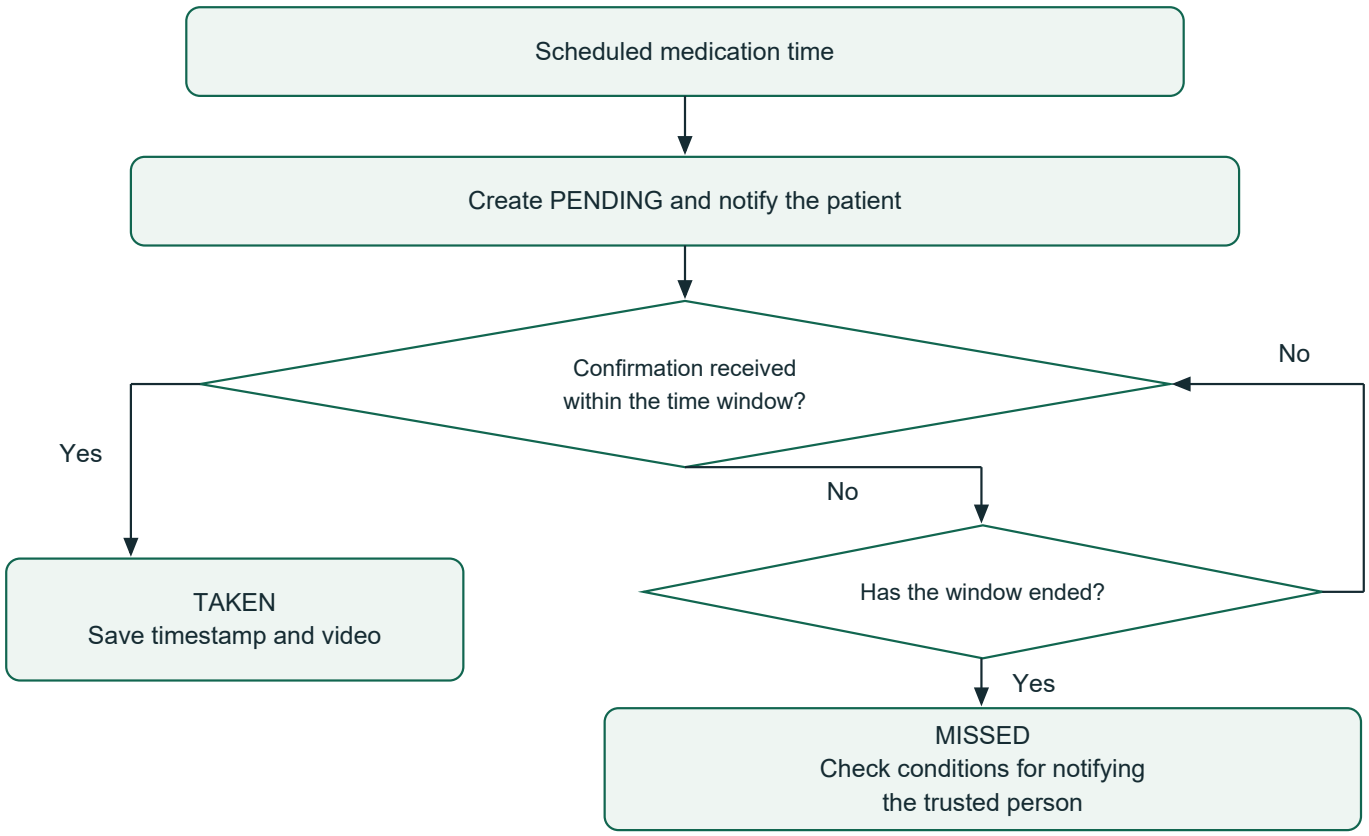


Figure 3. Conditions for notifying the trusted person.

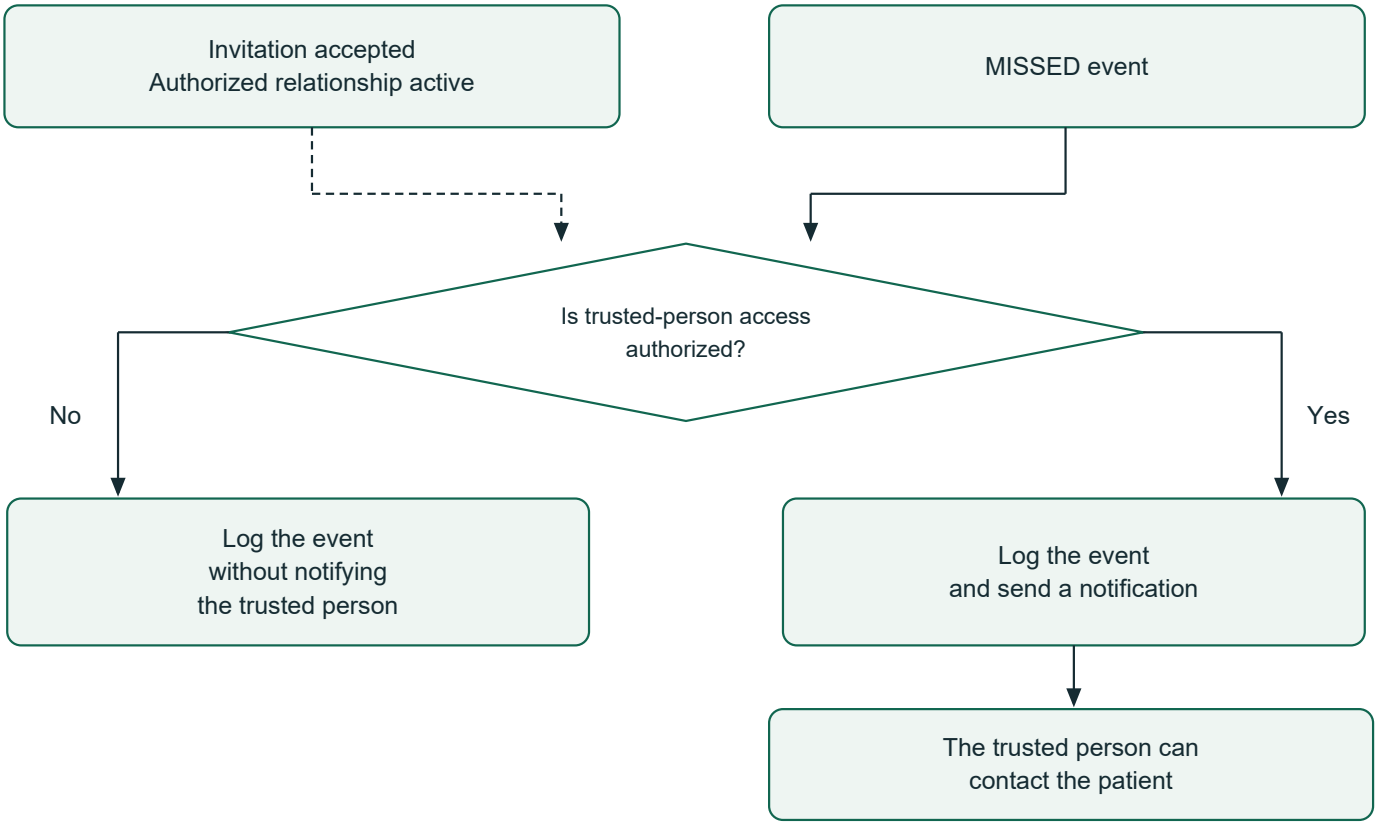


Table 4. Indicators for subsequent evaluation of digital monitoring.

Indicator	Calculation or recording unit	What it measures
Confirmation proportion C, %	Equation (1)	Completeness of recording events with closed windows
Unconfirmed-event proportion M, %	Equation (2)	Frequency of missing digital reports
Notification coverage E, %	Equation (3)	Notification-system operation with an authorized relationship
Consecutive unconfirmed events	Number of consecutive events	Periods requiring clarification of causes
Daily or weekly trends	Numerators and denominators for each period	Changes in recording under comparable counting rules

Table 5. Conceptual comparison of digital monitoring models.

Feature	Reference reminder model	DoseProof model
Confirmation	Manual patient tick	Tick with a short video linked to the event
Time logic	Schedule and notification	Schedule, confirmation window and final event state
Another person's involvement	Not included in the adopted baseline model	Authorized relationship and notification when confirmation is absent
Data interpretation	User self-report	Media-supported self-report; actual intake requires verification
Outcome assessment	Proportion of user ticks	Recording completed events and separate notification assessment