

CME Review

Where does health communication technology fit into allergy practice?



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ARTICLE INFO

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Key Messages

- Adherence interventions to date have been only moderately successful.
- Health communication technology brings new possibilities for improved asthma self-management.
- New biosensors, such as smartphone-compatible fractional exhaled nitric oxide and spirometers, could provide additional benefits.
- Allergists must exercise caution so that HCTs do not compromise patient confidentiality or safety.

INSTRUCTIONS

Credit can now be obtained, free for a limited time, by reading the review article and completing all activity components. Please note the instructions listed below:

- Review the target audience, learning objectives and all disclosures.
- Complete the pre-test.
- Read the article and reflect on all content as to how it may be applicable to your practice.
- Complete the post-test/evaluation and claim credit earned. At this time, physicians will have earned up to 1.0 AMA PRA Category 1 Credit™. Minimum passing score on the post-test is 70%.

Overall Purpose

Participants will be able to demonstrate increased knowledge of the clinical treatment of allergy/asthma/immunology and how new information can be applied to their own practices.

Learning Objectives

At the conclusion of this activity, participants should be able to:

- Identify the degree and consequent of patient nonadherence.
- Name at least 2 health communication technologies currently in use to promote adherence.
- Describe guidelines for appropriate use of HCT with patients.

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Target Audience

Physicians involved in providing patient care in the field of allergy/asthma/immunology

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Introduction

During the past 3 decades, health and communication technologies (HCTs) have evolved and joined forces to improve asthma management. Initially, technology was focused on the electronic measurement of patient adherence (Fig 1). As adherence measurement devices improved, investigators began to use them as interventions to boost adherence by giving feedback directly to patients and later by adding communication technology. The more recent upsurge of available communication technology has introduced the role of smartphones, mobile apps, and interactive voice recognition (IVR) technology to health care. The emergence of mobile biosensors could further increase the potential of technology to improve patient and provider management of asthma symptoms, but questions remain as to how to bring together all these technologies to direct care. This article reviews the evidence addressing adherence, communication, and biosensor technology, the potential for large-scale interventions, and gaps in evidence requiring further research.

Treatment Nonadherence

Nonadherence is a major barrier to successful asthma treatment.¹ Early assessments of treatment adherence were often inaccurate due in part to insufficient measurement tools. Only with advances in the science of adherence has the full extent of the problem

been identified, its impact on control been well documented, and the need for more effective interventions been recognized. Improved adherence measurement methodology during the past 3 decades has shown that self-report data from parents and children often greatly exaggerated levels of adherence^{2,3} and that long-term child and adult adherence measured through medication refill databases showed a startling “real-world” picture of nonadherence. More than a matter of missing some portion of prescribed doses of medication, refill persistence studies showed that most patients with asthma abandon their controller medication within a year of initial prescription (Fig 2).^{3,4} New strategies for addressing nonadherence have centered on technologies with potential to reach large numbers of patients. HCT tools that can address asthma nonadherence have progressed through 2 phases of development.

Adherence Measurement Devices

The initial inhaler adherence tracking devices (ATDs) were introduced more than 30 years ago for use in clinical trials to document adherence but not as an intervention to change adherence^{5,6} (Fig 1). Although more accurate than self-report adherence questionnaires, these early ATDs were expensive to use and susceptible to breakdown or error.^{7,8} Since their introduction, ATDs have progressed from use of a micro-switch that detected inhaler activation with a metered-dose inhaler (MDI)⁶ to a simple pressure cap placed on top of an MDI canister,⁹ a thermistor to detect medication

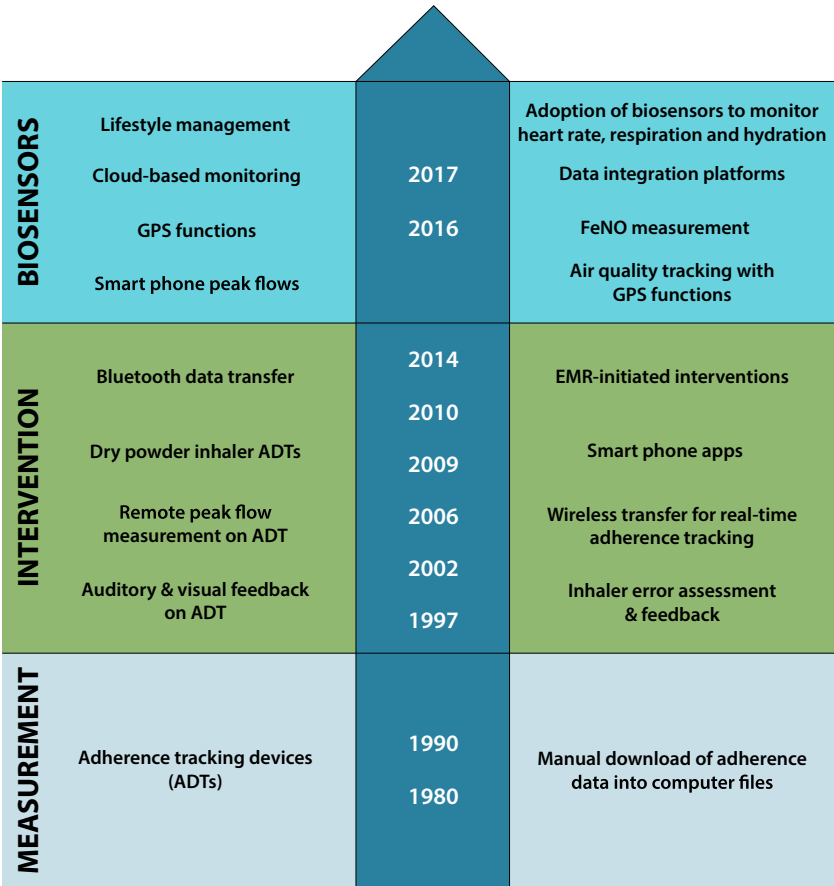


Figure 1. Timeline of existing and new technology emergence. ADT, adherence tracking device; EMR, electronic medical record; FeNO, fractional exhaled nitric oxide; GPS, Global Positioning System.

discharge,¹⁰ devices that can measure dry powder adherence,¹¹ and increasingly sophisticated ADTs that can record not only MDI activation but also quality of inhalation.^{12,13} Over time, these devices became more reliable and less prone to error and have been widely adopted in clinical trials. Two reviews have provided helpful information about commercially available ADTs.^{11,14}

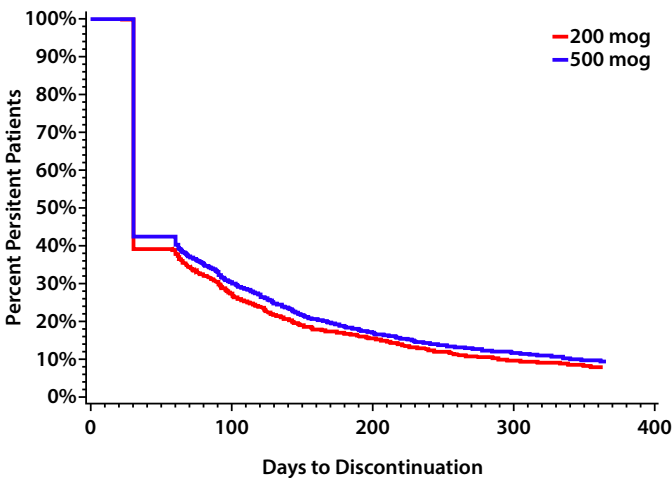


Figure 2. Fluticasone and salmeterol refill rates in 5,500 patients over 365 days. From Bender BG, Pedan A, Varasteh LT. Adherence and persistence with fluticasone propionate/salmeterol combination therapy. *J Allergy Clin Immunol.* 2006;118:899–904.

Atd Adherence Interventions

During the past 30 years, numerous provider-focused adherence interventions have been tested, with only modest success¹⁵ (Fig 3). However, emerging HCT creates new possibilities for greater adherence improvement in large groups of patients. In the progression of technology development, ADTs moved beyond simply measuring adherence to facilitating adherence intervention (Fig 1). ADTs began to adopt the capacity to give direct feedback to patients by visual display or sounds integrated into the device. Well ahead of most of its competition, the SmartMist (Oxnard, California) device provided immediate feedback in the form of a red light signaling excessively rapid or slow inhalation.¹⁶ Other devices have emerged that can detect canister shaking or quality of inhalation^{12,13} and connect by cable, Wi-Fi, or telephone line to a computer.

Communication Technology

The development of smartphone apps that work with ADTs expanded intervention potential with new capacity to reach out and communicate with patients in real time, delivering motivational messages, directing patients to contact their health care provider, or providing adherence reports directly to the provider.^{8,11,14} Two helpful recent reviews compared and contrasted some commercially available ADTs. ADTs can now connect by Bluetooth with smartphone apps to provide further coaching to improve patient adherence.^{14,17} The enormous uptake of mobile cell phones has opened the door to growing enthusiasm for patient and provider adoption of HCT. Communication technology applied to health care includes IVR

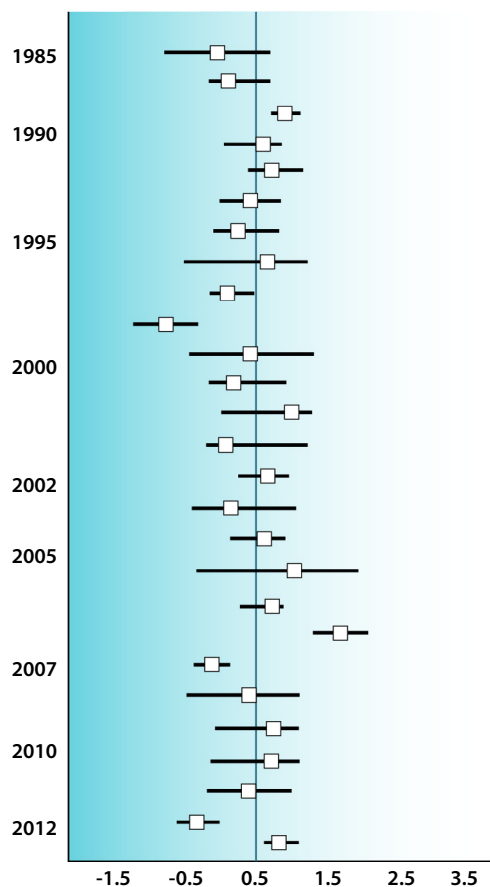


Figure 3. Effect size of adherence interventions. From Bender BG. Nonadherence to asthma treatment: getting unstuck. *J Allergy Clin Immunol Pract.* 2016;4:849–851.

telephone calls, emails, and short message service texts. The rapid expansion of communication technology tools, including websites and mobile apps, has flooded the marketplace.

Many health care providers have encouraged their patients to use one of the more than 500 available asthma apps to communicate with their provider by email or text.¹⁸ At the 2017 and 2018 annual meetings of the American Academy of Allergy, Asthma, and Immunology, 10 individual presentations cited strategies to use communication technology tools, with particular emphasis on smartphones, apps, texts, electronic medical records (EMRs), and patient registries. Similar interest emerged at annual meetings of the American College of Asthma, Allergy and Immunology, signaling that HCT uptake will likely continue among individual practitioners with or without research-based evidence. A recent “re-conceptualization of access for 21st century health care” proposed that the proliferation of HCTs including smartphones, IVR, texts messages, emails, home-based web cams, personal monitoring devices, and web-based clinic portals is continually moving health care away from the traditional conceptualization of in-office visits toward digital “encounterless” use.¹⁹

Providers who direct patients to one of the hundreds of commercial asthma apps could be operating outside US Food and Drug Administration (FDA) guidelines. Excitement about communication technology must be balanced by the recognition of the need for research establishing safety and efficacy of communication technology.²⁰ Safety concerns include the possibility of loss of confidentiality for protected health information, mismatching of data that land in the wrong place or even the wrong medical

record, use of commercial products containing code that does not integrate well with an established EMR, and lack of institutional systems for overseeing and monitoring for data entry or integration errors.²¹ Many ATDs have been studied in randomized trials, included in systematic reviews, supported by evidence of their capacity to improve adherence, and received FDA approval. In contrast, new mobile apps and websites have emerged at a staggering rate and become immediately commercially available with little regard to scientific evaluation. Research-based assessments of some of these products are beginning to appear, but most of these have never been tested in a research study. A recent review identified more than 165,000 available health apps, of which 84 were included in published reviews.²² A second large meta-systematic review identified 10,689 articles addressing the use of short message service texts to improve self-management in patients with a chronic illness.²³ The 2 reviews warned of low-quality studies and a need for better-controlled trials to fully assess the emerging technologies and associated software. A recent report provided a current review of medication adherence app development.²⁴

Biosensors

Biosensors have capability to collect physiologic data in real time, moving beyond adherence alone to create potential for broad health tracking and patient coaching. Wearable biosensors can include devices worn on a wrist or belt or even “smart clothing,” including hats, shirts, rings, belts, shoes, and contact lenses, to monitor heart rate, blood temperature, and even electrocardiography.²⁵ Available asthma technology includes fractional exhaled nitric oxide and pulse oximetry devices that connect directly to a smartphone and using the Global Positioning System already present on the smartphone to provide a broader amount of information about air quality.²⁶

Further into the future, biosensors might eventually include measurement of skin conduction, respiration rate, hydration, sleep patterns, and physical activity level in patients with asthma. These collective data could have the potential to become part of smart platforms to more broadly help manage patient health. Smart platforms are broader systems that gather data and use some variation of artificial intelligence to identify potential exacerbation risks and initiate interventions to prevent them. For example, a group at the Radboud University Nijmegen Medical Centre in The Netherlands created a health platform that linked 2,400 physicians and 66 regional networks, thus combining peer support, medical information, and communication tools to improve management of chronic conditions.²⁷ In the SMART-PD trial, patients with Parkinson disease linked to a platform delivered through the Parkinson’s Tracker App to provide them with information, encourage adherence, and connect them as needed with physicians and other patients and showed improved quality of life compared with the control group.²⁸ Such systems could be capable of directing more elements of the treatment, predicting exacerbations before they occur, and providing motivational feedback to promote healthy behaviors in patient.^{29,30} Although such ideas are exciting to contemplate, new implementation studies are essential to fully test their impact on clinical practice.

Development of Smart Platforms Integrated with EMRs

If use of a smart platform within a large health care system has potential to improve adherence and outcomes at a population level, then integration of the HCT platform must logically include EMR databases. The ultimate objective is to create and test HCT platforms that can easily be adopted in different health care and EMR systems. Such complete systems are in development and

being tested. For example, Kaiser Permanente, one of the nation's largest nonprofit health care systems serving 9 million patients, has been innovative in the application of HCTs. Kaiser Permanente Northwest reported on a large pragmatic controlled study involving 8,517 adults with asthma randomized to an IVR condition or control. When a corticosteroid refill was more than 60 days overdue, the IVR system automatically called the patient, asked questions, and provided information to promote an increase in adherence.³¹ Information from the EMR database, including the name of the physician, and medication, was included in the computer-generated IVR call.

Building on that study, researchers from the Institute for Health Research at Kaiser Permanente Colorado developed a similar automated outreach program to contact parents of children with asthma who had discontinued their use of inhaled corticosteroids. The call was further tailored with parent responses to questions contained in the call about the parent's desire for more information, to speak with an asthma nurse, or to be assisted in filling a medication. Families in the intervention group were 25% more adherent over a period of 24 months, although no changes were reflected in hospitalizations or urgent care visits.³² In a subsequent ongoing study, the Institute for Health Research group has further developed an automated system that identifies EMR database risk factors such as inhaled corticosteroid under-filling or frequent requests for β_2 -agonist refills to reach out to adults with asthma by email, text, or IVR telephone calls to prevent exacerbations (National Institutes of Health grant R01 HL126125-010). Within Kaiser Permanente, positive results from the pediatric study have become part of standard operating procedure; all patients 18 to 65 years of age now routinely receive automated IVR calls when a corticosteroid refill is more than 60 days overdue.³³ Although the IVR calls did not decrease urgent care visits in the pediatric study,³² their adoption was based on improved adherence and decrease in the number of live nursing call outreach to nonadherent patients.³³ The HCT platforms developed at Kaiser Permanente have not been exported to other health care systems, but other systems have developed their own platforms. For example, Geisinger Health in Pennsylvania has created Geisinger in Motion, a platform that includes a patient portal, iPads given to patients during hospital stays, and "patient mobile solutions" that include a system of text message reminders, access to prescription refills, and patient education materials (www.geisinger.org).

Closing the Gaps

Currently, few HCT systems are supported by sufficient data to endorse large-scale adoption in clinical practice. Most mobile apps have not been tested with any scientific rigor. Without such evaluation, there is no proof that apps or HCT systems, despite being heavily marketed, will not create new problems or have a negative effect on quality of life.³⁴ Fortunately, a rapidly growing body of literature is now establishing the potential of apps to improve health. Two recent reviews of asthma apps identified some to be of adequate quality for clinical use¹⁸ but also concluded that most require further testing to assure their value in practice.³⁵ One systematic review of 10 randomized trials testing smartphone apps identified a capacity to improve asthma self-management and, in 1 study, to decrease hospital admissions.³⁶ Data from randomized trials of diseases other than asthma provide additional evidence of improved outcomes. For example, apps directed at cardiovascular disease significantly improved adherence and, subsequently, blood pressure, body mass index, cholesterol, and hospitalization rates.³⁷ In another review, collective evidence from diabetes app trials showed significantly improved hemoglobin A_{1c} compared with control groups.³⁸

Further attempts to establish the full impact of HCT interventions must continue to test them on a large scale over longer periods. Results from carefully controlled efficacy studies often fail to change clinical practice.³⁹ Effectiveness, or implementation research, is intended to overcome that failing by conducting studies that occur in the "real world" (ie, diverse clinical settings, with existing clinical staff and patients who have comorbidities) to determine whether interventions are effective in the real world.^{40,41} My colleagues and I described the series of translational steps that can guide behavioral intervention research from initial observational studies to the development of health behavior models, efficacy studies, and eventually large-scale implementation research studies⁴² (Fig 4). Technology-driven, behavior-change research can follow this same sequence by adopting implementation research evaluation models such as the RE-AIM framework⁴³ to gather the evidence necessary to establish the real value of HCT interventions.⁴³

Conclusion

New HCT developments are emerging at a rapid pace. Collectively, these advances move beyond adherence promotion and are beginning to gather additional biosensor data. These data in turn create an opportunity for improved asthma management. HCTs have captured the attention of many health care providers, health care systems, and commercial developers. However, directives addressing how to adopt and use them in health care delivery have not been established. Clear guidelines for adopting secure and reliable HCT and wearable biosensors are lacking. A study from an Australian medical center concluded that many physicians were using smartphone technology to communicate with patients, often creating their own policies without reference to external guidelines.⁴⁴ A recent review of patient-directed mobile HCT identified concerns that included information security compromise, technology failure, and inability to navigate technology, particularly for older patients. Nonetheless, the same group saw potential benefits that included improved communication, access to providers, and convenience.⁴⁵ Four conclusions based on current knowledge follow to help providers navigate these challenges.

Security and Safety for HCT

Health care providers must first and foremost take great care to assure that HCT adoption does not compromise patient safety or security of transmitted information. It is essential to prevent access to protected health information contained in texts, emails, or other information passing between patients and providers including information transmitted from biosensors. Any use of protected health information must align with guidelines put in place by the Health Insurance Portability and Accountability Act (HIPAA), the Federal Trade Commission Act, the Federal Trade Commission's Health Breach Notification Rule, and the Federal Food, Drug, and Cosmetic Act.

Providers could inadvertently create potential danger when patients who are experiencing life-threatening symptoms expect but do not receive an immediate response when attempting to use communication technology to ask for help. Many systems give clear communications at the beginning or ending of a text or email instructing patients with immediate concerns to call their health care facility or 911. The use of multiple biosensors (eg, ATDs, fractional exhaled nitric oxide technology, activity monitors) could help identify patients at risk for an exacerbation, but without research and guidelines in place, providers could compromise patient safety when they rely on experimental risk-identification formulas. The FDA has standards for use and approval of "mobile medical applications." The FDA gives this admonition: "When they are marketed, promoted or intended for use in the diagnosis of disease or other

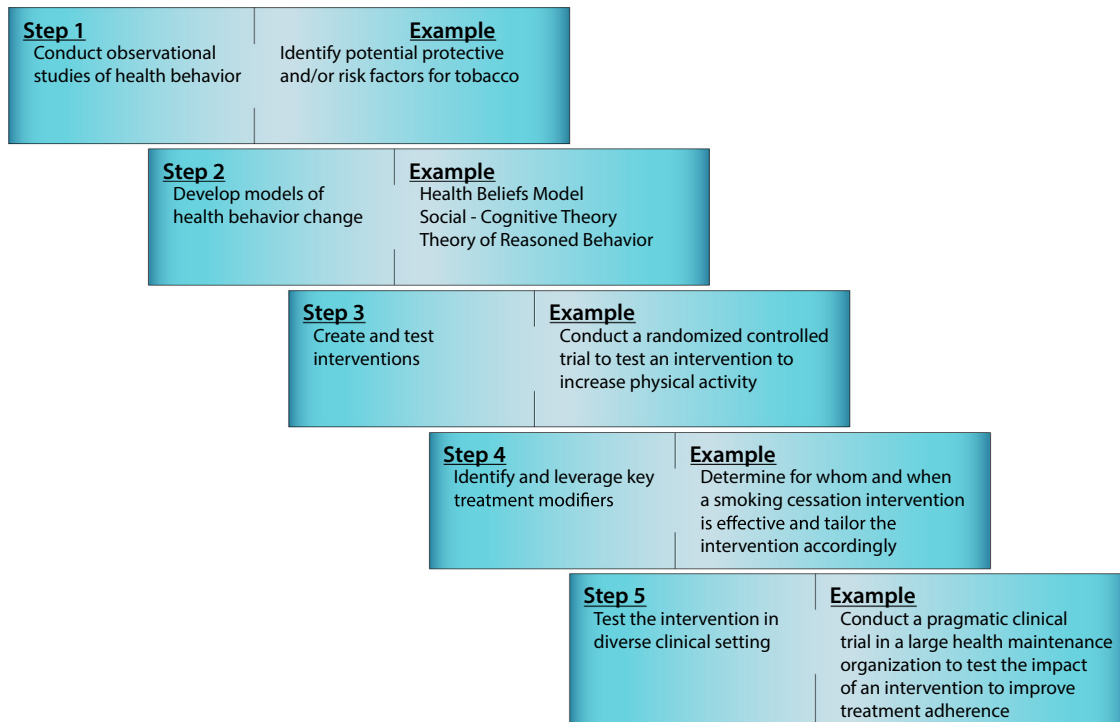


Figure 4. Translational sequence for health behavior research. From Bender BG, Aloia MS, Rankin AE, et al. Translational behavioral research in respiratory medicine. *Chest*. 2011;139:1279–1284.

conditions, or in the cure, mitigation, treatment, or prevention of disease, or otherwise meet the definition of medical device, FDA intends to exercise enforcement discretion.”⁴⁶ Websites from HealthIT.gov (<https://www.healthit.gov/resource/your-mobile-device-and-health-information-privacy-and-security>) and the FDA (<https://www.fda.gov/MedicalDevices/DigitalHealth/MobileMedicalApplications/default.htm>) provide some guidance for use of mobile devices and apps that include health information.

Provider Responsibility in the Use of HCT

Use of HCTs carries with it a responsibility for data security and patient safety. Any HCT is classified by the FDA and subject to their approval. The FDA has approved 36 health apps and devices. FDA-approved ATDs include the SmartTouch (Adherium Ltd, Auckland, New Zealand), MDILog (Medtrac Technologies; Lakewood, Colorado), SmartTrack (Nexus6 Ltd, Auckland, New Zealand), and Propeller Health (Propeller Health, Madison, Wisconsin) devices. Several reviews have offered comparisons between ATDs to help clinicians and researchers make an informed choice.^{14,17} Guidelines also exist for assessing new health apps.⁴⁷ Before recommending specific apps or online disease management tools, health care providers must be confident of the integrity of the tool they are recommending. Some national organizations are beginning to offer guidelines about app-based provider-patient communication tools, including the United Kingdom’s National Health Service and the United States’ National Library of Medicine, National Cancer Institute, Fogarty International Center, and National Institute for Mental Health.

HCTs and Wearable Biosensors Can Complement but Not Replace Provider-Patient Engagement

Emerging technologies are gaining an important role in the management of asthma but cannot replace the relationship between patient and provider requisite to adherence change. A growing consensus indicates that technology-based tools can augment

effective communication, care coordination, and efficiency.^{15,48–53} Guided by the principles of patient-centered care, effective provider communication strategies rest on the importance of listening to and addressing patient concerns, discussing treatment options, allowing patients a voice in choosing the treatment they prefer, and prescribing only when patients clearly indicate their commitment to sustained adherence.^{54,55} Shared decision making, which emphasizes working to increase patient-provider concordance about treatment goals and choices, can lead to greater adherence, greater satisfaction with care, and decreased exacerbations in patients with asthma.⁵⁶ Motivational interviewing is another behavioral communication strategy that, although time consuming in its original form, has evolved into a briefer version that can be adopted for patients with asthma.⁵⁷ Such provider-patient communication efforts could eventually be integrated with emerging technology to create systems of ongoing engagement aimed at improving adherence and asthma control. Future research can help clarify the specific combinations of provider communication strategies, communication devices, biosensors, and tailored technology-based messages to generate the greatest and most cost-effective changes to health behavior.

References

- [1] Williams LK, Pladevall M, Xi H, et al. Relationship between adherence to inhaled corticosteroids and poor outcomes among adults with asthma. *J Allergy Clin Immunol*. 2004;114:1288–1293.
- [2] Krishnan JA, Bender BG, Wamboldt FS, et al. Adherence to inhaled corticosteroids: an ancillary study of the Childhood Asthma Management Program clinical trial. *J Allergy Clin Immunol*. 2012;129:112–118.
- [3] Bender BG, Pedan A, Varasteh LT. Adherence and persistence with fluticasone propionate/salmeterol combination therapy. *J Allergy Clin Immunol*. 2006;118:899–904.
- [4] Bender BG, Hernandez Vecino RA, McGrath K, et al. Comparative analysis of persistence to treatment among patients with asthma or COPD receiving AirFluSal Forspiro or Seretide Diskus salmeterol/fluticasone propionate combination therapy. *J Allergy Clin Immunol Pract*. 2016;4:884–889.
- [5] Tashkin DP, Rand C, Nides M, et al. A nebulizer chronolog to monitor compliance with inhaler use. *Am J Med*. 1991;91(suppl 4A):33S–36S.

- [6] Nides MA, Tashkin DP, Simmons MS, et al. Improving inhaler adherence in a clinical trial through the use of the nebulizer chronolog. *Chest*. 1993;104:501–507.
- [7] Wamboldt FS, Bender BG, O'Connor SL, et al. Reliability of the model MC-311 MDI chronolog. *J Allergy Clin Immunol*. 1999;104:53–57.
- [8] Chan AH, Harrison J, Black PN, et al. Using electronic monitoring devices to measure inhaler adherence: a practical guide for clinicians. *J Allergy Clin Immunol Pract*. 2015;3:335–349, e331–e335.
- [9] Bender B, Wamboldt FS, O'Connor SL, et al. Measurement of children's asthma medication adherence by self report, mother report, canister weight, and Doser CT. *Ann Allergy Asthma Immunol*. 2000;85:416–421.
- [10] Bartlett SJ, Lukk P, Butz A, et al. Enhancing medication adherence among inner-city children with asthma: results from pilot studies. *J Asthma*. 2002;39:47–54.
- [11] Howard S, Lang A, Patel M, et al. Electronic monitoring of adherence to inhaled medication in asthma. *Curr Respir Med Rev*. 2014;10:50–63.
- [12] Julius SM, Sherman JM, Hendeles L. Accuracy of three electronic monitors for metered-dose inhalers. *Chest*. 2002;121:871–876.
- [13] Foster JM, Smith L, Usherwood T, et al. The reliability and patient acceptability of the SmartTrack device: a new electronic monitor and reminder device for metered dose inhalers. *J Asthma*. 2012;49:657–662.
- [14] Kikidis D, Konstantinos V, Tzovaras D, et al. The digital asthma patient: the history and future of inhaler based health monitoring devices. *J Aerosol Med Pulm Drug Deliv*. 2016;29:219–232.
- [15] Bender BG. Nonadherence to asthma treatment: getting unstuck. *J Allergy Clin Immunol Pract*. 2016;4:849–851.
- [16] Farr SJ, Rowe AM, Rubsamen R, et al. Aerosol deposition in the human lung following administration from a microprocessor controlled pressurised metered dose inhaler. *Thorax*. 1995;50:639–644.
- [17] Chan AH, Reddel HK, Apter A, et al. Adherence monitoring and e-health: how clinicians and researchers can use technology to promote inhaler adherence for asthma. *J Allergy Clin Immunol Pract*. 2013;1:446–454.
- [18] Tinschert P, Jakob R, Barata F, et al. The potential of mobile apps for improving asthma self-management: a review of publicly available and well-adopted asthma apps. *JMIR Mhealth Uhealth*. 2017;5:e113.
- [19] Fortney JC, Burgess JF Jr, Bosworth HB, et al. A re-conceptualization of access for 21st century healthcare. *J Gen Intern Med*. 2011;26(suppl 2):639–647.
- [20] Ventola CL. Social media and health care professionals: benefits, risks, and best practices. *P T*. 2014;39:491–520.
- [21] Committee on Patient Safety and Quality Improvement Committee of Practice Management. Committee opinion no. 621: patient safety and health information technology. *Obstet Gynecol*. 2015;125:282–283.
- [22] Sharp M, O'Sullivan D. Mobile medical apps and mHealth devices: a framework to build medical apps and mHealth devices in an ethical manner to promote safer use—a literature review. *Stud Health Technol Inform*. 2017;235:363–367.
- [23] Marcolino MS, Oliveira JAQ, D'Agostino M, et al. The impact of mHealth interventions: systematic review of systematic reviews. *JMIR Mhealth Uhealth*. 2018;6:e23.
- [24] Ahmed I, Ahmad NS, Ali S, et al. Medication adherence apps: review and content analysis. *JMIR Mhealth Uhealth*. 2018;6:e62.
- [25] Ajami S, Teimouri F. Features and application of wearable biosensors in medical care. *J Res Med Sci*. 2015;20:1208–1215.
- [26] Lucas RW, Dees J, Reynolds R, et al. Cloud-computing and smartphones: tools for improving asthma management and understanding environmental triggers. *Ann Allergy Asthma Immunol*. 2015;114:431–432.
- [27] van der Eijk M, Faber MJ, Aarts JW, et al. Using online health communities to deliver patient-centered care to people with chronic conditions. *J Med Internet Res*. 2013;15:e115.
- [28] Lakshminarayana R, Wang D, Burn D, et al. Using a smartphone-based self-management platform to support medication adherence and clinical consultation in Parkinson's disease. *NPJ Parkinsons Dis*. 2017;3:2.
- [29] Bender BG. Technology interventions for nonadherence: new approaches to an old problem. *J Allergy Clin Immunol Pract*. 2018;6:794–800.
- [30] Dima AL, de Bruin M, Van Ganse E, et al. Mapping the asthma care process: implications for research and practice. *J Allergy Clin Immunol Pract*. 2016;4:868–876.
- [31] Vollmer WM, Feldstein A, Smith DH, et al. Use of health information technology to improve medication adherence. *Am J Manag Care*. 2011;17(12 Spec No):SP79–SP87.
- [32] Bender BG, Cvietusa PJ, Goodrich GK, et al. Pragmatic trial of health care technologies to improve adherence to pediatric asthma treatment: a randomized clinical trial. *JAMA Pediatr*. 2015;169:317–323.
- [33] Cvietusa PJ. Implementing health care research technology to improve asthma management. *J Allergy Clin Immunol*. 2018;141:AB406.
- [34] Piwek L, Ellis DA, Andrews S, et al. The rise of consumer health wearables: promises and barriers. *PLoS Med*. 2016;13:e1001953.
- [35] Huckvale K, Morrison C, Ouyang J, et al. The evolution of mobile apps for asthma: an updated systematic assessment of content and tools. *BMC Med*. 2015;13:58.
- [36] Farzandipour M, Nabovati E, Sharif R, et al. Patient self-management of asthma using mobile health applications: a systematic review of the functionalities and effects. *Appl Clin Inform*. 2017;8:1068–1081.
- [37] Coorey GM, Neubeck L, Mulvey J, et al. Effectiveness, acceptability and usefulness of mobile applications for cardiovascular disease self-management: systematic review with meta-synthesis of quantitative and qualitative data. *Eur J Prev Cardiol*. 2018;25:505–521.
- [38] Bonoto BC, de Araujo VE, Godoi IP, et al. Efficacy of mobile apps to support the care of patients with diabetes mellitus: a systematic review and meta-analysis of randomized controlled trials. *JMIR Mhealth Uhealth*. 2017;5:e4.
- [39] Westfall J, Mold J, Fagnan L. Practice-based research—“Blue Highways” on the NIH roadmap. *JAMA*. 2007;297:403–406.
- [40] Bender BG, Krishnan JA, Chambers DA, et al. American thoracic society and national heart, lung, and blood institute implementation research workshop report. *Ann Am Thorac Soc*. 2015;12:S213–S221.
- [41] Tunis SR, Stryer DB, Clancy CM. Practical clinical trials: increasing the value of clinical research for decision making in clinical and health policy. *JAMA*. 2003;290:1624–1632.
- [42] Bender BG, Aloia MS, Rankin AE, et al. Translational behavioral research in respiratory medicine. *Chest*. 2011;139:1279–1284.
- [43] Glasgow RE, Dickinson P, Fisher L, et al. Use of RE-AIM to develop a multimedia facilitation tool for the patient-centered medical home. *Implement Sci*. 2011;6:118.
- [44] Nerminathan A, Harrison A, Phelps M, et al. Doctors' use of mobile devices in the clinical setting: a mixed methods study. *Intern Med J*. 2017;47:291–298.
- [45] Abelson JS, Kaufman E, Symer M, et al. Barriers and benefits to using mobile health technology after operation: a qualitative study. *Surgery*. 2017;162:605–611.
- [46] US Food and Drug Administration. Mobile medical applications. https://google2.fda.gov/search?q=mobile+medical+applications&client=FDAgov&site=FDAgov&lr=&proxystylesheet=FDAgov&requiredfields=archive%3AYes&output=xml_no_dtd&getfields=*. Accessed June 12, 2018.
- [47] Stoyanov SR, Hides L, Kavanagh DJ, et al. Mobile app rating scale: a new tool for assessing the quality of health mobile apps. *JMIR Mhealth Uhealth*. 2015;3:e27.
- [48] Patel MS, Asch DA, Volpp KG. Wearable devices as facilitators, not drivers, of health behavior change. *JAMA*. 2015;313:459–460.
- [49] Bender B, Depew A, Emmett A, et al. A patient-centered walking program for COPD. *J COPD Found*. 2016;3:769–777.
- [50] Kurti AN, Davis DR, Redner R, 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;2:128–152.
- [51] Badawy SM, Kuhns LM. Economic evaluation of text-messaging and smartphone-based interventions to improve medication adherence in adolescents with chronic health conditions: a systematic review. *JMIR Mhealth Uhealth*. 2016;4:e121.
- [52] Head KJ, Noar SM, Iannarino NT, et al. Efficacy of text messaging-based interventions for health promotion: a meta-analysis. *Soc Sci Med*. 2013;97:41–48.
- [53] Granger BB, Bosworth HB. Medication adherence: emerging use of technology. *Curr Opin Cardiol*. 2011;26:279–287.
- [54] Irwin RS, Richardson ND. Patient-focused care: using the right tools. *Chest*. 2006;130(suppl):735–825.
- [55] Bender BG, Oppenheimer J. The special challenge of nonadherence with sublingual immunotherapy. *J Allergy Clin Immunol Pract*. 2014;2:152–155.
- [56] Wilson SR, Strub P, Buist AS, et al. Shared treatment decision making improves adherence and outcomes in poorly controlled asthma. *Am J Respir Crit Care Med*. 2010;181:566–577.
- [57] Borrelli B, Riekert K, Weinstien A. Brief motivational interviewing as a clinical strategy to promote asthma medication adherence. *J Allergy Clin Immunol*. 2007;120:1023–1030.