



Using AI to increase medication adherence

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Abstract

Although different measures have been taken to increase medication adherence, it still remains a significant challenge with research indicating that the rates of non-adherence remain as high as 40 to 50%. Increasing medication adherence because non-adherence has a direct impact on patient outcomes. Non-adherence contributes significantly to treatment failure. It also increases the rates of hospitalizations, mortality, and morbidity. Non-adherence also adds to healthcare costs affecting the ability of healthcare systems to provide the needed quality of care. Despite the implementation of traditional measures to increase adherence, these measures have led to mixed results. Most of these measures are limited because they rely on patient self-reports to measure adherence. They also do not verify whether a patient takes medication or not. Without verifying or confirming a patient has taken medication, it becomes significantly challenging to measure the rate of adherence. This necessitates the need for additional technologies to increase medication adherence. Leveraging technologies such as AI can help to address the limitations of traditional approaches to ensuring medication adherence. AI can be used to both predict adherence and improve adherence. However, to gain the full benefits offered by AI, it is important to address the challenges these technologies present such as ethical issues with regard to patient privacy and confidentiality of their data. The use of AI to increase medication adherence is also limited by limited knowledge and skills on how to use these technologies effectively and the type of technologies available. Therefore, this review explores how AI-based technologies can be used to increase medication adherence.

Keywords: Medication adherence, non-adherence, Artificial Intelligence, patient outcomes, machine learning

Introduction

Medication adherence remains a significant challenge despite numerous measures taken to improve adherence and years of advocacy on the importance of the same. Globally, non-adherence remains as high as 40% to 50%, particularly for patients grappling with chronic diseases.^{1,2} Medication adherence is imperative because non-adherence has a direct impact on patient outcomes.³ In fact, medication adherence has a more direct impact on patient outcomes than the treatment itself. In the United States, non-adherence accounts for up to 50% of treatment failure, contributes to about 25% of hospitalizations and leads to up to 125,000 deaths.⁴ Despite the measures that have been taken to increase medication adherence, it remains a significant challenge mainly because the responsibility of medication adherence largely falls on patients. As a result, it becomes extremely challenging to attain significant success. Different factors contribute to the high rates of medication non-adherence. Patient-related barriers account for the highest cases of non-adherence. They include forgetting to take medications when expected, forgetting to go for refills, poor understanding of dosage and schedules, patient attitudes and beliefs about medication, side effects, impaired cognition, and lack of patient engagement in the treatment decisions among others.⁵

Although the factors that contribute to non-adherence are known, addressing them is still a significant challenge. Different traditional measures of ensuring adherence such as pill counts, examining the rates of prescription refills, and electronic medication monitors have been taken over the years

but despite this effort, the problem persists.⁶ This necessitates new measures to be adopted to increase medication adherence. The increasing adoption of technology in healthcare shows a lot of promise in different areas including medication adherence. According to research by Treskes et al., smart technology has been shown to increase medication adherence in patients with cardiovascular disease.⁷ The research investigated the potential of different types of technologies including phone interventions, short message service (SMS), smart pill boxes, web-based interventions, and mobile apps and showed that they had a lot of potential to increase adherence.⁷ Technology-based methods of monitoring medication adherence show a lot of promise as they have been shown to have accuracy when it comes to monitoring adherence rates. However, successful implementation of these methods is still a challenge with results indicating mixed results when it comes to their efficacy in monitoring adherence.^{8,9} The mixed results on the effectiveness of these technologies require further research in this area.

AI-powered technologies are coming up as better alternatives to improve medication adherence. Research has shown that these technologies improve medication adherence for different conditions.^{10,11,12,13} To aid in medication adherence, AI-powered tools can perform a number of functions. These functions include identifying non-adherent individuals, sending reminders, educating patients on the importance of medication adherence, and monitoring patients' adherence.¹¹ Identifying non-adherent individuals is important because it will lead to dedicated and personalized efforts to increase adherence. It is

also important to educate patients on the importance of adherence and send reminders. All these measures can help to increase adherence.

This review seeks to explore how AI can be used to increase medication adherence. It bases its findings on past review papers that have documented the use of AI to increase medication adherence. As such, it explores both the positives and limitations of the same.

Importance of Medication Adherence

The World Health Organization recognizes the importance of medication adherence on disease outcomes by noting that non-adherence leads to poor patient outcomes and compounds the challenge of improving health.¹⁴ Medication non-adherence also results in wastage of the already limited healthcare resources. The problem of non-adherence is a significant challenge with research showing that up to 50% of people living with chronic illness do not take their medications as prescribed or expected.^{2,15,16}

Poor adherence has a negative impact on health. In addition to increasing morbidity and mortality rates, non-adherence leads to wastage, disease progression, increased hospital visits and admissions, and lower quality of life.^{6,17,18} In addition to the negative impact on health, medication non-adherence has significant cost implications. According to Cutler et al., the disease-specific economic cost of medication non-adherence averages \$949 to \$44 190 per person.¹⁹ When it comes to all causes, the cost rises significantly to an average of \$5271 to \$52 341.¹⁹ These cost implications pose a significant burden to healthcare systems which are already burdened by high costs of care which impacts people's ability to get medications for prescribed conditions.²⁰

Addressing non-compliance remains a significant challenge because it is attributed to different causes. The causes can be patient-related, treatment-related or even provider-related. Patient-related non-adherence results from patient views and beliefs, social contexts, access or service issues.¹⁴ Patients' views and beliefs play a crucial when it comes to non-adherence. Beliefs and views about the illness can inform their decision to adhere to medication or not.¹⁴ For instance, if patients believe they need medication for their disease, then they are likely to adhere to it. Patients who believe the illness can go away without the medication are likely to be non-adherent. Non-adherence can also be informed by patients' cultural or religious beliefs. Non-adherence may also be informed by the patients' motivation to manage illness. If they are motivated to manage the illness, then they are likely to adhere to medication. Other factors such as forgetfulness, psychological stress, inadequate knowledge and skills, anxiety about medication adverse events, and lack of perceived need for treatment also inform patients' decision to not adhere to medication. Inadequate knowledge and skills can affect patients' ability to read and understand medication instructions which can inform decisions not to adhere to medication.⁶ Research has documented that patients who have low health literacy are likely to have negative disease outcomes.^{21,22} This is informed by factors such as the inability to understand medication instructions hence making them not to take medications or take them in a way that is not prescribed. Such can lead to negative outcomes. Fear of side effects is another commonly reported factor that contributes to medication non-adherence.²³ Fear of side effects may be informed by factors such as negative reactions towards similar medication in the past, unpleasant withdrawal effects, and patient perceptions of the drugs.²⁴

Other patient-related factors that are attributed to poor medication adherence are complex regimens that involve

taking many medications with varying dosage schedules, long-term drug regimes, inadequate access, cost, inconvenience of taking medications, unpleasant taste, and busy work schedule.^{6,23}

Provider-related barriers can also contribute to poor medication adherence. Poor provider-patient communication is one of the provider-related barriers that is attributed to medication non-adherence.²⁵ Effective communication is important to improve adherence because it enables patients to understand their illness better, the benefits of adhering to the medication regimen, and the risks that may arise if medication is not adhered to.²⁶ Patient-provider communication is identified as instrumental in the patient-provider relationship which has been identified as a factor that informs medication non-adherence.²⁷ For example, a poor-patient provider relationship can make it difficult for patients to ask relevant questions regarding their medication. Failing to clarify issues of concern can lead to confusion, misunderstanding, and subsequent non-adherence. Poor-patient-provider relationships may also make patients feel that doctors are not telling their patients the whole truth. Such feelings may inform non-adherence to the prescribed medications. Good communication makes patients feel more involved and are likely to take more control over their health including taking medications as prescribed. Provider-related barriers can also result from inadequate knowledge.^{28,29,30} Providers who lack adequate knowledge about a disease or the assigned treatment are less likely to provide patients with the needed information. This results in non-adherence.

Patient-physician discordance has also been attributed to non-adherence. Patient-physician discordance is defined as the difference between patient and physician evaluations of health-related information.⁶ Such discordance leads to poor health outcomes. Research suggests patient-physician discordance as one of the factors that lead to non-adherence.⁶ If patients and physicians have different views of health-related information, conflict is likely to emerge affecting medication adherence.

Limitations of Traditional Methods of Ensuring Medication Adherence

Traditional measures of ensuring medication adherence have shown mixed results with some showing high success rates in increasing adherence while others showing very little success when it comes to increasing adherence. Some of the most commonly used measures to measure adherence are pill counts, self-reports, measures involving clinician assessment, patient diaries, and patient interviews.^{2,31} Some of these methods have had more success than others. For example, although pill count is a simple and low-cost method of assessing medication adherence, it has several limitations. Pill count is not feasible when it comes to assessing non-discrete dosages. Underestimation of adherence also occurs regularly because pill count does not consider the likelihood of having surplus medication. Other limitations that are associated with pill count are the inability to determine whether the dosage units removed are really taken and the inability to determine whether the patient is following the regimen even after the removal of the right number of units.³²

Clinician assessment and patient self-report have low success rates when it comes to measuring adherence rates. It is difficult to determine whether the patient is correctly reporting adherence by simply relying on an assessment of the same or a self-report.² Patients may also have difficulty communicating or answering the questions as expected. However, despite being highly unreliable, they are still preferred because of low cost, simplicity, and real-time feedback. Patient diaries are also a

simple method to measure adherence but they are unreliable, limited by overestimation, and false reporting.³³

Medication events monitoring systems (MEMS) have shown more accuracy when it comes to medication adherence compared to methods such as pill counts, patient diaries, and self-reports. Research has shown that MEMS is able to determine non-adherence because it records both the time and date when medication is taken from a container.² As such, it is able to establish whether there is an abnormal medication-taking pattern or the number of doses missed. Research has shown that the ability to note the exact time and date the medication is taken from the bottle makes it more reliable than patient diaries or self-report. Besides, research has shown that MEMS helps to increase adherence.^{34,35}

The limitations of traditional measures of medication adherence are what inform the need to explore other measures to increase adherence. AI-powered measures are being considered valuable tools to increase adherence by both predicting adherence and providing a comprehensive assessment of patients' adherence behavior.³⁶ AI has been explored for different conditions including chronic diseases. In some instances, it has been shown to increase adherence by up to 70 to 80%.³⁷ With such high adherence rates, AI tools are likely to be a good alternative to traditional methods of ensuring medication adherence.

The Role of AI in Increasing Medication Adherence

Capitalizing on AI and machine learning-based technologies to increase medication adherence can have a positive impact on patient outcomes. AI-based tools and technologies together with traditional tools of ensuring medication adherence can make a significant impact in this area and lead to positive outcomes. There is research documenting the use of different AI-powered technologies in ensuring medication adherence.¹¹ The technology has a lot of potential when it comes to increasing adherence because it leverages data to offer personalized and intelligent support to patients that can aid in behavioral change and lead to increased adherence. AI-powered technologies and tools have documented varied levels of success in different areas of medication adherence including prediction, reminders, and monitoring of patient adherence.

One of the areas where AI-based tools and technologies are being used is to predict medication adherence and non-adherence. Predicting adherence or non-adherence is important in increasing medication adherence. It helps to determine the patient's likelihood of adhering to the prescribed medication regimen. According to Koesmahargyo et al., the prediction of medication adherence traditionally relies on the assessment of factors such as tolerability, treatment length, and demographics.³⁸ However, with the introduction of technologies with the ability to automatically measure medication dosing in real-time, it becomes easier to measure adherence. Such technologies rely on real-time data. As such, it becomes much easier to predict whether the patient will adhere to medication or not. AI-based technologies provide accuracy when it comes to making such predictions. Gu et al. suggest that predicting medication adherence can be done using ensemble learning and deep learning models.³⁹ These models provide an opportunity to identify patients who have a high risk of non-adherence within a specific time frame. Wu et al. found that using machine learning algorithms to predict non-adherence in type 2 diabetes patients helped to identify risk factors that increased the likelihood of non-adherence.⁴⁰ Identifying risk factors made it easier to provide individualized diabetes care and education hence increasing the likelihood of adherence. Similarly, Li et al. established that machine learning could be

used to predict the risk of non-adherence in patients with type 2 diabetes.⁴¹ Predicting medication adherence and non-adherence is imperative because it helps to identify factors that make it difficult for patients to adhere to medications and design personalized solutions to the problem. For instance, it becomes easier to tailor patient education and care if factors that make it difficult to adhere to medication are known.

In addition to predicting adherence levels, AI-powered tools can be used to increase adherence. Research has documented the success of AI when it comes to improving medication adherence.^{11,12} Labovitz et al. showed that AI improved adherence in patients on anticoagulation therapy by up to 50%.¹² The study showed that even patients who had limited experience with using smartphones were able to use the technology effectively to increase their adherence. The study attributed the improvement in adherence to a number of factors including real-time monitoring, ability to accurately monitor medication ingestion, and change in patient behavior. AI-based technologies can also be used to monitor patient compliance. A novel artificial intelligence platform on mobile devices increased dosing compliance by 17.9% in patients with schizophrenia.⁴² For patients who were monitored using the AI platform, the compliance was 89.7% which was higher than the 71.9% that was recorded for patients who were not monitored using AI.⁴² The AI platform collected data on the date and time stamps the medication was taken for each pill. It also collected data on missed doses, skipped doses, and doses taken in the clinic. Other data that was collected was visual confirmation of the patient ingesting the drug which was done using the tool. Visual confirmation increased the accuracy of the platform when compared to traditional methods of monitoring medication adherence such as pill counts or patients' self-reports.

AI-powered technologies can also be used to increase medication adherence in conditions that require long-term therapies such as tuberculosis (TB) and chronic diseases. Long-term drug regimens are recognized as a barrier to medication adherence.⁶ Diseases such as TB are managed through long-term therapies with some therapies lasting up to 6 months. These long-term therapies pose a significant challenge to patients which explains why non-adherence is commonly reported in TB patients.⁴³ Considering the importance of adhering to medication when it comes to the management of TB, it is important to use technology to increase adherence. One study has documented the significance of using AI algorithms to increase medication adherence in patients living with TB.⁴⁴ The study documented success with AI algorithms resulting in effective management of TB therapies. Besides, research has documented that digital adherence technologies have high success rates in increasing adherence to TB therapy particularly when they are integrated with clinical strategies.^{45,46} Some of these technologies are powered by AI. Other areas where AI can be used to increase medication adherence are to increase patients' rates of refill, monitor patients' adherence, and monitor adverse events.

AI has a lot of potential when it comes to increasing medication adherence. Leveraging this potential can lead to positive outcomes for both patients and healthcare systems. AI-powered technologies can be used to address patient-related barriers that affect medication adherence such as forgetfulness and poor reporting. Leveraging AI can also help to reduce costs associated with medication non-adherence. Some studies have documented that AI-powered tools significantly increase adherence which means that they can help to fill the gaps left by traditional methods of measuring adherence such as pill counts, patient self-reports, and clinical assessment. However, to gain the full benefits of AI, there is a need to address the challenges posed by AI use in monitoring medication adherence.

Challenges of Using AI to Increase Medication Adherence

Although AI shows a lot of potential in addressing medication adherence challenges, it presents unique barriers that need to be addressed to optimize its potential. One of the unique barriers presented by AI use in medication adherence is ethical issues.¹¹ The use of AI in healthcare has always presented a challenge when it comes to patient data, privacy, and confidentiality.⁴⁷ AI and machine learning deal with large datasets most of which contain patient-sensitive information. As a result, securing patient privacy and confidentiality when it comes to the use of this data becomes challenging. Securing patient privacy and confidentiality when it comes to the use of AI in ensuring medication adherence becomes particularly challenging considering such technologies require the use of patient data to be effective. For instance, to ensure patients adhere to medication, it is important to have personal data on these patients. Securing this data and ensuring patient anonymity can be challenging limiting the use of AI to increase medication adherence.

An additional issue that emerges from the use of AI to increase medication adherence is the lack of knowledge and skills on how to effectively use these technologies. Research has documented limited skill sets as one of the challenges that limit the use of AI in healthcare. A lack of knowledge and skills on how to use these technologies to monitor adherence can limit their use and implementation.³⁶ Limitations of knowledge on the available AI-based technologies also limit their use. Although significant advances have been made in the development of AI-based solutions for different areas of healthcare, most of these technologies are not known to healthcare providers limiting their use. Addressing the limitations in knowledge and skillsets can increase AI use in monitoring medication adherence.

Conclusion

Increasing medication adherence is vital to improve patient outcomes. However, despite the implementation of different measures to improve adherence, it still remains a significant challenge with these measures producing mixed results. Most of the traditional measures of ensuring medication adherence are limited by the fact that they do not verify medication administration. Without verifying medication administration, it becomes really challenging to measure adherence. Increasing medication adherence is recognized as instrumental in improving patient outcomes. Non-adherence also compounds the challenge of improving health. Other problems attributed to non-adherence are increased morbidity, increased mortality, increased hospital visits and admissions, significant disease progression, and poor quality of life. Non-adherence also costs healthcare systems billions of dollars each year. Leveraging technologies such as AI can help to address the limitations of traditional approaches to ensuring medication adherence. AI-powered technologies are being used in different areas of healthcare and medication adherence is not an exemption. AI can be used to both predict adherence and improve adherence. However, to gain the full benefits offered by AI, it is important to address the challenges these technologies present. For instance, ethical issues remain a prevalent problem when it comes to AI use in healthcare. Maintaining patient privacy and confidentiality on sensitive issues is a significant problem. The use of AI to increase medication adherence is also limited by limited knowledge and skills on how to use this technology effectively.

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