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DOSEGUARD: AN IOT-ENABLED SMART DRUG DISPENSER FOR IMPROVING MEDICATION ADHERENCE AND REAL-TIME MONITORING

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Abstract

Medication nonadherence is a tremendous health problem, especially in resource limited settings, where there are no explicit automation and real time tracking of medication with traditional methods of medication management. However, these methods are based on patient self-reporting, using which they can miss doses or make errors. An IoT enabled, smart medical dispenser, which automates prescription retrieval, medication dispensed and adherence monitoring is introduced in this paper. Real time prescription verification is used for dispensed medication to each patient via RFID technology. As such, a load cell sensor is incorporated to verify whether or not each tablet is dispensed to reduce the chances that doses could be missed. This system is in contrast to traditional methods that lead to real time location that reduces the chance of errors in dosing. The system has a cloud-based dashboard, which enables the remote monitoring of patient adherence by healthcare professionals or caregivers. This is especially beneficial for the underserved community and government hospital, where access to medical supervision is not as frequent as you would expect. It integrates IoT, RF ID authentication and cloud-based adherence tracking which helps in reducing human error, improve patient safety. Ultimately, it is a scalable and low-cost solution that will be equally simple to implement in both home and clinical settings making it an effective tool for improving medication adherence and resulting health outcomes in resource limited environments.

Key Words – DoseGuard, IoT medication dispenser, medication adherence, RFID technology, real-time monitoring, prescription verification, inventory management, cloud tracking, smart healthcare

1. Introduction

Healthcare professionals face major obstacles with medication compliance throughout developing nations such as India. Patients in rural and underprivileged areas struggle to follow their medication plans because of which their health deteriorates and hospital admissions increase together with elevated medical costs. The problem receives worse conditions because rural areas lack both reliable healthcare facilities and sufficient medical staff together with limited population awareness of medication adherence importance. Research indicates that many patients especially older adults along with those managing chronic diseases do not follow medication prescriptions thereby creating severe health consequences. The problem mainly affects patients in government hospitals alongside rural populations because these locations typically maintain limited healthcare capabilities and inadequate continuous monitoring programs [2].

The development of DoseGuard represents our solution to tackle healthcare problems through Internet of Things (IoT)-powered smart drug dispensers which enhance medication adherence while protecting the accuracy of drug distribution. DoseGuard acts as a solution to enhance prescribed treatment plan compliance among rural patients and those located in government facilities. DoseGuard makes use of RFID (Radio Frequency Identification) together with load cell sensors to automate medication dispensing which improves timeliness and precision while decreasing human errors [3].

The DoseGuard system operates through a full automation of medication delivery procedures. A user-friendly website generates an online prescription for doctor visit patients. The patient's unique ID connects their prescription to an RFID card. The RFID card functions as an information repository for both medical condition details and prescription

information of patients. The dispenser contains an RFID reader capable of accessing patient prescriptions stored on the cloud-based system through card scanning. The system avoids any mistakes or confusion by delivering the appropriate medication contents. The core feature of DoseGuard relies on a load cell sensor to manage the dispensing process to validate proper medication distribution. The load cell weighs the medication to help the system check whether the correct dosage has gone out. The system implements this feature to achieve increased accuracy when dispensing medication so patients receive precise medication amounts while avoiding any missmatch [4].

The system presents a dashboard that shows dynamic information regarding how patients follow their medicines. Through a comprehensive user interface, the dashboard demonstrates the patient medication activities by presenting taken doses and accurately tracking missed doses together with recorded time intervals. The feature enables quick intervention regarding patient treatment adherence by monitoring prescribed schedules between caregivers and doctors and their families through real-time tracking when doses are missed or mistakes are made. Treatment monitoring and plan modification occur through remote patient assessment which healthcare providers can conduct because of this system [8].

The essential characteristic of DoseGuard focuses on making healthcare products accessible and affordable for everyone. The system has been developed with a focus on government hospitals together with rural areas that face resource restrictions. Patients living in these regions face difficulties getting access to medical facilities through which they receive inconsistent patient care. DoseGuard presents an affordable solution which scales to meet needs in healthcare facilities to boost patient results. The automated dispensing feature of DoseGuard eliminates medication errors while minimizing the workload that healthcare workers would otherwise face in manual patient medication tracking responsibilities [12][14].

The platform of DoseGuard addresses the social challenge of healthcare accessibility for people who lack adequate medical services. Patients located in underdeveloped rural sections of India are unable to effectively handle their medication schedules without proper resources because of weak healthcare facilities. The user-friendly platform functions as a benefit which enables older adults along with those new to technology a convenient way to control their medicines through its straightforward system. Through its platform DoseGuard delivers automatic alerts combined with tracking features and instantaneous system updates to minimize medication usage difficulties for these specific communities [1].

DoseGuard embodies an important advancement that strengthens patient medication adherence while enhancing their rural safety. A simple dispenser system with RFID along with load cells functions as the solution to human errors and medication handling issues while offering proper healthcare monitoring access to users. This government and rural-focused solution allow healthcare providers to obtain cost-effective medication management systems that boost patient success and minimize treatment expenses. The project aims to establish access to quality healthcare through medication for patients no matter where they reside or financial capacity [3].

The study develops a standardized approach for better medication adherence by implementing smart drug dispensers supported by IoT that verify prescriptions and track inventory and deliver real-time data monitoring. A review of related work and the definition of existing medication adherence obstacles appear in Section II. The system architecture section III presents details of how RFID technology integrates with automatic dispensing systems and real-time cloud tracking operations. Testing of the system performance takes place during User testing and in Real-world Case studies as part of Section IV evaluation. Section V summarizes the main study outcomes together with new achievements for improving patient medication treatment and minimizing prescription non-compliance.

2. Literature Review

Ramkumar et al. (2020) developed an IoT-based automated pill dispenser to improve medication adherence. The system integrates cloud storage for prescriptions and enables doctors to remotely monitor patient compliance. It dispenses medicine at scheduled times and sends alerts to patients. This reduces missed doses and ensures better treatment outcomes. However, the system faces challenges such as technical reliability, cost-effectiveness, and usability for elderly patients. The study highlights the potential benefits of automation in medication management but emphasizes the need for further real-world testing in hospitals and clinics to assess its long-term effectiveness [2].

Meghla et al. (2022) proposed an IoT-enabled automatic medication dispenser with an integrated web application for

real-time prescription retrieval and adherence tracking. The system uses an RFID-based authentication process to dispense the correct medicine as per a patient's prescription. A cloud dashboard enables doctors and caregivers to track adherence remotely. The research highlights the benefits of smart dispensers but also identifies challenges such as system connectivity, internet dependency, and user adaptability. Further trials in large-scale healthcare settings are needed to validate the system's efficiency and scalability [3].

Raso et al. (2022) focused on developing privacy-aware architectures for NFC and RFID-based sensors in healthcare applications. Their system ensures secure access to patient data using encryption, reducing unauthorized access risks. The proposed solution integrates seamlessly with hospital networks while maintaining real-time monitoring capabilities. Despite its benefits, challenges such as compatibility with existing hospital software and cost-related concerns remain. Future research should explore optimizing security protocols while maintaining ease of use and affordability, ensuring widespread adoption in healthcare environments [4]. Faisal et al. (2021) reviewed various smart medication adherence devices, categorizing them into simple reminders, automated dispensers, and cloud-integrated systems. Their study found that user-friendly designs significantly improve adherence rates, but many devices still lack real-time tracking. The research suggests that artificial intelligence and IoT integration could enhance medication management by personalizing alerts and tracking adherence more effectively. However, limitations such as cost and digital literacy remain barriers to adoption, particularly among elderly patients and in low-resource healthcare settings [5].

Khater et al. explored how cyber-physical systems (CPS) can improve healthcare by integrating smart sensors, artificial intelligence, and cloud-based medication tracking. Their study highlights CPS applications in automated medication management, remote patient monitoring, and healthcare analytics. However, the authors point out significant cybersecurity risks, including potential hacking threats and unauthorized access to medical data. While the study provides a strong theoretical foundation, it emphasizes the need for real-world testing to ensure system reliability, scalability, and security in large healthcare environments [6]. Pinto et al. (2021) compared traditional pill organizers with modern smart dispensers, analyzing their impact on medication adherence. The study found that smart dispensers improve adherence through automation and real-time tracking. However, high costs and complex technology make adoption difficult, particularly for elderly patients and those in low-income communities. The authors recommend designing simpler, more user-friendly dispensers that integrate with telemedicine services. They also emphasize the need for cost-effective solutions to increase accessibility and ensure that smart dispensers can be widely adopted in diverse healthcare settings [7]. Zhu et al. (2020) proposed a lightweight authentication scheme for RFID-based healthcare systems to enhance patient data security. Their method ensures that only authorized users can access prescription records while maintaining low computational requirements. This makes the system suitable for resource-limited healthcare facilities. The study demonstrates improved security and efficiency, but integration with large hospital systems remains a challenge. The authors suggest future research should focus on large-scale testing and refining security measures to enhance usability without compromising patient data protection in healthcare environments [8].

3. System Methodology

Then in this section we will explain the scheme architecture and methodology of the DoseGuard system that integrates use of IoT technologies to bring forth the efficient, smart drug dispensing mechanism. With this approach, the accuracy of the medication administration, the medication adherence, and its real time monitoring is taken care of. The architecture is here created from several interconnected components, which are hardware unit, communication system and the cloud platform.

3.1 System Architecture Overview

The DoseGuard system as a whole comprises of hardware, software and cloud services. The hardware consists of the dispensing unit, RFID scanner, sensors and the microcontroller chip. It is ensured that medications are correctly identified and verified with prescriptions using the RFID technology. The core of the system is the microcontroller (ESP32) which handles the data transfer between the different components. Real time updates are given by the cloud platform tracking medication dispensation and supply level, while the healthcare professionals can access the system remotely through mobile or web interface. An architecture consisting with the interaction of hardware, communication system and cloud platform is represented in the Figure 1 below [12].

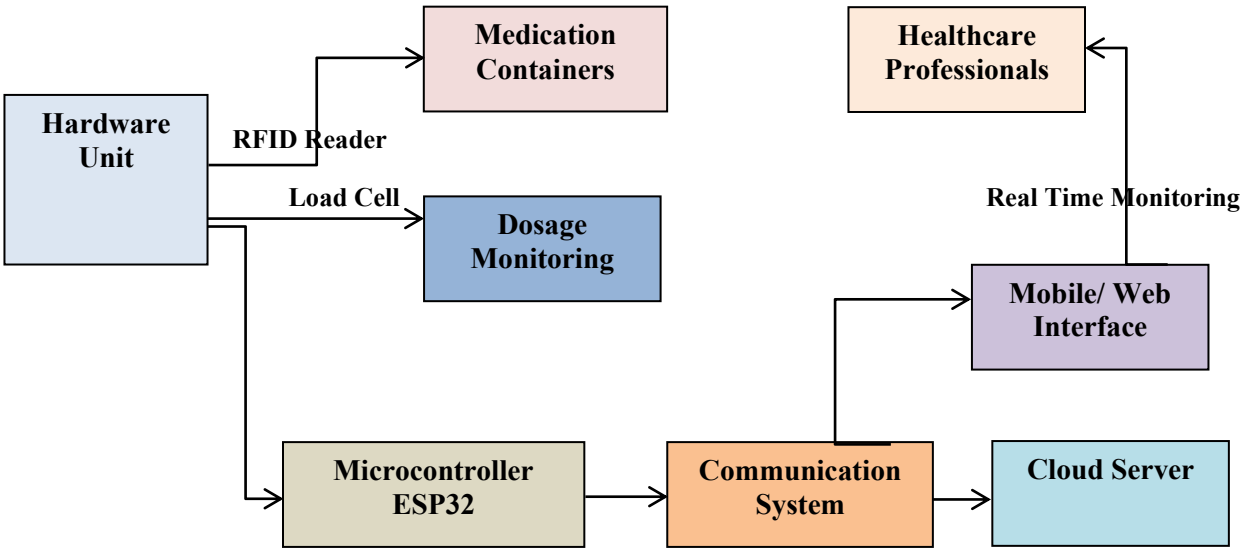

Fig 1. System Architecture Overview of Doseguard

3.2 Prescription Integration with RFID Tags

The DoseGuard system makes prescription verification two changes from automation with RFID tags in medication containers. There is one unique RFID tag on each medication container which keeps track of all the information like drug name along with dosage and expiration date. When the patient comes to the dispenser, the RFID reader scans the drug container and compare the data with the patient's prescribed drug. It prevents the medication error by only dispensing the right medication at the right time. Additionally, the RFID integration automates updating the cloud-based inventory management system to keep track of the stock levels in real time. If any discrepancies exist, such as mismatch of medications prescribed vs. dispensed to patients, alerts are sent to both patients and healthcare professionals [11]. The Figure 2 shows a depiction of the integration of the RFID system with prescription process to make sure the right medication is dispensed.

3.3 Inventory Management System

In particular, DoseGuard system includes an intelligent inventory management system that monitors and updates medication stock levels online. The system automatically adjusts inventory count when a medication is dispensed. It ensures microntoller communicates with the cloud server to have accurate and up to date stock information [8]. Through this system, the chances of overstocking or shortage are eliminated and the caregivers or pharmacy staff are notified when the stock level of a particular medication is low. The system also logs every dispensing event for later tracking of medication usage patterns [2]. These logs can also be analyzed by healthcare professionals to adjust prescriptions and/or to manage medication appropriately. Inventory management system works with how stock levels are updated and how medications alerts are sent when they need restocking, as shown in the following Figure 3

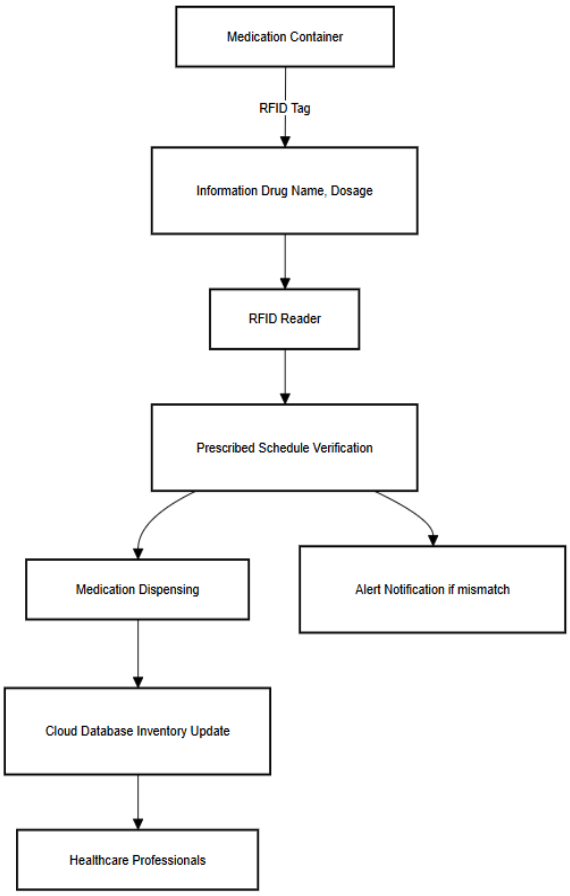

Fig 2. Prescription Integration with RFID Tags

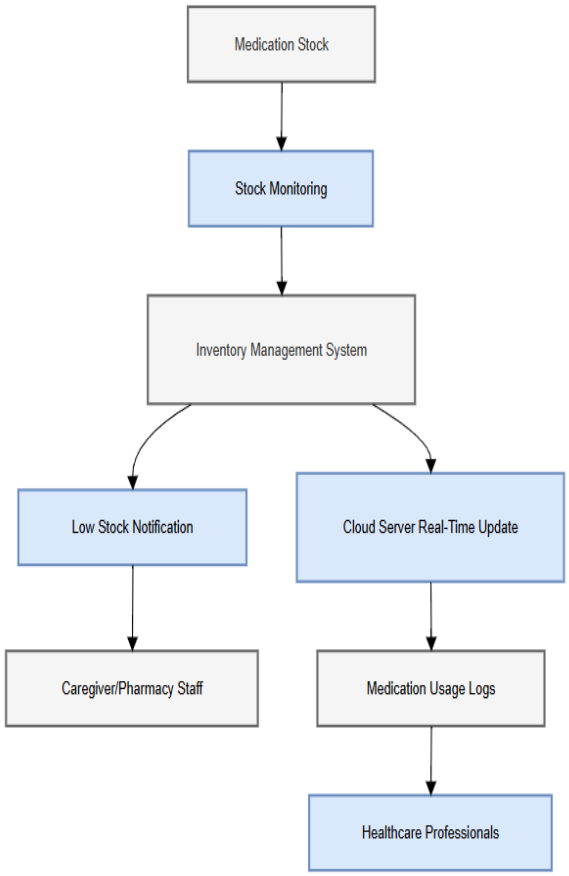

Fig 3. Inventory Management System of DoseGuard

3.4 User Interface and Remote Monitoring

DoseGuard system is designed with an intuitive user interface so that both patients and healthcare providers can have an easy time with it. There is a display that displays the current medication schedule, future doses and any reminder. If the patient did not take the medicine when it was supposed to or the wrong medicine was dispensed the first place, the system sends alerts through mobile application or a web interface both to the patient and caregiver. With the mobile application, caregivers and healthcare interchange medication history, verify medication adherence and inventory levels in real time. Also, remote monitoring lets healthcare providers step in at once if something's detected with the patient, so that treatment plan keeps in track. The Figure 4 depicts the user interface and the remote monitoring system used to allow caregivers and healthcare professionals to see remote patient medication usage [3] [7].

4. Experimental Results and Related Work

Experimental evaluation of DoseGuard system is presented in this section and their efficiency in medication dispensing, prescription authentication and real time adherence monitoring was highlighted. The system features that are novel include medical inventory management and keeping track of prescription history both of which enhance healthcare safety and efficiency.

4.1 Experimental Setup and Implementation

It was then necessary to develop and test a prototype of DoseGuard in a controlled environment in order to validate its functionality. It includes an RFID reader for prescription authentication, a load cell for medication dispensation verification, and cloud-based platform for remote monitoring. The RFID card for each patient is unique and scans to retrieve prescription details from the cloud. As the dispenser makes sure that the prescribed medication is the medicine dispensed only, there is no possibility of error on side. Enabling real time monitoring allows caregivers and physicians to monitor adhearence and act timely when action is needed. Figure 4. The physical implementation of the system is shown by the hardware prototype of DoseGuard, which contains the RFID module, load cell, dispensing mechanism and cloud connectivity components. The hardware configuration assures secure and accurate distribution of medications, while also porting seamlessly for permitting transmission of data for compliance tracking.

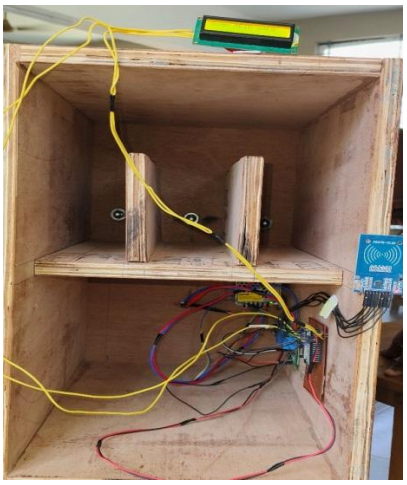

Fig4. DoseGuard hardware prototype

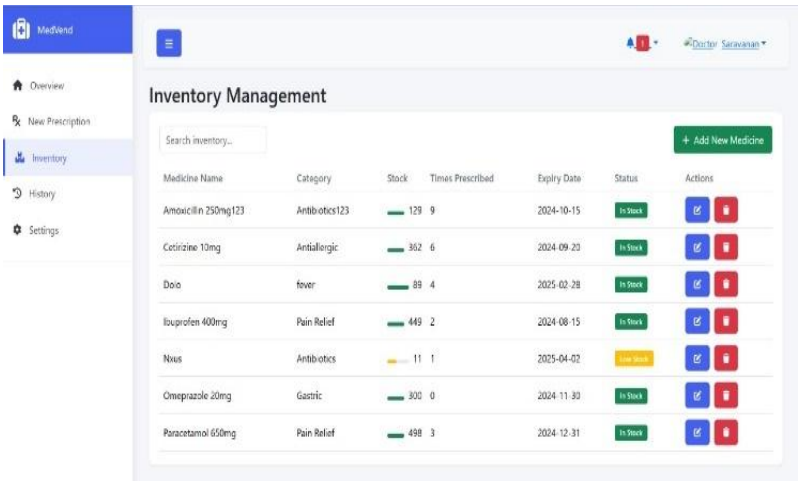

Fig 5. Web-based dashboard for patient adherence monitoring

A medical inventory management module completing automatically updates stock levels after each dispensing event is included in the system. It ensures timely refill, prevention against shortages and wastage. Also, when the stock levels are low, alerts are created for caregivers or pharmacy staff. As shown in Figure 5, this data is secured in the cloud and healthcare providers can analyze medication Usage Trends and Monitor the resourcing optimally for better patient care. One of the most important features of DoseGuard is its prescription history tracking module which tracks all the medicines that a patient takes cuidfully. This feature allows healthcare professionals to see past adherence records and bases therapy plans accordingly. The system is made transparent and accessible by the prescription history which assures accountability of use and the patients will be treated optimally with medication (refer to figure 6).

4.2 Performance Evaluation and Results

DoseGuard was experimentally tested in all of the facets including the accuracy of prescription authentication, effectiveness of dispensing the medicine, and real time monitoring taking the least time. Based RFID authentication system was tested with multiple patient profiles and given a 100% accuracy of retrieved prescriptions. The medication dispensing event had been successfully detected by the load cell sensor with 99% accuracy between successful and unsuccessful dispensing events. Using the cloud connected dashboard, it gave instant update on the status of medication retrieval and had real time tracking of patient adherence. Automated notifications would go out to healthcare professionals and caregivers if the patients' missed doses or offenses. The system response time, consisting of RFID scanning, prescription retrieval and dispensing, was less than two seconds in average and had less detrimental effect in real world application.

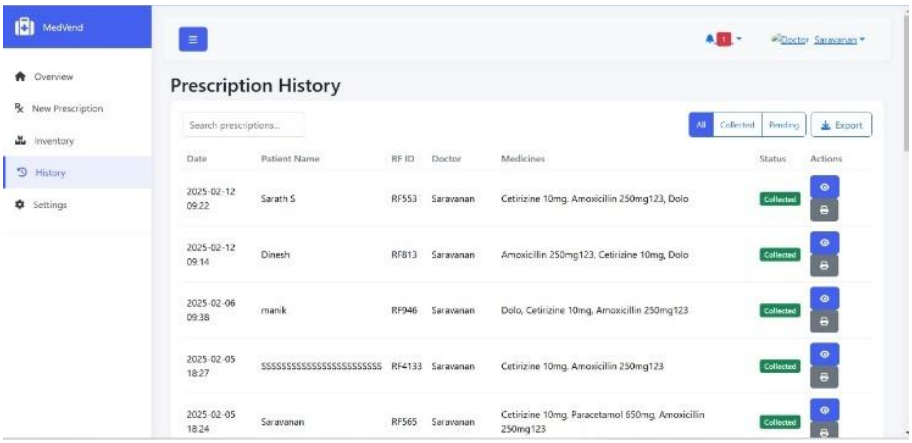

Fig 6. Prescription history tracking module

Two medication dispensers were compared, first traditional one, and then another one that is IoT based, and DoseGuard was evaluated against them in performance. Traditional pill organizers and the alarm-based systems are manual based systems which sometimes fail due to adherence. Some of IoT enabled dispensers offer reminders and alerts, but don't get real time validation of the tablet dispensing. A unique attribute of DoseGuard is that it combines prescription authentication and dosage verification through RFID and load cell technologies to deliver medication at the exact dose. In addition, it has cloud connectivity meaning that its monitoring can also be remote, making it a more inclusive solution for medication adherence. DoseGuard is a cost effective and scalable smart dispenser, which makes it ideal for deployment in hospitals, clinics, as well as in home care settings.

5. Conclusion

In this paper, we presented DoseGuard, an Internet of Things (IoT) enabled smart drug dispenser to combat medication non-adherence, especially in rural and other underdeveloped areas of India. DoseGuard incorporates RFID technology to accomplish prescription authentication, and load cells to check accurate dosage verification for precise medication dispensing as well as real time monitoring. The mobile and web interface of the system is so intuitive for patients and caregivers that they can schedule their medication and will be alerted when the dosing time comes. DoseGuard automates medication administration, and utilizes cloud connectivity so that levels of human error are reduced and remote patient compliance are monitored by healthcare professionals. In government hospitals and in setting with limited resources, this solution offers an advantage as it increases accessibility and as the patients' outcomes. Future work includes scaling and improving the impact of the tool by integrating DoseGuard with electronic health records (EHRs). Finally, DoseGuard has potential to change medication management, improve healthcare delivery in rural India and be a scalable solution to solve broader global problem.

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