Telemedicine (TM) has become a popular method of accessing medical services between providers and patients and is viewed as a cost-effective alternative to more traditional episodic face-to-face encounters. TM overcomes 2 barriers that patients face when seeking health care: distance and time. It is as effective as in-person visits for outpatient treatment of asthma, and it is a convenient way to provide inpatient consultations for patients when the allergist practices outside of the hospital. TM also has been used to manage patients with asthma in schools. Patients tend to be as satisfied with TM or they prefer TM over in-person visits for outpatient treatment of asthma, and it is a cost-effective alternative to more traditional types of visits that involve episodic face-to-face encounters. TM facilitates patient access to allergy services. As patients take more control of their health care, use of TM is likely to increase because a large part of the move to adopt TM is driven by patient preference. (J Allergy Clin Immunol 2020;145:445-54.)

Telemedicine (TM) is defined by the Centers for Medicare & Medicaid Services as “the use of telecommunications and information technology to provide access to health assessment, diagnosis, intervention, consultation, supervision and information across distance.” TM has become an increasingly popular method for accessing medical services between providers and patients and is viewed as a cost-effective alternative to more traditional types of visits that involve episodic face-to-face encounters.
encounters. As patients take more control of their health care, it seems inevitable that this type of encounter will increase because a large part of the move to adopt TM is driven by patient preference. The use of TM can be traced back to as early as 1948.7 Currently, the technology is widely used across many medical specialties including Neurology, Ophthalmology, Psychiatry, Dermatology, and Allergy.8

Unlike models of health care that focus on continuous improvement of the current system, the use of TM, particularly when combined with information technologies such as electronic health records (EHRs), has the potential to cause a transformational change in the way care is delivered by altering the process of interaction between patient and provider. Currently, it has undergone 5 of the 9 steps of transformational change described by Tipton (see Table 1)9 and is now moving beyond Tolerance toward Acceptance by most health care organizations. Once the technology has passed the tolerance stage, it is difficult to return to the old way of care, which was restricted to episodic in-person visits. The move toward continuous healing relationships between patients and providers has become inevitable. We anticipate rapid movement toward Agreement and eventually expect Advocacy to become widespread.

TM is on its way to becoming routine in medical practice. It is likely that in the future, the terms tele-, mobile, virtual, remote, distant, facilitated, and nonfacilitated all will become obsolete as their use becomes routine.4 The use of TM will be simply seen as how health care is done. The assumption is that if technology can deliver what the patient needs to where the patient is located when they want it, then it will happen.

Traditionally, patient care has centered around discrete visits to a health care provider who uses information obtained during the visit to make a diagnosis and to recommend treatment. This places the provider in a gatekeeper position because many treatments cannot be obtained without either a prescription or a provider’s order. Patients who want to manage their own health without seeking a provider’s input have limited resources for doing so including over-the-counter medications, homeopathic treatments, and alternative medicine remedies. Most effective treatment options are unavailable unless a provider gives access to it. In theory, this is because patients lack enough medical knowledge to determine what they need and to use prescription treatments effectively and safely. The problem with this model of care is that it is expensive, inconvenient, and in some cases unnecessary.

In general, patients who want on-demand services frequently seek care in urgent care facilities. According to Consumer Reports, the number of urgent care facilities has increased from 6400 in 2014 to 8100 in 2018.8 The use of TM may be able to reduce unnecessary urgent care visits by delivering a convenient alternative while also providing continuity of care for patients. In one study of 28,222 TM encounters between 24,040 patients and 277 primary care physicians, respiratory infections were diagnosed in 35% of encounters and 69% resulted in a prescription. Had the patients not used TM, 43% of the patients reported that they would have gone to an urgent care or retail clinic instead, 29% would have gone to their doctor’s office, 15% would have done nothing, and 6% would have gone to an emergency department.9 So, although TM is not the only alternative to urgent care, it provides a convenient care equivalent that allows for diagnosis and treatment.

Although TM does not remove the provider from a central role in guiding medical care, it can reduce the inconvenience and expense of obtaining it. TM overcomes 2 barriers that patients face when seeking health care: distance and time. TM also alters the dynamics of medical encounters by placing an artificial barrier between patients and providers. This slightly reduces the provider’s authority as the central health care professional, and therefore it equalizes the hierarchy between the provider and the patient. Some patients prefer that because they feel more empowered to state their concerns and express their desires without feeling intimidated by the provider. This may account for the observation that patients tend to be equally satisfied with TM or they prefer TM over in-person visits, but infrequently they do prefer in-person visits.10

Another important reason that the use of TM has increased is its impact on health care costs. Physicians are increasingly facing pressure to meet relative value unit goals. No-show appointments or cancellations can place a financial burden on providers.11
Missed health care appointments are estimated to cost $150 billion to the US health care system. TM can not only serve to improve access to rural communities but may also be valuable in filling no-show slots on a provider’s clinic schedule. Reasons for no-shows include work restrictions, transportation, forgetfulness, and a perceived lack of value on the part of the patient. By making follow-up appointments more accessible through TM, these barriers can be minimized, leading to fewer no-shows and improved patient compliance. A study from Alaska in collaboration with Mayo Clinic for high-risk patients with breast cancer demonstrated a low percentage of no-shows to the clinic (3.3%) while maintaining high patient satisfaction. In addition, although it is thought that TM would only be useful in those rural settings where there is a high demand for access to care, we also see value of TM in urban settings. Studies have demonstrated the benefit of TM in urban settings as well for monitoring blood pressure and telepsychiatry.

**TM: THE NUTS AND BOLTS**

The nuts and bolts of getting started with TM and how to use it in clinical practice have been reviewed recently. Basically, before implementing a TM program it is necessary to determine which aspects of health care could be improved with the use of the technology and then to arrange to provide them that way. There are many perceived barriers that practices and practitioners face when implementing TM. These include the need to learn how to use the technology and a concern that patient care will be compromised by its use. In addition to poorer patient outcomes, providers are concerned that the provider-patient relationship will be diminished, leading to reduced patient satisfaction.

The most common barrier that allergists face is simply knowing how to get started. Although it is possible to obtain the necessary equipment and supplies to implement a TM service, the requirements may seem daunting at first. For that reason, many first-time TM providers initially contract with one of the TM platforms. These offer various options.

One option is for a provider to join an online practice. This space is largely dominated by companies that provide health care services to employers and health plans, such as American Well (www.americanwell.com), Teladoc (www.teladoc.com), MdLive (www.mdlive.com), or Doctor on Demand (www.doctorondemand.com). These companies largely provide virtual urgent care services, although virtual primary care is an area gaining traction. Another option is to use an established platform only for the technical aspects of TM while maintaining control of a private practice. This could be used to see patients who live at a distance, extend hours of service to evenings and weekends, and provide on-call services. A provider may also opt to provide asynchronous TM services. One option is to join a platform that provides e-consultations to other practices such as Rubicon MD (www.rubicommd.com) and AristaMD (www.aristamd.com). Another option involves joining a practice that reviews patient-entered health information and makes treatment decisions on the basis of those data inputs such as DirectDerm (www.directderm.com), Curology (www.curology.com), Lemonaid (www.lemonaidhealth.com), and Zipnosis (www.zipnosis.com). And similarly, to the synchronous TM space, a practice may opt to include these capabilities (text, photo upload, online intake) in their practice. It is important to note, however, that to date reimbursement exists only for synchronous TM encounters and remote patient monitoring (RPM).

**PATIENT CARE**

When used for patient care, TM can be separated into triage or second opinion care, proxy care, and virtual visits. One use of triage or second opinion care TM is to screen patient appointments for appropriateness. An example of this is the use of e-consults in which a referring provider sends a brief description of their patient with specific questions to a specialty service for review and recommendations regarding treatment. In one study, 13.4% of e-consults sent to an allergy service resulted in diagnostic, therapeutic, or alternative referral recommendations, 59.8% resulted in an in-person Allergy/Immunology consult, and the rest required additional information before a recommendation could be made. This led to reduced wait times for in-person visits despite an increase in the overall number of consults to the allergy service.

Proxy care involves the use of TM-based virtual intensive care units or emergency departments, which provide intensive care or emergency specialist expertise to patients who need specialized care when providers with less expertise are present on site. Using TM, an intensivist can guide an on-site provider in the care of patients with complex problems. This virtual intensive care unit model has been shown to improve mortality and/or length of stay as well as staff acceptance, particularly in rural areas with specific patient populations. Staicu et al described a program of inpatient allergy consults to perform penicillin testing using TM when a physician assistant was present at the patient’s location. An allergist guided the consult using TM by interpreting antibiotic skin test results and recommending oral challenges.

**Virtual visits**

Virtual visits are used to connect patients and providers when an in-person visit is inconvenient and not necessary (see Fig 1). Such visits can occur synchronously (the patient and the provider are online at the same time) or asynchronously (the patient and the provider are not online at the same time). Both types of virtual visits overcome the barrier of distance by permitting the encounter to occur without the patient having to travel to where the provider is located. Asynchronous visits also overcome the barrier of time by permitting encounters to occur without the need to schedule the patient and the provider to be online at the same time.

**Asynchronous patient care**

Asynchronous care occurs when the patient and the provider are not online at the same time. Two types of asynchronous care include store & forward and RPM, which is discussed later in this review. Store & forward occurs when clinical information (eg, imaging studies, laboratory results, procedure results, and patient questions) are sent from one location to an intermediate location where the information is stored (see Fig 1). A provider subsequently accesses the information for interpretation and patient management. The advantage of this is that patients and providers do not need to be available at the same time and they both can be located anywhere. Patients can travel for medical tests to a facility that is convenient to them and providers can access test results as soon as they are available, reducing waiting times. Recommendations also can be communicated asynchronously, though it also may be necessary to have a synchronous visit to discuss test results depending on the nature of the information.
Examples of store & forward include imaging results from a remote radiology location, laboratory results, images of a rash sent to a dermatologist for diagnosis, pulmonary function tests, and patient portals that permit communication between a patient and the provider. Patients also can use this technology to schedule office appointments and to rate providers on Web sites.

**Synchronous patient care**

The use of TM for synchronous patient care can be done using either facilitated or unfacilitated visits (Fig 1). The difference between the need for these types of visit is whether a complete physical examination is necessary. In an unfacilitated visit, patients use their own equipment to connect with the provider. As a result, they can be located virtually anywhere that has an Internet connection, though some states limit this to specified types of locations such as hospitals, clinics, schools, and patient homes. Although a complete physical examination inclusive of listening to the heart and lungs or visualizing the tympanic membrane is not available for this type of visit, unless the patient has purchased a peripheral device (eg, digital stethoscope and otoscope), an examination reliant upon observation (evaluation of general appearance, palor, skin conjunctiva, oropharynx) and patient participation (eg, patient self-palpation of the sinuses, abdomen, following commands for neurologic and musculoskeletal) can provide substantial information depending on the condition being evaluated. Unfacilitated visits also have been referred to as direct-to-consumer encounters. This is because the visit is being initiated by the patient as opposed to by the provider.

Facilitated visits require a patient to travel to a facility where digital examination equipment and a facilitator are available to perform an examination (see Fig 1). This is referred to as the near location to emphasize the patient’s importance in the interaction. During a facilitated visit, the patient uses the provider’s equipment. The near location should be equipped with a TM room that is designed to look like a traditional examination room. The TM equipment usually is incorporated into the room in as unobtrusive a manner as possible. Although the necessary credentials of the telefacilitator are not defined, for allergy visits the facilitator usually is a nurse or respiratory therapist. Recently, a telehealth facilitator certificate program has been described, which hopefully will standardize this role. A clinical TM cart with a camera, microphone, and speaker provides the 2-way video connection between the near and distant locations. It should permit transmission of information from digital examination equipment to the provider.

The provider is located at the distant location. This can be anywhere that has a reliable Internet connection. The provider should see the patient in a screen that is near to the camera so that the patient sees the provider looking at them (Fig 2). A typical arrangement consists of 2 screens: one for patient interaction and the other for interaction with the EHR. The video connection with the patient often permits 2 windows to be open: one to see the patient and the other to examine parts of the patient’s body using high-resolution cameras.

Facilitated visits are typically scheduled in advance unless a walk-in clinic model has been established. Because visits tend to be the same length or slightly shorter, patient visits initially can be
scheduled using the same time slots as are used for in-person visits. Once the provider has experience with TM, the duration of visits can be modified as needed. Unfacilitated visits lend themselves to more of an on-demand or same-day model but can also be scheduled in advance.

A facilitated visit is desirable when additional objective information is needed such as vital signs, auscultation with a digital stethoscope for a heart and lung examination, and visualization with a digital otoscope or high-resolution camera for an ear or nasal examination. Pulmonary function tests and blood draws usually also are available during a facilitated visit though they also can be ordered and performed at a different nearby facility. A physical examination is necessary for Current Procedural Terminology coding of an initial encounter or if an examination is medically necessary for an established patient. Therefore, if the visit is unfacilitated, the encounter type has to be appropriate to the type of physical examination that is necessary to make a diagnosis.

Patients who do not require a physical examination can be seen and their visits billed without a facilitated visit. Established patients can still be seen without doing an examination; however, initial visits require an examination, and so health plans cannot be billed for unfacilitated initial visits. An alternative model is to charge a flat fee for a visit (typically $49.95 for primary care and $79.95 for specialty care). Many health plans subsidize this type of visit to incentivize patients to use TM rather than go to an urgent care center.

A criticism of unfacilitated visits for urgent care of respiratory infections is that there is an increased tendency for providers to prescribe antibiotics. In one study of 8437 encounters with 85 providers, 66% resulted in prescription of an antibiotic. Patients who received an antibiotic tended to be more satisfied with their visit than those who did not. In addition, there is variability in terms of quality of the video connection. The American Telemedicine Association has proposed guidelines for clinical TM encounters. They recommend that several quality review metrics be routinely assessed, including equipment or connectivity failures, number of attempted and completed visits, patient and provider satisfaction and complaints, measures of whether the visit was appropriate for a virtual encounter, and adherence to established standards of care, such as Healthcare Effectiveness and Data Information Set measures for antibiotic prescribing.

The results of asthma management using TM have been reported in a few studies. Brown and Odenthal described a prospective cohort study in which 20 patients who live in rural North Dakota were seen by TM for asthma management. After 12 months, improvements were seen in Asthma Control Test scores (up from 18.3 to 21.3) and in FEV1 predicted (up from 87.1% to 89.1%). Because this was a cohort study, direct comparison with a group that had in-person visits was not performed. In another study by Portnoy et al., asthma control in 69 children seen by TM was compared with asthma control in 100 children who had in-person visits. A total of 34 in-person and 40 TM patients completed 3 visits over 6 months. Patients in both groups had a small improvement in asthma control over time. The study demonstrated that there was a 95% probability that asthma control was not inferior when care was delivered by TM as opposed to in-person visits. The authors emphasized that they did not expect control to be superior when care was provided by TM. The goal was to show that outcomes are not diminished when TM is used.

Multiple studies have demonstrated the effectiveness of using TM on health care costs as well as patient satisfaction. A recent study published on the use of TM for penicillin skin testing demonstrated a high satisfaction level from patients. On a scale of 0 (strongly disagree) to 5 (strongly agree), patients reported an average score of 4.5 for satisfaction with the TM encounter. The total cost savings including physician time and antibiotic savings per patient were estimated to be $510 per patient. In addition, a retrospective analysis was performed at Henry Ford Hospital, looking at 184 TM visits between 2015 and 2018. Multiple insurance companies covered up to 67% of the costs for the patient, with the patient out-of-pocket cost averaging $12.55. Although facilities can still charge site fees with facilitated visits, this method of health care delivery could be largely cost beneficial to patients.

### PROVIDER-PATIENT RELATIONSHIP

One issue that frequently comes up is whether a provider-patient relationship can effectively be established and maintained using TM. Some clinicians are concerned that TM visits will negatively affect patient-provider relationships and cause patient opposition. However, studies have shown high satisfaction and acceptance with telehealth consultations even among older patients. Recommendations to avoid potential disapproval include starting with a pilot project and moving forward gradually.

Some providers feel that seeing a patient in-person is important because it provides an opportunity for informal conversation and for “getting to know the patient.” Encounters using TM do tend to be shorter and there tends to be less chit-chat. The question is whether this interferes with effective communication and development of a healing relationship.

Despite the shorter visits that are more problem-oriented, satisfaction surveys show that patients report 95% to 100% satisfaction when compared with traditional, in-person encounters. The most common factors that drive patient satisfaction in favor of TM include reduced distance driven,
less time overall, and the convenience it offers, particularly if the patient can be seen from home or work. Many patients also describe having curiosity about the TM technology. In addition, patients often develop a close relationship with the TM staff including the facilitators that they do not get to experience during an in-person visit. This adds an additional positive human interaction for the patient, which is particularly helpful for patients who may be reluctant to use technology. Patients who are seen by TM are more likely to request future TM visits if they have had a positive experience. Because there usually are a limited number of TM providers in a particular practice, patients are more likely to see the same provider than they would if they were seen in-person. Patients also can frequently get an earlier appointment if they agree to be seen by TM because they are not competing for appointments with non-TM patients. This can be accomplished without a reduction in work hours or opening additional physical locations to accommodate patients.

In our experience, patients tend either to be as satisfied with TM visits as they are with in-person visits, or they prefer TM visits. Patients who are dissatisfied with a TM visit usually have experienced technical issues during the encounter, which is why it is important to have contingency plans for when the technology fails.

SCHOOL-BASED TM
A recent review by Perry and Turner described 5 different studies of the use of TM in school-based asthma programs. In one program in Rochester, New York, elementary school students were treated either with standard asthma education or with TM-assisted asthma assessments with a primary care provider who delivered follow-up care. The number of symptom-free days was greater for students who participated in TM than in those who relied on visits to their primary care provider for asthma care. Another program in Arkansas enrolled 7- to 14-year-old students to receive asthma education by an asthma specialist via TM with follow-up treatment recommendations. This program demonstrated improved use of peak flows and medication use compared with usual care, but there was no change in asthma outcomes. This was felt to be due to the low (61%) participation rate of participants.

A San Francisco–based school program involving 3 inner-city elementary schools provided students with asthma either 4 TM visits with an asthma specialist along with treatment recommendations or in-person asthma education and usual care. After 32 weeks, there was a significant improvement in asthma control and satisfaction with care was high. Another program in Hart, Texas, enrolled 5- to 18-year-old students to receive TM and follow-up care by an asthma specialist. When compared with baseline, after 24 weeks there was an improvement in symptom-free days, spirometry, and quality of life in these students. Finally, a school-based program in Tucson, Arizona, used TM to assess students with asthma. Although there was no intervention in this program, clinicians felt that TM was easy to use, and they felt that their assessment was as accurate when done by TM as in-person.

EDUCATION FOR PATIENTS AND PROVIDERS
Another expanding use of technology for health care is medical education. Medical education for patients and providers traditionally has consisted in-person teaching, though the availability of online resources has supplemented that. Such resources can be either stored for use on-demand or they can be viewed live, which requires the learner to participate at a specific time. The advantage of stored resources is that they can be accessed when it is convenient for the learners and they can be used in various settings. For example, printed educational resources are available to subscribers of medical journals. Podcasts consisting of recorded audio or video files can be downloaded to a user’s device for subsequent playback. One example of a podcast is AllergyTalk, which is a bimonthly roundup of information in the field of allergy and immunology covered by Allergy Watch. Streaming videos generally are not downloadable, so they need to be watched on a smart phone, tablet, or computer that is connected to the Internet. An example of a streaming video is Conferences On-Line Allergy. Patients frequently access various online Web sites to obtain medical information, though the accuracy of such information is not always clear.

To obtain interactive education, it is necessary for a learner to participate in a live event. A Webinar is an online meeting or presentation held via the Internet in real time. An example of an allergy Webinar is Conferences On Line Allergy, which is broadcast as live interactive online presentations that are recorded and subsequently posted as a series of streaming videos. Project Extension for Community Healthcare Outcomes uses free Web-based video conferencing technology to offer mentoring from interdisciplinary specialty teams to multiple primary care teams.

PHYSICIAN WELLNESS
Another benefit of the use of TM can be on provider wellness and reduction of burnout. A survey in 2018 was performed by Medscape and 15,000 US physicians responded. An article published by Physicians Weekly described how the use of TM can reduce provider burnout and ultimately help to increase physician wellness. The article proposed that TM can increase time savings, dedicated/consistent care, and patient access to care. Among the physicians responding to the survey, 20% said greater flexibility in work schedule can help to reduce burnout. One physician responded that the use of TM saves over an hour of commute time. TM can help to reduce cost of overhead, decrease the time per patient encounter, and increase patient volumes, leading to better physician compensation. TM can reduce the rush of physicians moving from room to room while continuing to provide patient care in a normal workday. In addition, if a physician moves out of state, they can continue care with their patient panel with the use of TM. Providers with young children could see patients from home.

Becoming familiar with a new practice and building a new patient panel can place stress on a physician, especially those who have been at a practice for a very long time. TM can help to reduce the stress of having to find a new job. If physicians become licensed in different states and in TM, it can allow them to expand their patient panel. In a survey from American Well called “Telehealth Index: 2019 Physician Survey,” physicians using telehealth responded as follows: “93% said it improves patients’ access to care, 77% said it contributes to more efficient use of time for doctors and patients and 71% said it helps to reduce healthcare costs.” All these factors can help to improve provider wellness with the use of TM.
NEW OPPORTUNITIES FOR TM

Despite the practice of using TM as a part of patient care, it is still a heavily underused practice, especially among allergists. Kane and Gillis found that allergy/immunology was the specialty least likely to use TM as a part of the medical practice (6.1% of encounters). According to American Association of Medical Colleges data, in the period 2017 to 2018 58% of US medical schools had TM integrated into their curriculum compared with 40% in the period 2013 to 2014.

TM has created an opportunity for providers to see patients when they would otherwise not be able to. For example, it is not uncommon for a provider who moves to a different location to continue seeing their patients by TM. Providers (and patients) who are not able to travel to a clinic for medical or other reasons can continue to see patients. In addition, by subscribing to one of the TM platforms, you can see patients without having to invest in medical infrastructure. You can even bypass the need to have your own billing process as the platform can do that for you.

It is important to recognize that the evidence for benefits of this new technology in chronic disease management is still limited. In a systematic review of systematic reviews, beneficial effects were found for asthma including improvement in symptoms, peak flows, and FEV1 and reduced hospitalization rates and deaths. Most of these studies used reminder systems such as text messaging to improve adherence. For virtual visits, there have been few controlled studies, so the long-term impact of TM is unclear. Clearly, more controlled studies are needed to understand the best application of this new technology.

EMERGING TECHNOLOGIES

In addition to virtual visits using TM, there are several emerging technologies that are relevant to the practice of allergy/immunology including electronic diaries (e-diaries) (eg, symptoms and medication use), wearable technology (eg, to monitor activity and vital signs), RPM (eg, environmental exposures and medication adherence) as well as electronic medical records augmented with clinical decision support. Finally, analysis of “Big Data” to use information acquired through electronic platforms can identify new ways to diagnose and treat allergic conditions.

e-Diaries

An e-diary is a device, an app, or a Web site in which patients can keep track of various aspects of their physiologic status in a digital format. This provides a flexible input/output interface that can improve adherence. To test this, one study compared asthma severity and anxiety as tracked either on paper or with an e-diary in 24 patients. Both diaries were supposed to be completed twice a day for 14 days. The authors noted that evening entries were missed more often than morning ones in both types of diary and that retrospective entries tended to be made for evening entries. It was estimated that 20% of entries contained errors in both types of diary; however, such errors could more easily be identified in the e-diaries because they were time coded. Therefore, although adherence is not necessarily better with e-diaries, use of a digital format makes it possible to identify lack of adherence more easily.

By providing a platform for tracking clinical information in real time, the use of e-diaries can improve the accuracy of the information by reducing errors that occur when recall is relied on. For this reason, e-diaries are commonly used in clinical trials for symptom and adherence data that need to be collected frequently between visits. To test the reliability of a paper versus e-diary for tracking asthma symptoms, 47 patients were randomly assigned to one or the other tracking method. After 14 days, intraclass correlations among 3 measures of asthma control (global patient report of symptoms, ≤15% change in FEV1, and Asthma Control Test) were determined for each group. Correlations for rescue-free days and symptom-free days were higher for patients using e-diaries than paper diaries. E-diaries, when integrated with a monitoring device such as a spirometer, also can permit tracking of more complicated information than paper ones would.

Wearable devices

Use of wearable devices can provide a patient with personal information about their health. One of the more common uses of such devices is accelerometers to monitor physical activity (usually in the form of steps). In one study, 62 patients with asthma, aged 9 to 18 years, tracked their activity by wearing an accelerometer and they also reported their physical activity using an e-diary. The correlation between the 2 was only moderate (r = 0.48), with the greatest difference occurring for light activity. Patients basically tended to overestimate their activity. By combining wearable devices with e-diaries, this type of bias can be reduced.

Remote patient monitoring

RPM involves the use of devices, mobile apps, or Web sites to gather patient data when they are outside of traditional health care settings for transmission to a remote location where it can be monitored and acted on by health care professionals if indicated. Many devices and apps are available for RPM including accelerometers to track activity, glucometers to track blood glucose levels, and devices to monitor heart rates. Comprehensive reviews of RPM devices that track symptoms of allergic rhinitis and asthma were recently published by Bousquet et al and by Kagen and Garland. The advantage of this approach over patient self-report is that the devices can directly report objective information to the monitor, which overcomes distortions introduced by patient bias. The principle limitations of RPM for allergy are that very few studies of their effectiveness have been performed, there are no consistent measures of device or app quality, and consumer devices and apps are not regulated by the Food and Drug Administration (FDA).

There is also a question of how active monitoring of transmitted information is to be used. If it is sent to a provider’s office or health plan case worker, it is unclear who will monitor the results, how frequently they will be monitored, and how recommendations will be made and provided to the patient. These issues need to be resolved before widespread use of active monitoring is implemented. Because the area is rapidly growing, the FDA has put together a Digital Health Innovation Action Plan to guide its implementation. This is to ensure that consumers and health care professionals have timely access to high-quality, safe, and effective digital health products, and it includes a new approach to digital health technology oversight known as the FDA Pre-Cert for Software program.

Digital inhalers

Inhaler-based devices have been developed for monitoring and assisting with asthma management. Measurement of
medication adherence that relies on self-report can be biased because patients tend to overreport their adherence. In one study of 221 children with asthma, nebulizer use was automatically logged, and patients were asked to record nebulizer use on diary cards for 12 weeks. There was an 85% concordance between diary and electronic data; however, overreporting on diary cards occurred on 15% of the days, confirming that patients tend to overestimate their medication adherence. Similar results were found in a study of meter-dose inhaler–based digital counters. Use of nebulizers or inhalers that automatically log their use could create an opportunity to design decision algorithms that can act on accurate use information in real time. For example, an acute increase in the number of actuations of a quick reliever could trigger a signal to alert a patient (or monitoring service) that their asthma may be getting out of control and it could offer suggestions for treatment. Adherence with this treatment could be monitored by tracking the use of an inhaled corticosteroid. When augmented by digital spirometers that are now available to patients, an asthma episode could be managed using artificial intelligence algorithms. In addition, such algorithms could learn from the patient’s response to each episode and provide improved patient-specific advice for subsequent episodes. One device (ProAir Digihaler; Teva, Tel Aviv, Israel) received FDA approval in December 2018. The device is a digital inhaler with built-in sensors that connect to a companion mobile application to provide inhaler use information to patients who have asthma and/or chronic obstructive pulmonary disease.

**ELECTRONIC HEALTH RECORDS WITH CLINICAL DECISION SUPPORT**

According to the Centers for Medicare & Medicaid Services, an EHR is “an electronic version of a patient’s medical history, that is maintained by the provider over time, and may include all of the key administrative clinical data relevant to that person’s care under a particular provider.” An EHR has the potential to streamline a clinician’s workflow and to support other care-related activities such as evidence-based decision support, quality management, and outcomes reporting. The top vendors of EHRs in the United States in 2018 were Epic, Cerner, Meditech, and CSPI. Initially, EHRs were designed to mimic paper records; however, as they have evolved, the full potentials of electronic systems are starting to be realized.

By storing clinical information in a digital format, it potentially can be analyzed using Big Data techniques (see below). Use of EHRs can expedite medical care in many ways; for example, it has allowed automated surveillance of infection control by monitoring days of indwelling urinary catheter devices, central venous catheters, in hospitalized patients. In addition, EHRs have implemented tools for sepsis surveillance and for identifying drug-drug interactions and drug allergies. In one study, using artificial intelligence algorithms, data from an electronic medical record were used to track patients who had experienced anaphylaxis even when the patients were not specifically diagnosed with that condition. In another study, an e-diary was used to detect exacerbations in 169 patients with severe asthma by tracking measures of lung function, symptoms, and medication use for 1 year. An algorithm that combined a 20% decrease in peak expiratory flow or a 20% increase in day symptoms on 2 consecutive days was able to detect exacerbations with 65% sensitivity and 95% specificity when compared with physician-diagnosed exacerbations. These surveillance tools can assist physicians in decision making without removing the provider as the central role in patient care.

Unfortunately, electronic medical record downloads also have been cited as one of the most frequent causes of burnout among physicians. Studies have reported that for every 1 hour spent with a patient in the office, a physician may spend double that time on documentation. EHR documentation can cause a clerical burden on physicians and create a sense of depersonalization with patients. Because many EHRs now offer full integration with TM, this combination may help to maximize the utilization of EHRs in a way that benefits both providers and patients.

**BIG DATA**

Big Data is a term that refers to a massive volume of both structured and unstructured information that is so large that it is difficult to process using traditional database and software techniques. Such data sets can be analyzed computationally to reveal patterns, trends, and associations that might not be apparent to the humans who collected it. An example of the use of Big Data was in an epidemiologic study in which the incidence of anaphylaxis was determined automatically using data from an EHR. The investigators used several different analytic techniques to identify patients with anaphylaxis and found that a convolutional neural network provided the best performance; however, linear methods required less training time.

One of the most promising uses of Big Data is the use of omics (eg, genomics, transcriptomics, proteomics, metabolomics, microbiome, and exposome) to identify asthma phenotypes and its application for the management of individual patients. When combined with EHRs and clinical decision support systems, inclusion of omics data has the potential to allow personalized medicine finally to become a reality.

**CONCLUSIONS**

TM is an important addition in the world of medical technology and informatics that can improve medical care by increasing patient access, reducing health care costs, and increasing patient satisfaction. Although there will continue to be situations in which visits to a medical office will be necessary such as to undergo procedures that cannot be done at home, advances in technology will displace many of those visits over time. By integrating TM into the EHR, it is likely that technology will permit improvements in patient care that would not have been possible just a few years ago.

Emerging technologies including use of digital diaries, wearable devices, remote monitoring of patients’ physiologic information, use of EHRs with decision support, and analysis of Big Data are just beginning to demonstrate their value. As the technologies and strategies for their use improve, we are optimistic that patients with allergic conditions will benefit.

We acknowledge Dr David Lang for his leadership in inspiring us to recognize the transformational potential of telemedicine and the other new technologies.
What do we know?

- Use of telemedicine (TM) is increasing. The allergy field needs to get on board to keep up.
- Patients generally are satisfied with encounters using TM.
- TM can lead to reduced health care costs, decreased provider burnout, improved provider compensation, and flexibility in how patients are seen.

What is still unknown?

- Large-scale studies of patient outcomes comparing in-person versus TM visits are needed.
- How TM visits can most effectively be integrated into a clinical practice.
- What the long-term effects of TM use will be on health care costs and patient outcomes.

REFERENCES