

Technology Interventions for Nonadherence: New Approaches to an Old Problem



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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 algorithms 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 2018;6:794-800)

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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

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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 followed⁷; 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

TABLE I. *mHealth* technology to improve adherence and asthma management

Technology	Application
Currently available	
First-generation tracking devices (TDs)	Record date and time of medication use
Second-generation TDs	Record date and time of medication use, send feedback and reminders to patients
Inhalation detection	Coach patient toward appropriate inhalation
Smartphone apps	Add greater sophistication, tailored feedback, data compiled over time, deliver motivational messaging
Peak flow devices	Can be plugged into smartphone and integrated into apps and websites
GPS capability	Can track activity and provide environmental feedback
Coming in the future	
Biosensors	FeNO, heart rate, and respiratory rate may be measured and utilized in predictive algorithms to prevent asthma exacerbations
Incentives	TDs can use behavioral economic models to automatically measure and reward adherence
Electronic medical home	TDs can enter data into an EMR to more broadly assist in disease management
Big data	Large scale data collected by TDs can be used to better understand adherence patterns and their relationship to disease control

EMR, Electronic medical record; FeNO, fractional exhaled nitric oxide.

TABLE II. *mHealth* research needs

GAP in research evidence	Suggested solution
Evidence for effective integration of multiple biosensor data	Conduct initial RCTs to demonstrate in a controlled setting that these data can be digitally integrated to predict and improve outcomes
Generalizability	Conduct implementation studies in diverse practices and health care systems
Data security in digital platforms	Develop and test tools for securing protected health information
Sustainability	Conduct studies of 12 mo or longer to establish sustainability
Cost effectiveness	Introduce implementation research in large health care systems to allow for cost analysis
Patient and provider acceptance	Survey provider and patient in all <i>mHealth</i> studies
Time efficiency	Establish within all studies that digital platforms and tools improve provider time efficiency
Turnkey-ready application	Create and test digital platforms easily adopted within any EMR system

EMR, Electronic medical record; RCT, randomized controlled trials.

app. With real-time measurement, pop-up videos can provide immediate instruction, for example, on correct inhaler use, avoidance of pollen exposure, or the need to contact a health care provider. Much of this technological capability is in development, remains to be tested, and in time must meet all security and HIPAA requirements (Table II).

Integrated *eHealth* and *mHealth* systems

The task of harnessing the remarkable possibilities of *eHealth* and *mHealth* is beyond the resources of most practices or even large health care organizations. A few organizations, such as Kaiser Permanente, are employing some of the available *eHealth* tools. Our research group at the Institute for Health Research, the research arm of Kaiser Permanente of Colorado (KPCO), has been working for the past decade with the goal of building *mHealth* interventions that can be integrated with the *eHealth* system to automatically reach out to nonadherent patients. In the Breathewell study, a speech recognition phone call to parents of a child with asthma was automatically triggered when a controller medication refill was more than 60 days overdue. Database information allowed the computer-based program to tailor the call with name of child, prescriber, medication, and date of most recent refill. A series of questions within the call allowed for further tailoring depending on whether the parent indicated a desire to learn more about the goals of treatment, to speak with a

provider, or to quickly refill the medication. Although KPCO providers were aware of the intervention, the intervention itself required no additional provider time and, in many cases, resulted in increased medication adherence with no further provider interaction. Adherence in the intervention group was increased by 25% over the control group, a difference sustained over 2 years although urgent care use did not change¹⁹ (Figure 1).

Interventions for children versus adults

Data on age difference in the adoption of mobile telephone technology are limited. In the Breathewell study, we conducted focus groups with parents to determine what communications would be most helpful and accepted. Parents indicated a preference that they, not their child, be the recipients of all communications. This approach also simplified communications because content would necessarily vary with the child's age. Hence mobile technology communication directed to children of different ages has not been studied. In contrast, *eHealth* communication with adolescents has been studied,²⁰ but again occurs only with written permission from parents. An ongoing follow-up study (NIH 1 R01 HL126125-01) expands the first *eHealth/mHealth* intervention in KPCO to prevent asthma exacerbations in adults by intervening when adult patients request a β_2 -agonist refill or fail to refill their controller medication. Recognizing that β_2 -agonist overuse is a powerful

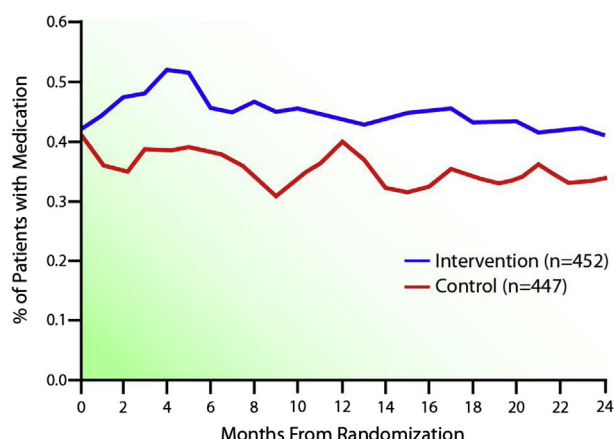


FIGURE 1. Pediatric asthma adherence following interactive voice recognition intervention.²¹

predictor of asthma exacerbations,²¹ patients are contacted by IVR call, SMS text, or email and questioned about their need for the β_2 -agonist. Frequency of symptoms, controller medication use, and exacerbations are factored into a decision tree that can direct a number of possible automated interventions aimed at (1) improving controller medication adherence, (2) adding a controller medication where none has been prescribed, (3) referral to a smoking cessation program, or (4) initiating a nurse telephone call to the patient. *mHealth* offers additional possibilities for connected health interventions. Wireless technologies allow real-time transmission of data from TDs or other devices, uploaded to a cloud database via a smartphone and responded to in real time.

The potential use of *mHealth* is increasing in all age groups. A 2017 report from the Pew Research Center, 85% of adults 18-29, 79% of adults 30-49, and 54% of adults 50-64 owned smartphones. Further, smartphone use in adults over 65 continues to increase. Across the adult population, 62% reported that they search for health information on their smartphone.²² One review of the “connected health” literature reported no studies directly contrasting *mHealth* use by children, adolescents, and adults, but concluded that even elderly patients were willing to use mobile health tools and that *mHealth* uptake was likely to continue in all age groups.²³ Understanding how to reach each age group with *mHealth* remains an important but understudied question.

System platforms

Other organizations are moving toward system-based interventions to improve disease management and control. For example, Geisinger Health System is testing the use of technology to better connect patients and providers, increase adherence, and improve outcomes. Much health-technology innovation at present results from collaboration between engineering, software development, and communication technology businesses with vision and funding to develop devices, platforms, and systems. The ultimate objective is to create turnkey-ready products that health care organizations and practices can easily adopt into their existing electronic medical record (EMR) system, require limited training and provider time, are well accepted by patients, and are cost effective. Recognizing that the development of technology-

based adherence interventions has profit potential,²⁴ more than 2 dozen companies have entered the marketplace with technology that proposes employment of TDs, smartphone apps, wireless enabled wrist watches, and various promises of automated behavior-changing technology. Several companies have specifically focused on asthma (eg, Adherium, CapMedic, Cohero Health, Gecko Health, Philips Health Suite, Propeller Health). Although many of the available tools have not moved beyond sending reminders to patients to take their medication, some are advancing further with more comprehensive, multi-component ideas for cloud-based data sharing that connects patients and health care teams.

As with many start-up ventures, some companies make a brief appearance in the marketplace, whereas others endure and continue to develop new systems. Few have established a clear, integrated platform and published studies establishing the value of their product. One exception is Propeller Health, a Madison, Wisconsin group that has developed a platform using TDs, mobile phone apps, predictive analytics, and patient-provider reports. In a study conducted within 4 health care centers, patients with asthma enrolled in the Propeller Health intervention demonstrated a decrease in rescue medication use and improvement in Asthma Control Test scores when compared with controls.²⁵ Adherium, a New Zealand company, has tested a TD with audiovisual reminder functions in an RCT showing capacity to increase asthma medication adherence and reduce symptoms scores in children.²⁶ With such systems, providers will soon be able to enter patients into an automated program that tracks adherence through a TD and transmits data via the cloud into a centralized system. The system in turn can send reminders, reports, and recommendations to both patients and providers. Pharmaceutical companies have partnered with device and platform development companies, in some cases purchasing the smaller device companies.²⁷ Pharmaceutical companies are also beginning to develop medication inhalers equipped with microchip technology that will be included with every inhaled medication sold to patients, ushering in the era of “smart inhalers.”¹³

FUTURE POSSIBILITIES

The understanding of the possible benefits from bringing together health and communication technology requires separation of existing technology from future potential (Table I). The early emergence of TDs led to a variety of methods of delivering adherence feedback, mostly to patients but in a few instances to providers, using SMS texts, email, and smartphones apps. New technology is able to coach patients toward a correct inhaler technique. Platforms are beginning to appear that allow information exchange between patients and providers, and commercially available peak flow measurement devices that attach to smartphones can be purchased. At this point, we are approaching the threshold of being able to choose a packaged set of technology-based interventions that providers may be able to purchase and install into their EMR.

Targets for future exploration and research include the following:

1. *eHealth* medical homes: Communication and health information technology have the potential to create an “electronic medical home” with more effective *eHealth* management of adherence data gathered from TDs and integrated with other

health information contained in an EHR database. In the KPCO Breathewell study, a recent history of asthma exacerbation or tobacco use and underfilling of controller medication flag patients in need of a more intensive intervention to prevent another exacerbation. Where data suggest a needed change in diagnosis (eg, from intermittent to persistent asthma), or a need for intensified treatment and/or spirometry, an actionable “clinical report” is sent to the provider. Patients with chronic nonadherence may also be referred to an asthma nurse specialist who then calls the patient for a shared decision-making discussion addressing treatment choice and adherence. Armed with the decision-support clinical report and automatically generated patient decision aids, the clinician can move more quickly to a discussion of key concerns. The electronic medical home can facilitate information transfer between providers (eg, between primary care and specialist providers) or between health care institutions to optimize care coordination and delivery.

2. **Biosensors:** Beyond TDs, a variety of additional potential biosensors may be employed to gather data that can be assimilated with other health information to guide both patient and clinician. Currently available technology includes smartphone-connected peak flow readings and GPS-based functions with capacity to warn patients entering environments with asthma-trigger potential. For example, such warnings might be transmitted to patients during urban high pollution days or where high winds are distributing agricultural or sand particulates in rural areas. At a higher level, risk logarithms can use individual allergy profiles to tailor environmental threat messages. For example, a patient with strong allergic reactions to juniper trees may not receive a message unless in an area where juniper trees are prevalent. Other wearable biosensors may be provided to patients with asthma to record FeNO, heart rate, respiration rate, breath volume, hydration, and sleep patterns. Although the ability of these data to produce predictive risk profiles remains to be established, their potential to rapidly flag risk and suggest interventions is appealing. Finally, widely available lifestyle modification biosensors (eg, Fitbit, Jawbone, LifeTrak, Misfit, Withings, Xiaomi) deliver additional motivation and data recording that may help patients with asthma to adopt health-promoting behaviors including exercise, diet, and sleep. Lifestyle information could also be integrated with the patient’s personal EHR data to provide even further individualized self-management recommendations and encouragement.
3. **Incentives:** Technology that can track and record behavior also has the potential to automatically reward patients with incentives for their adherence. These incentives can take the form of positive feedback and praise, or financial rewards that may include reduced copays or even money. For example, a patient reaching his or her predetermined medication adherence goal may be rewarded with a credit toward his or her next visit or medication copay. Although appealing, evidence supporting financial incentives for adherence behavior is incomplete and leaves many unanswered questions. A recent review of 39 studies in which technology was used to remotely implement financial incentives reported that 71% recorded a significant behavior change.²⁸ As one example, 75 diabetic patients were randomized to an incentive intervention in which they received a lottery-based incentive in return for

monitoring blood glucose, blood pressure, and weight for 3 months with home monitoring devices; patients in both the low incentive group (\$50) and high incentive group (\$100) were significantly more adherent than in the control group.²⁹ Similar studies with patients with asthma have not yet been conducted. Though intriguing, before incentives can be effectively put into place in a large scale program, additional information is needed about the type, frequency, size, and duration of incentive required to create and sustain change, as well as the cost effectiveness of using financial incentives to induce behavior change.

4. **Big data:** With the advent of smart inhaler technology contained in every asthma inhaler, the potential large-scale collection of deidentified data from thousands of patients may deliver a better understanding of the relationships between behavior and health. Large administrative databases have been used for years to establish, as an example, the cost of managing uncontrolled asthma³⁰ or the relationship between adherence and asthma outcomes.³¹ Data collection through *mHealth* and integrated with *eHealth* databases, and subsequently subjected to advanced analytics, could reveal previously unrecognized patterns and associations that can aid the development of risk stratification profiles and help tailor more powerful interventions. Analysis of complex inhaler data may also provide insights that inform the development of new inhalers.¹³ However, it remains to be determined whether, when, and how to obtain patient permission to utilize data collected both from mobile devices and EMRs. Even with a permission process in place, growing wariness about the theft of digital information may create reluctance to give permission to use personal health information in this manner.

CONCLUSIONS

The explosion of *eHealth* and *mHealth* technology creates exciting possibilities for patient engagement, behavior change, and improved health. However, the rapid pace of technology innovation creates special challenges. Interventions that seemed clever a couple of years ago are quickly outdated. For example, sending texts or emails to patients with reminders to take their medication may provide some value, but in view of the fast advancement of communication technology, such strategies are outdated. As innovations accelerate, technology frequently gets ahead of science, and strategies for technology-based interventions are introduced into the marketplace without careful evaluation of whether they can deliver on their promise. We now have biosensor tools to provide direct feedback or tailor interventions to give instruction based on recent behaviors (eg, exercising, taking medications, inhaler errors). The addition of other biosensor capability, such as employing GPS, mobile FeNO, or peak flow recordings, will greatly extend the touch capability of digital interventions in asthma care. Further personalization of the intervention may follow with integration of other patient information contained in the EHR. For example, the Breathewell study uses the patient’s history of asthma exacerbations to determine whether the intervention requires a digital or human interaction. Importantly, *mHealth* interventions can never substitute completely for human communication. They can, however, enhance and magnify provider-patient communication, add new dimensions of education and instruction, and expand motivational strategies. Further research may identify the

TABLE III. mHealth and eHealth technology resources for providers and researchers

Apple ResearchKit (https://www.apple.com/researchkit/): Open source app framework to support medical research
Microsoft Research (https://www.microsoft.com/en-us/research/?from=http%3A%2F%2Fresearch.microsoft.com%2Fen-us): Assistance in computer science and software research applications
WellDoc (https://www.welldoc.com): Develops technology-based solutions to improve disease outcomes
Text to Change (https://ttcmobile.com): Nonprofit that helps develop health education and medication adherence through mobile communication technology
FrontlineSMS (http://www.frontlinesms.com): Free, open-source software for the development of communication hubs utilizing mobile communication technology
<i>mHealth</i> : New horizons for health through mobile technologies (http://www.who.int/goe/publications/ehealth_series_vol3/en/): Case studies demonstrating <i>mHealth</i> applications in various settings
Current NIH funding announcements for <i>mHealth</i> and <i>eHealth</i>
PA-14-180: May mHealth Tools for Individuals with Chronic Conditions to Promote Effective Patient-Provider Communication, Adherence to Treatment and Self-Management (R01)
PAR-16-249: Innovative Approaches to Studying Cancer Communication in the New Media Environment (R01).
PAR-14-118: Technologies for Healthy Independent Living (R01)
PAR-16-292: Mobile Health: Technology and Outcomes in Low and Middle Income Countries (R21)
RFA-HS-10-016: Active Aging: Supporting Individuals and Enhancing Community-based Care through Health Information Technology (HIT) (P50)

“sweet spot” or optimal blend of device-generated data and human communication to provide cost-effective interventions that motivate positive health behavior.³²

How do we align the rapid pace of changing technology and the need for proper evaluations to establish intervention effectiveness?

Novel digital communication devices such as smartphones quickly generate excitement and sales, but the decision rules change when trying to convince health care organizations to purchase the latest technology. Such decisions are not driven by eagerness to have the newest and most attractive piece of technology, but by consideration of scientific evidence and with some assurance of a return on investment.²⁴ Most National Institutes of Health (NIH) research-granting mechanisms move at a pace that is often too slow to keep up with this rapidly evolving technology. However, “adaptive” study designs allow investigators to test and change the intervention through a series of interim data analyses, making trials more flexible, efficient, and fast-moving and allowing investigators to accomplish in a single study what might otherwise require a series of independent studies.³³ The NIH has recognized the potential of communication technology to change health outcomes and provides research funding for *mHealth* innovation (Table III). Another pathway to swifter testing of emerging technology is to create partnerships between health care researchers and technology companies, crafting the facility to quickly engage in a sequence of trials testing the potential of new technology to create clinical efficiency and improved health. Through such partnerships, and with an implementation research paradigm, innovative, technology-based adherence interventions are more likely to advance quickly, demonstrate effectiveness, and make their way into health care systems. Realistically, such partnerships are most likely to happen at an organizational level, rather than between individual providers and large technology companies. Nonetheless, several websites offer free tools to clinicians and researchers to foster the development of new *mHealth* projects, large and small (Table III).

Are we ready to introduce *eHealth* and *mHealth* interventions in clinical practice?

eHealth and *mHealth* interventions have great potential to assist clinicians caring for patients with allergic disorders and asthma. As demand on providers increases and time available to encourage patient adherence decreases, *eHealth* and *mHealth* may provide tools to expand ongoing communication with patients efficiently and effectively. The provider-patient relationship remains essential to direct disease self-management. Technology can enhance, but will not replace that relationship. Off-the-shelf *mHealth* is not yet ready for widespread adoption. Many of the interventions described in this *clinical commentary* are not yet easily adopted into clinical practice. However, this has not stopped creative and generally younger clinicians from discovering ways to do so, proceeding to put into place innovative but untested strategies. Both patients and providers are ready to embrace such interventions. Technology adoption efforts move quickly and, regardless of existence of published studies, may be captured in public media or through social networking rather than peer-reviewed medical journals. Physician age appears to partially mediate interest in adoption. Eighty-two percent of younger physicians (25-34) but only 51% of older providers (65-74) wanted to communicate with patients through a patient portal.³⁴ In a 2013 survey of physicians,³⁵ 72% reported using a smartphone to access drug prescribing information, 44% to communicate with other medical staff, 33% to communicate with patients, and 17% to access medical records. In a 2015 survey conducted by the Healthcare Information and Management Systems Society, 93% of surveyed physicians endorsed the opinion that smartphone apps can be used to improve patient health. Among patients, 61% reported that they had downloaded at least one health care related app, and 71% of smartphone users approved of interacting with their health care organization through their phone.³⁶ In short, it has become increasingly common that providers encourage patients to use a patient portal, download a health-related app, or even directly email or text their provider.^{35,37} This strong interest from providers and patients signals that desire, innovation, and uptake of information technology in medical care are inevitable.

REFERENCES

- Bender BG, Pedan A, Varasteh LT. Adherence and persistence with fluticasone propionate/salmeterol combination therapy. *J Allergy Clin Immunol* 2006;118:899-904.
- Bender BG, Hernandez Vecino RA, McGrath K, Jones S. Comparative analysis of persistence to treatment among patients with asthma or COPD Receiving AirFluSal Forspiro or Sereotide Diskus salmeterol/fluticasone propionate combination therapy. *J Allergy Clin Immunol Pract* 2016;4:884-9.
- Normansell R, Kew KM, Stovold E. Interventions to improve adherence to inhaled steroids for asthma. *Cochrane Database Syst Rev* 2017;4:CD012226.
- Bender BG. Nonadherence to asthma treatment: getting unstuck. *J Allergy Clin Immunol Pract* 2016;4:849-51.
- Wamboldt FS, Bender BG, O'Connor SL, Gavin LA, Wamboldt MZ, Milgrom H, et al. Reliability of the model MC-311 MDI chronolog. *J Allergy Clin Immunol* 1999;104:53-7.
- Gong H Jr, Simmons MS, Clark VA, Tashkin DP. Metered-dose inhaler usage in subjects with asthma: comparison of Nebulizer Chronolog and daily diary recordings. *J Allergy Clin Immunol* 1988;82:5-10.
- Kikidis D, Konstantinos V, Tzovaras D, Usmani OS. The digital asthma patient: the history and future of inhaler based health monitoring devices. *J Aerosol Med Pulm Drug Deliv* 2016;29:219-32.
- Charles T, Quinn D, Weatherall M, Aldington S, Beasley R, Holt S. An audiovisual reminder function improves adherence with inhaled corticosteroid therapy in asthma. *J Allergy Clin Immunol* 2007;119:811-6.
- Chan AH, Reddel HK, Apter A, Eakin M, Riekert K, Foster JM. Adherence monitoring and e-health: how clinicians and researchers can use technology to promote inhaler adherence for asthma. *J Allergy Clin Immunol Pract* 2013;1:446-54.
- Apter AJ, Wang X, Bogen DK, Rand CS, McElligott S, Polsky D, et al. Problem solving to improve adherence and asthma outcomes in urban adults with moderate or severe asthma: a randomized controlled trial. *J Allergy Clin Immunol* 2011;128:516-523.e1-e5.
- Rush JL, Ibrahim J, Saul K, Brodell RT. Improving patient safety by combating alert fatigue. *J Grad Med Educ* 2016;8:620-1.
- Khalifa M, Zabani I. Improving utilization of clinical decision support systems by reducing alert fatigue: strategies and recommendations. *Stud Health Technol Inform* 2016;226:51-4.
- Bender B, Chrystyn H, Vrijens B. Smart pharmaceuticals. In: Thuemmler C, Bai CE, editors. *Health 4.0: How Virtualization and Big Data Are Revolutionizing Healthcare*. Cham, Switzerland: Springer; 2017:61-90.
- Granger BB, Bosworth HB. Medication adherence: emerging use of technology. *Curr Opin Cardiol* 2011;26:279-87.
- Weinstein AG. The potential of asthma adherence management to enhance asthma guidelines. *Ann Allergy Asthma Immunol* 2011;106:283-91.
- Head KJ, Noar SM, Iannarino NT, Grant Harrington N. Efficacy of text messaging-based interventions for health promotion: a meta-analysis. *Soc Sci Med* 2013;97:41-8.
- Ingerski LM, Hente EA, Modi AC, Hommel KA. Electronic measurement of medication adherence in pediatric chronic illness: a review of measures. *J Pediatr* 2011;159:528-34.
- Chauhan BF, Jeyaraman M, Mann AS, Lys J, Skidmore B, Sibley KM, et al. Behavior change interventions and policies influencing primary healthcare professionals' practice—an overview of reviews. *Implement Sci* 2017;12:3.
- Bender BG, Cvietusa PJ, Goodrich GK, Lowe R, Nuanes HA, Rand C, et al. Pragmatic trial of health care technologies to improve adherence to pediatric asthma treatment: a randomized clinical trial. *JAMA Pediatr* 2015;169:317-23.
- Mosnaim GS, Pappalardo AA, Resnick SE, Codispoti CD, Bandi S, Nackers L, et al. Behavioral interventions to improve asthma outcomes for adolescents: a systematic review. *J Allergy Clin Immunol Pract* 2016;4:130-41.
- Zeiger RS, Schatz M, Li Q, Solari PG, Zazzali JL, Chen W. Real-time asthma outreach reduces excessive short-acting beta2-agonist use: a randomized study. *J Allergy Clin Immunol Pract* 2014;2:445-456.e1-5.
- Smith A. Record shares of Americans now own smartphones, have home broadband; 2017. Available from: <http://pewrsr.ch/2bjymk>. Accessed July 18, 2017.
- Colorafi K. Connected health: a review of the literature. *Mhealth* 2016;2:13.
- Bender B. Can healthcare organizations improve health behavior and treatment adherence? *Popul Health Manag* 2014;17:71-8.
- Merchant RK, Inamdar R, Quade RC. Effectiveness of population health management using the propeller health asthma platform: a randomized clinical trial. *J Allergy Clin Immunol Pract* 2016;4:455-63.
- Chan AH, Stewart AW, Harrison J, Camargo CA Jr, Black PN, Mitchell EA. The effect of an electronic monitoring device with audiovisual reminder function on adherence to inhaled corticosteroids and school attendance in children with asthma: a randomised controlled trial. *Lancet Respir Med* 2015;3:210-9.
- Comstock J. Teva Pharmaceuticals buys smart inhaler company Gecko Health Innovations; 2015. Available from: <http://www.mobihealthnews.com/47039/teva-pharmaceuticals-buys-smart-inhaler-company-gecko-health-innovations>. Accessed July 18, 2017.
- Kurti AN, Davis DR, Redner R, Jarvis BP, Zvorsky I, Keith DR, et al. A review of the literature on remote monitoring technology in incentive-based interventions for health-related behavior change. *Transl Issues Psychol Sci* 2016;2:128-52.
- Sen AP, Sewell TB, Riley EB, Stearman B, Bellamy SL, Hu MF, et al. Financial incentives for home-based health monitoring: a randomized controlled trial. *J Gen Intern Med* 2014;29:770-7.
- Zeiger RS, Schatz M, Dalal AA, Qian L, Chen W, Ngor EW, et al. Utilization and costs of severe uncontrolled asthma in a managed-care setting. *J Allergy Clin Immunol Pract* 2016;4:120-129.e3.
- Zeiger RS, Schatz M, Chen W, Li Q, Khatri DB, Tran TN. Adherent uncontrolled adult persistent asthma: characteristics and asthma outcomes. *J Allergy Clin Immunol Pract* 2015;3:986-990.e2.
- Bender B, Depew A, Emmett A, Goelz K, Make B, Sharma S, et al. A patient-centered walking program for COPD. *Chronic Obstr Pulm Dis* 2016;3:769-77.
- Kairalla JA, Coffey CS, Thomann MA, Muller KE. Adaptive trial designs: a review of barriers and opportunities. *Trials* 2012;13:145.
- Goldzweig CL, Orshansky G, Paige NM, Towfigh AA, Haggstrom DA, Mlake-Lye I, et al. Electronic patient portals: evidence on health outcomes, satisfaction, efficiency, and attitudes: a systematic review. *Ann Intern Med* 2013;159:677-87.
- Wolters Kluwer Health 2013 Physician Outlook Survey; 2013. Available from: <http://wolterskluwer.com/>. Accessed July 18, 2017.
- 2015 HIMSS Mobile Technology Survey; 2015. Available from: <http://www.himss.org/2015-mobile-survey>. Accessed July 18, 2017.
- Govette J. 30 Amazing Mobile Health Technology Statistics for Today's Physician; 2017. Available from: <https://getreferrallmd.com/2015/08/mobile-healthcare-technology-statistics>. Accessed July 18, 2017.

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