Rostrum

Technology Interventions for Nonadherence: New Approaches to an Old Problem

Bruce G. Bender, PhD *Denver, Colo*

Nonadherence to asthma medications is well recognized. Interventions to improve adherence, however, have been only moderately successful and are not often adopted because of limited provider time, training, or institutional support. The potential for mobile communication technology to improve adherence has gathered sharply growing interest. Technology-based adherence tracking devices have been in existence for almost 3 decades, but have only recently reached a level of reliability and utility to be considered in allergy practice. Adherence intervention technology includes smartphones, apps, and a growing number of potential new asthma uses such as inhaler technique assessment, portable fractional exhaled nitric oxide devices, and GPS activity trackers with environmental contaminant alerts. As technology has advanced, new capability has emerged including drawing information from electronic health records to tailor automated interventions, give real-time feedback to patients, leverage incentives, utilize predictive logarithms that identify patients at exacerbation risk, and initiate an intervention. Technology development moves faster than clinical trial tests of these new interventions, and gaps in evidence will need to be closed. As researchers establish cost effectiveness, sustainability, and patient and provider acceptance, technology-based adherence intervention systems are likely to be increasingly adopted into small and large practice settings. © 2017 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2017;■:■-■)

Key words: *Adherence; eHealth; mHealth; Tracking devices*

THE PROBLEM

Three decades of research into adherence to inhaled asthma medications has established the disappointing fact that most patients take far less asthma medication than prescribed, and half fully abandon their medication in the first year of its prescription.[1,2] Numerous adherence-improvement interventions have been introduced, but most have been only moderately successful with little evidence of long-term sustainability or reduction of health care utilization and cost.[2,3] Further, over a period of 30 years, the effectiveness of adherence interventions has not progressively improved.[4] Despite awareness of the problem and efforts to improve adherence, numerous barriers have impeded attempts to mitigate nonadherence and, consequently, improve asthma symptom control. Among the most recognized barriers to adherence interventions are limited provider time and training to address behavior. The initial availability of adherence tracking devices (TDs) did not lead to rapid adoption because of the time and expense required to employ these in routine practice. For example, the Nebulizer Chronolog, one of the first commercially available TDs, was priced in the hundreds of dollars, required time-consuming programming, and often experienced mechanical failure.[5] However, more reliable and sophisticated technology has emerged in recent years that can be leveraged to improve adherence and, consequently, symptom control and health care cost in allergy practice. In particular, rapid advances in health information and communication technologies have provided novel opportunities to change patient behavior and decrease asthma exacerbations. Some technology-based interventions are supported by research data, but many have not yet been fully studied in controlled trials. Therefore, this *clinical commentary* will examine current evidence, identify evidence gaps, and assess future potential for use of these technology tools in clinical practice.

POTENTIAL SOLUTIONS

Methodology

Because much of the rapidly emerging health communication technology has not been around long enough to be the subject of controlled trials, information used in this *clinical commentary* was gathered through a variety of sources including published literature searches, presentations at national meetings (eg, the 2017 American Academy of Allergy, Asthma and Immunology meeting included 7 presentations about the uses of communication technology in practice), and information appearing in print and online news articles (eg, business journals and websites have taken interest in this topic).

Health information and communication technology

Electronic health information (*eHealth*) technology includes electronic health record (EHR) systems and their associated databases. *Mobile communication technology* (*mHealth*) includes smartphones, tablets, apps, and a growing number of potential new asthma uses such as inhaler technique assessment, portable fractional exhaled nitric oxide (FeNO) devices, and GPS-associated activity trackers with environmental contaminant alerts. Table I contains a listing of *mHealth* technology, both currently available and emerging in the near future. The rapid growth of *mHealth* technology and consequent enormous uptake

Division of Behavioral Health, Department of Pediatrics, National Jewish Health, Denver, Colo

No funding was received for this work.

Conflicts of interest: The author declares that he has no relevant conflicts of interest.

Received for publication July 31, 2017; revised October 23, 2017; accepted for publication October 24, 2017.

Available online ■■

Corresponding author: Bruce G. Bender, PhD, National Jewish Health, 1400 Jackson Street, Denver, CO 80206. E-mail: benderb@njhealth.org.

2213-2198

https://doi.org/10.1016/j.jaip.2017.10.029

Abbreviations used
EHR- Electronic health record
EMR- Electronic medical record
FeNO- Fractional exhaled nitric oxide
IVR- Interactive voice recognition
KPCO- Kaiser Permanente of Colorado
RCT- Randomized controlled trials
TD- Tracking device

in all age groups creates continuously evolving opportunities to engage patients with chronic illness. However, enthusiasm for technology-based adherence interventions often moves ahead of scientific evidence. Although creative new ideas for applications continue to emerge, many remain untested and the existing evidence base for utility in clinical practice is incomplete. Research into technology-driven adherence interventions is limited by constantly changing technology and a focus on small-scale efficacy studies. Additional implementation research is needed to establish cost-efficient, large-scale applications of *mHealth* technology in tandem with *eHealth* to improve adherence, delivery of care, and, consequently, health (Table II). An assessment of existing research data, incomplete evidence, and future research needs can guide forward-looking investigative steps.

Electronic adherence TDs

TDs designed to track inhaler use first appeared with the Nebulizer Chronolog,[6] a portable device that was attached to a standard metered-dose inhaler to record date and time of each actuation. A series of 23 TDs have since followed[7]; many are no longer available, having been replaced by more sophisticated and reliable devices. Existing TDs have expanded capabilities including capacity to assess inhaler errors and inspiratory flow and to provide direct feedback to patients (Table I). By gathering information on both the frequency and accuracy of inhaler usage, researchers and clinicians can now make a more refined assessment about "true adherence," defined as *adherence X Accuracy/100*.[7] In other words, the newer TDs can better evaluate how consistently medication is delivered correctly to the lungs.

Sending information to patients and providers

Patient-directed reminder and feedback functions from TDs that have been tested in behavioral randomized controlled trials (RCTs) and have shown modest capacity to increase adherence.[8,9] Feedback to the provider to encourage discussion with the patient appears to have greater impact.[10] However, sending countless alerts to providers when patients are not taking their medication contributes to the problem of *alert fatigue*[11]; 33% to 96% of clinical alerts are ignored.[12] Excessive alerts also create potential legal liabilities when providers are unable to respond to alerts that could foretell an asthma exacerbation.[13] TDs that send only generic reminders to patients are less effective than those providing personalized messages drawing from information provided by patients.[14] Although introduction of these devices into clinical practice has been advocated,[15,16] device cost, time required to set them up and download data, and patient reluctance make TDs impractical in many clinical settings. Most RCTs have examined adherence over short time periods with narrowly defined patient groups. TD-based interventions need to be tested in larger trials within health care systems and include evaluation of cost effectiveness, sustainability, reliability, patient acceptance, EHR data transfer, and capacity to change health care outcomes[9,17] (Table II).

Utilizing TDs within *eHealth* systems

The early vision of TDs was restricted to delivering feedback direct from the device to the patient (eg, by auditory alerts or simple screens on the device) or to providers by downloading data onto a computer in the clinic or laboratory. As investigators initially perceived the potential for this technology to improve adherence, early studies began to experiment with combining TDs with email, interactive voice recognition (IVR), and texting in RCTs. Recognizing the importance of behavioral economics and decision making, investigators also began to adopt more sophisticated approaches based on behavioral theories to motivate patients.[18] Still TD interventions face significant limitations. To deliver *eHealth* interventions, most studies depended on costly and labor-intensive systems to reach out to patients. Often, research assistants combed medical records to determine which patients might qualify for a study of technology-based interventions, recruited and consented individual patients, programmed TDs, explained to patients how to use them, and in some cases arranged an incentive payment to the patient. Although this was an appropriate starting point, it soon became apparent that more automated systems of data management needed to be in place before dissemination from RCT to actual clinical practice settings would be possible.

CREATING CLOUD-BASED SOLUTIONS

In recent years, EHRs and cloud computing entered the picture with the objective of creating automated systems for data management and intervention initiation. EHR databases include valuable health information that can be utilized to tailor messages to patients about their adherence. This information can include demographic data, medical visit history, spirometry results, exacerbations, prescriptions, dosing schedules, drug allergies, comorbidities, and refill history. Cloud data can be utilized for coordination of care across providers and health care systems. These data can also be used to facilitate communication to and between providers and patients. Patient instructions, recommendations, encouragement, and access to information or provider contacts can all be managed with systems integrated through the cloud. One remaining challenge is to create automated systems that use these databases to determine a need for intervention, to individualize the intervention with available information, to initiate and monitor the intervention, to motivate patients, and to record the event in the EHR.

Biosensors

Beyond leveraging TDs to promote adherence, the emergence of new biosensor technology offers even greater potential for *mHealth*. Wearable biosensors and smartphone apps are being developed to correct inhaler errors and monitor patient FeNO, heart rate, respiration rate, hydration, and sleep patterns (Table I). Further, environmental exposures and physical activity can be tracked through smartphone-equipped GPS technology. Several commercially available apps include mouthpieces that can measure peak flow when plugged into a smartphone; these recorded peak flows can then be tracked over time through an