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ADVANCES IN PEDIATRICS

Pediatric Telehealth

Approaches by Specialty and Implications for General Pediatric Care

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Keywords

• Telehealth • Telemedicine • Pediatrics • Informatics • mHealth • Teleconsultation • Telepractice • Telecare

Key points

- Telehealth is the use of electronic information and telecommunication technologies to support clinical care and public health, and to promote patient education and professional development.
- Advances in technology, access to care, service reimbursement, and consumer demand are primary drivers for pediatric telehealth.
- The effectiveness and applicability of a telehealth approach may vary by pediatric specialty, care delivery setting, and patient preference.
- The expanding demand for real-time telemedicine services may have disruptive effects on the practice of pediatrics.

INTRODUCTION

Telehealth is the use of electronic information and telecommunication technologies to support clinical care and public health, and to promote patient education and professional development [1]. Telehealth technologies run the gamut from telephones and e-mail, to transmitted images, to real-time videoconferencing and robotic surgery. Telehealth has been an area of formal informatics research for more than 2 decades [2], and has recently generated broader

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interest as an alternative mode of health care delivery that can cost-effectively expand access to care. In pediatrics, telehealth has found success in specialty niches, but remains mostly unproven as a model for general pediatric care. Understanding the effectiveness of telehealth approaches by specialty and context may provide guidance on how best to apply telehealth to present and future challenges in the pediatric health care landscape.

Terminology

The term telemedicine is often used interchangeably with telehealth, as it was once the all-encompassing term for the use of remote communication technologies in health care. Under Medicaid, telemedicine is not recognized as a distinct service from telehealth; rather, it has been redefined as a narrowly-focused subset of telehealth: Telemedicine is the use of 2-way, real-time interactive audio and video communication between a patient at an originating (or "spoke") site and a physician or a practitioner at a distant (or "hub") site [3]. This administrative definition provides a reference point for an expansive nomenclature (Table 1) that better differentiates by characteristics (Table 2) the breadth of applications of telehealth in pediatrics.

Telemedicine uses 2-way, real-time (or synchronous) videoconferencing to transmit clinical information for interactive assessment. By contrast, telehealth embraces both synchronous and asynchronous (not real-time) modes. Sometimes referred to as "store and forward," asynchronous technologies involve the acquisition, storage, and transmission of clinical information (whether data, images, or other multimedia) from originating to distant site for remote interpretation at a later time.

Table 1
Telehealth and subordinate categories

Telehealth	The use of electronic information and telecommunication technologies to support and promote long-distance clinical health care, patient and professional health-related education, public health and health administration, using technologies including video conferencing, the Internet, store-and-forward imaging, streaming media, and terrestrial and wireless communications
Telemedicine	The use of 2-way, real-time interactive audio and video communication between a patient and a physician or a practitioner at a distant site
Teleconsultation	The synchronous or asynchronous use of information communication technologies between practitioners to guide the diagnosis or care of a patient
Telepractice	The synchronous or asynchronous use of information communication technologies between a patient and a practitioner
Telecare	The use of information, communication, and monitoring technologies to remotely evaluate health status, give educational intervention, or deliver health and social care to patients in their homes
Tele-education	The provision of remote training to health practitioners to improve knowledge and skills, and for continuing education or maintenance of certification

Table 2
Telehealth terminology

Asynchronous (''store and forward'')	The acquisition, storage, and transmission of clinical information (including data and multimedia) from one site to another for remote assessment
Synchronous	The transmission of clinical information in real time for remote assessment
Originating (''spoke'') site	The location of the patient at the time of the telemedicine service
Distant (''hub'') site	The location of the practitioner at the time of the telemedicine service
Telemedicine platform	Software that a practitioner uses to interact with patients
mHealth	An abbreviation for ''mobile health''—the use of mobile device technology in health care
Remote patient monitoring (RPM)	The use of technology to capture physiologic or behavioral data outside of the traditional clinical care setting
Direct-to-consumer (DTC) telehealth	A form of telehealth, often delivered using an mHealth device, that is marketed directly to patients with service initiated by patients

In addition, telemedicine focuses specifically on communication between a patient and a practitioner but does not explicitly acknowledge the use of technologies between practitioners to provide consultation. To that end, the terms telepractice and teleconsultation are well suited to characterize other pediatric telehealth activities [4]. Telepractice here refers to the synchronous or asynchronous use of information communication technologies between a patient and a practitioner, building on the formal definition of telemedicine and allowing for the use of asynchronous applications, such as e-mail or store-and-forward imaging. Teleconsultation here refers to the synchronous or asynchronous use of information communication technologies between practitioners to guide the diagnosis or care of a patient.

Although telepractice or teleconsultation may extend traditional paradigms of physician-patient or physician-physician interaction, they do not generally gather information or provide intervention outside of the formal health care setting. Telecare is the use of technologies to remotely evaluate a patient's health status or to provide educational, health, or social interventions to patients in their life environment [5], conceptually extending the medical home to a ''health home'' to periodically or continuously monitor for disease risk factors or aggravators and provide intervention as needed [6]. Telecare may use remote patient monitoring (RPM) to capture physiologic, behavioral, social, or environmental data about a patient outside of the health care setting. The use of smartphones, or other portable communication or monitoring devices, to enable RPM and provide education or other interventions, is sometimes referred to as mobile health (mHealth).

Although tele-education is sometimes used in the context of telecare, to refer to remote health education provided to patients, the term tele-education generally refers to the provision of remote training to health practitioners to improve

knowledge and skills, or to participate in continuing education or maintenance of certification.

Drivers

Advances in information and communication technology, barriers in access to care, evolving policies in service reimbursement, and expanding consumer demand are the principal drivers that have fostered interest and innovation in pediatric telehealth.

Technology

Fast and reliable broadband Internet is a foundation of effective telehealth. At the advent of the telemedicine era, prevailing Internet bandwidth allowed for asynchronous transmission and display of static images but limited the quality of real-time video interactions; present-day Internet speed and capacity, coupled with high-definition videoconferencing equipment, have made real-time interactive audio and video synonymous with telemedicine. Although scarce and sluggish Internet access has limited telehealth opportunities in rural and underserved areas, the debut and expansion of 5G wireless networks may reduce infrastructure barriers.

The cost-prohibitive acquisition and maintenance of high-definition equipment once limited videoconferencing technology to large health care networks and academic centers that were able to host patient-convenient originating sites. Now, vendors of telemedicine platforms are marketing software to small and solo practices that allows practitioners to interact with patients using consumer-oriented devices, such as smartphones and tablets. These mHealth technologies may readily support both telemedicine and telecare scenarios: The integration of patient surveys and environmental or physiologic sensors into mobile devices may allow the medical home to continuously monitor risk factors, including social determinants of health, and provide for real-time interventions, such as medication reminders or videoconference consultations, which can be delivered when and where needed to prevent problems or mitigate further harm.

Electronic health records (EHRs) may not immediately come to mind as a telehealth technology, but it may be convenient to think of an EHR as a "store-and-forward" repository for clinical information that may be reviewed and interpreted remotely by a practitioner participating in a patient's care. As of 2017, more than 90% of hospitals [7] and nearly 90% of physician offices [8] had access to EHRs. In a teleconsultation scenario, a physician could use the EHR to transmit relevant documentation or studies to a specialist for assessment; if the specialist has shared access to the patient's EHR the process of transmitting information can be bypassed, further expediting the process. An EHR patient portal may allow practitioners and patients to exchange messages securely and asynchronously; additional patient portal resources may provide patient education and self-triage, and other tools to support scheduling of in-person or telemedicine visits. A patient being seen by a practitioner outside of their medical home, perhaps even via a telemedicine visit, may be able to provide their acute care practitioner with "break-the-glass" access to their

electronic records, allowing for a more complete review of history than the patient may be able to recall or express.

Provider access

Inability to access pediatric specialty care may be a conflation of several issues, including absolute shortages of specialists and their geographic concentration: Since the American Academy of Pediatrics (AAP) Future of Pediatric Education (FOPE II) workforce survey in 1998, pediatric subspecialists are working fewer hours and spending less time in direct patient care, and practicing in academic medical centers in greater proportion [9]. Differential access to pediatric specialists in rural or underserved areas may create disparities that contribute to poorer health outcomes [10].

Telehealth strategies may improve pediatric subspecialty access [11]. These strategies may leverage readily available technologies, such as e-mail and telephone consultations, or specialist access to remote EHRs; other strategies may require significant technology investment, including videoconferencing equipment, or mHealth devices for patients, or even establishing broadband Internet access in a community. Although investment in new technologies may be initially cost prohibitive, with sufficient volume to justify infrastructure commitments, telehealth services can be a cost-effective alternative to in-person care, particularly when time and effort for patient travel is considered [12]. In addition, when remote subspecialty care is made available in originating settings that are convenient for patients, such as primary care offices or community hospitals, pediatric patients in rural and underserved areas are more likely to receive and adhere to evidence-based care [13]. Telehealth may even support the role of nonphysician intermediaries in nonclinical settings, such as school nurses, to increase access to primary pediatric care [14].

Families are interested in telehealth opportunities, independent of specific clinical problems, disease severity or chronicity, or distance from hospital [15], although for ongoing specialty care beyond an initial assessment, the use of telehealth should complement existing relationships [16].

Reimbursement

Evidence for telehealth has often come from pilot projects, many of which have been grant funded. For example, the Health Resources and Services Administration Office for the Advancement of Telehealth has specifically supported funding opportunities to promote telehealth services in rural areas and pediatric populations [17]. However, these types of funding sources are not generally designed to sustain or expand telehealth programs over the long term. As a result, it is not surprising that, despite technology advances and inaccessibility to pediatric specialty care, the use of telehealth has remained the exception rather than the rule with larger practices (more than 50 physicians) being more likely to sustain a telemedicine program [18].

Recently, Medicaid has come to view telemedicine as a cost-effective alternative to traditional in-person care, and has provided states with the flexibility to determine which services and providers to reimburse for telemedicine care [19].

Although policies for reimbursement vary from state to state, Current Procedural Terminology codes and modifiers have been identified to support the standardized documentation of pediatric telemedicine services for Medicaid reimbursement; although the billing of private insurance for telemedicine services has not become universal, these codes provide a mechanism for private payers to cover these services [20]. At present, 37 states and the District of Columbia have parity laws that mandate private payer reimbursement for telemedicine services at the same rate as in-person care, with 2 other states having parity laws proposed or pending [21].

As telehealth services have become increasingly reimbursable, accountable care organizations and health maintenance organizations have looked to telemedicine visits as an alternative for cost-effective access to care. Likewise, employers may look to telemedicine providers as less expensive and timelier alternatives to traditional in-person office or emergency room visits.

Finally, with the Affordable Care Act having an optional Medicaid benefit for states to establish health homes, toward better coordinated care for patients with chronic conditions, telecare may become a reimbursable telehealth opportunity.

Consumer demand

Consumers highly value convenience in accessing health care, as has been seen with the increase in urgent care centers. Urgent care visits are particularly popular in the pediatric population [22], and free-standing urgent care centers have become a common source of pediatric health care outside of the traditional medical home [23]. As savvy consumers have become accustomed to having other services available on demand, such as ride sharing or food delivery, it should come as no surprise that there would be similar demand to access health care at any time and from any location [24].

This consumer interest has been reinforced by health care networks offering access to telemedicine services, and payers and employers increasing their coverage of these services. Although many physicians remain skeptical of offering telemedicine services, providing consumers with the opportunity to connect remotely to their care can promote patient satisfaction and engagement [25], potentially enhancing the physician-patient relationship.

Health care entrepreneurs are eager to fulfill unmet consumer demand for telemedicine, as several national companies have leveraged technologies of the sharing economy to connect practitioners and patients for virtual visits using direct-to-consumer (DTC) offerings. As these companies continue to expand telemedicine access outside of traditional health care networks, there will be a need for licensed physicians to staff their virtual telemedicine offices.

SELECTED EXAMPLES BY TELEHEALTH CATEGORY AND PEDIATRIC SPECIALTY

With the stage set for broader use of telehealth, it may be helpful to consider examples of telehealth in different pediatric specialties and care delivery

contexts, to understand in which milieus telehealth may be effectively applied or where more study or innovation may be required.

Teleconsultations: addressing specialty access

The use of teleconsultation between practitioners may bridge gaps to timely access to pediatric specialists, and has been shown to be effective asynchronously and synchronously, where supported by appropriate infrastructure.

Cardiology

The use of telehealth in pediatric cardiology consultations and specialty care has been well studied for nearly 30 years [26], with significant applications in evaluating congenital heart disease, murmurs, and arrhythmias.

Echocardiography is a safe and cost-effective modality that makes use of noninvasive ultrasound images to assess the anatomy and function of the heart, and its use in teleconsultations is now considered routine. An asynchronous approach has traditionally been used to obtain, transmit, and interpret echocardiogram images. From a remote workstation, a pediatric cardiologist can accurately confirm or exclude congenital heart disease with comparable accuracy and improved timeliness over bedside interpretation [27]. Improvements in Internet bandwidth and videoconference quality have allowed for the evaluation of echocardiograms remotely in real time. In a Brazilian study, neonatologists performed echocardiograms with remote video supervision by a cardiologist, resulting in improved detection of congenital heart disease than without consultation [28]. In another study, real-time video was successfully used remotely by pediatric cardiologists to evaluate echocardiograms, consult with referring physicians, and provide direct education to the family on the need for surgery [29].

Although echocardiography for congenital heart disease has been the most common use of pediatric cardiology telemedicine consultation, the evaluation of a heart murmur remains the most common reason for referral to a pediatric cardiologist. Echocardiography has been evaluated for acute evaluation of murmur [30], although this modality may not be available in many ambulatory settings. Tele-auscultation (the electronic capture of heart sounds, asynchronously or in real time, for remote interpretation) has generated some interest as an alternative teleconsultation approach, and has been shown to allow reliable differentiation between innocent and pathologic murmurs [31], although the technology is best reserved for purposes of screening and referral [32]. However, as digital signal analysis of transmitted heart sounds is improved, there may be a future role for artificial intelligence in distinguishing between murmurs to improve the diagnostic utility of tele-auscultation [33].

Although the evidence of its effectiveness in this area is not yet well established, RPM may be well suited to some pediatric cardiology applications. Remote monitoring of implantable pediatric cardiovascular devices, such as pacemakers, improves the detection of adverse events [34], with a cardiologist or care nurse able to analyze transmitted data and contact patients or families if

action is required. Remote electrocardiographic monitoring via wearable devices (such as smartwatches and biomedical shirts) has the potential to provide continuous recording and visualization of data, which may be monitored in real time or evaluated asynchronously [35]; though not adding significant information to what may be offered via traditional Holter monitoring options, these wearable devices may offer additional convenience and acceptability for patients, with implications for both telemedicine diagnosis and home monitoring telecare.

Ophthalmology

The use of telehealth in pediatric ophthalmology has been best studied in the context of retinopathy of prematurity (ROP). Ophthalmologic teleconsultations may support both diagnosis and monitoring of ROP in neonatal intensive care units (NICUs), reducing the need for in-person examination and minimizing exposure of the neonate.

Although direct fundoscopic examination is considered the gold standard, asynchronous screening of high-definition retinal images can provide accurate and timely feedback to determine whether an in-person neonate examination is necessary [36], and has been shown to be a viable option when access to an ophthalmologist is limited [37]. However, this image-centered approach is constrained by the cost of technology investment as well as the risk of capturing less detailed information to stage the extent of ROP [38]. For example, the sensitivity of ROP detection is reduced when a full set of 5 retinal images cannot be obtained [39]; furthermore, the quality of ROP grading using images is subject to reviewer variability, indicating the importance of standardized approaches and protocols [40].

Looking to the future, specific characteristics detected in retinal images may be suggestive as predictors for ROP [41]; although this finding requires additional validation, it may have implications for using imaging informatics tools and artificial intelligence to enhance the predictive ability of using retinal images for diagnosis and referral [42].

Nephrology

Like cardiology and ophthalmology, pediatric nephrology is an example of successfully implemented specialty teleconsultation: relevant medical information and digital images can generally be exchanged asynchronously, mitigating the need for investment in real-time audiovisual equipment. This application of teleconsultation has proven to be cost-effective, timely, and convenient for diagnosing congenital anomalies of the kidney and urinary tract, nephrotic syndrome, urinary tract infections, and the need for kidney transplant, without requiring in-person evaluation [43]. Patient and provider reception to this use of telehealth for pediatric nephrology consultation has generally been favorable [44].

Although more relevant to telepractice and telecare than teleconsultation, nephrology care and follow-up may also be provided remotely to support patient convenience. The use of RPM to monitor blood pressure in the home

setting can provide more representative status than periodic clinic measurement, and technology to transmit data via remote cuffs connected to smartphones is evolving; that said, blood pressure cuffs are not always well tolerated in children and adolescents, which may affect the suitability of this telecare adjunct [45]. Recent changes to Medicare benefits have expanded the use of telehealth services, including real-time video visits, to dialysis in the patient's home or in free-standing dialysis clinics [46]; if a similar benefit is afforded to the pediatric population, video visits could augment nurse visits to improve the effectiveness and convenience of home dialysis [47].

Dermatology

The reliance on visual observation, sometimes to the exclusion of what the patient has to say, has made teleconsultation a natural match for dermatology [48]. Although most evidence for the use of dermatology teleconsultation has been in adults, there is evidence of its effectiveness in the pediatric population [49].

For example, parental use of smartphones can capture images with quality so high that, even when parents are provided little or no instruction, there is high concordance between diagnosis using smartphone images and in-person assessment [50]. The use of live video transmitted via a mobile phone, when compared with transmitted images, has been shown to be a reliable method for evaluating pediatric nevi [51]; however, although high-resolution video can approach traditional store-and-forward image interpretation or in-person evaluation for diagnostic accuracy, video resolution may be compromised by bandwidth constraints, making in-person evaluation the preferred approach [52].

Emergency medicine

In addition to the previous examples of consultations with pediatric subspecialists, teleconsultation can bring general pediatric and subspecialty expertise to adult settings. Although an in-person assessment is always preferred, and consultation via telephone may be useful in some instances, the use of real-time videoconferencing to consult on ill children has been shown to be effective in adult or after-hours emergency department (ED) settings.

When evaluating respiratory distress, there is excellent agreement between bedside and remote video observers on measures such as respiratory rate, retractions, and dyspnea [53]; this concurrence has likewise been demonstrated on febrile children in respiratory distress [54]. If a pediatric intensive care unit (PICU) admission becomes necessary, the use of pediatric teleconsultation in the ED setting has been associated with illness of lower severity at the time of PICU admission and lower mortality rates [55]. The use of pediatric video consultations in rural EDs has also resulted in fewer medication errors than telephone consultation [56].

Despite these effective uses, few EDs nationally use teleconsultation to assist in pediatric evaluation, and those that do are primarily consulting for patient placement or transfer coordination [57]. Among the identified challenges to

implementing teleconsultation in the ED setting is the difficulty in incorporating virtual consultations into the ED physician's workflow in comparison with an in-person consultation.

In some instances general pediatric expertise may be available in the ED setting, but additional subspecialty consultation is required, particularly with pediatric imaging in the management of trauma. Remote radiography consultation via tablet devices has been effective in reducing in-person orthopedic consultation for children with suspected bone fractures [58], facilitating determination of whether urgent surgical management is necessary. As specialists are increasingly able to access digitized images remotely in EHRs, the tie to a specific tablet-device scenario may be unnecessary. Even photographs of radiographic images taken via cellphone and transmitted via e-mail have a high concurrence with expert image evaluation [59], although this approach should be limited to ad hoc assessment when the formal digital image is not accessible remotely. In an example from another imaging modality, ED pediatricians guided in ultrasonography by an expert radiologist using videoconferencing were able to produce reliable and timely diagnoses in the evaluation of abdominal trauma and nonspecific abdominal pain, when compared with an in-person assessment conducted by a radiologist [60].

Surgery

Remote surgery is a form of telepractice that uses medical robotics and real-time video communication. The particulars of telesurgery are beyond the scope of this review; however, some aspects of presurgical evaluation and postsurgical follow-up are amenable to teleconsultation.

In surgical telementoring, one surgeon provides teleconsultation to another surgeon remotely; this is generally reserved for a procedure that would require patients to travel for consultation. The evaluation of images and video of a lesion, paired with telephone consultation, can provide definitive diagnosis in some instances and may avoid unnecessary referrals [61]. In some instances, telementoring (using real-time videoconferencing) may extend to guidance during the surgical procedure. In a survey regarding surgical telementoring for the pediatric population, this form of teleconsultation was acceptable to nearly half of parental respondents; however, a desire for an in-person consultation, and concern regarding physician competence, were cited as reasons against surgical telementoring [62].

Telecare: managing chronic conditions

The use of telehealth technologies to connect with the pediatric patient in the home environment has had mixed results, but the advent of mHealth has the potential to passively monitor status and actively modify behaviors to improve health outcomes, particularly for chronic conditions.

Asthma

Asthma is the most common pediatric illness in the United States, disproportionately burdening families of lower socioeconomic status [63]. Using telecare

to deliver asthma education and case management to improve behavioral outcomes is an area of great interest, although the evidence for effectiveness of telecare in improving asthma outcomes is limited.

Among the shortcomings of asthma telecare has been the need for the pediatric patient, or patient and family, to be actively engaged with Web-based interventions. For example, online asthma communities may provide helpful supportive benefits but do not necessarily improve asthma medication adherence [64] or reinforce ongoing engagement with the online communities. Providing a layer of patient-specific self-management may personalize and enhance Web-based telecare: The use of nurse-mediated telephone case management, when combined with Web-based self-management tools, improved overall pediatric asthma control, although medication adherence did not improve [65]. In another study, online asthma self-management was associated with a higher quality of life, but not necessarily improvement of asthma control [66].

The use of mobile technology has been posited as an approach to make asthma telecare more convenient for the patient than Web-based interventions, although it may be insufficient alone as a motivator. In one large trial, the use of mobile devices for active self-management was comparable to paper-based protocols in asthma control and self-management, although the associated technology investments were found not to be cost-effective [67].

The use of mobile devices to make participation in telecare interventions more passive shows promise for the future of asthma self-management, when incorporating RPM and alerts. In one study, plan-based medication and trigger reminders were more likely to result in reporting improved asthma management, although it did not significantly decrease asthma-related ED visits or hospitalizations [68]. The use of mobile or wearable devices with environmental sensors may be the next major step in asthma telecare: Analysis of sensor data may allow temporal correlation of environmental triggers (such as weather or air quality) with asthma symptoms to provide more specific and timely assessment of asthma risk [69] and better predict when a need-based (rather than schedule-based) medication reminder is needed [70]. Further personalization of reminders, integrating patient-centered messages of encouragement, may also improve their effectiveness [71].

Risk factors for overweight

Adolescent behaviors related to unhealthful diet and physical inactivity can contribute to overweight and obesity that may lead to chronic disease in the future. The evidence that telecare interventions may mitigate behavioral risk factors for overweight is mixed.

There is evidence that behavioral group intervention can be an effective use of telecare. In one study treating pediatric obesity for families living in rural areas, both video and telephone-only interventions were shown to be effective and acceptable methods for group intervention delivery, and there were no differences in the video and telephone groups on primary outcomes [72].

Telecare studies that have focused on individual management of risk factors for overweight have often used Web sites to directly engage with patients. Web-site interventions that made significant change in risk behaviors were generally associated with multidimensional approaches, including education, goal-setting, self-monitoring, and parental involvement as intervention strategies [73]. However, maintaining active patient engagement with a telecare intervention remains a significant barrier to effecting weight-change outcomes [74].

Mobile applications directed at intervening in behavioral risk factors for chronic disease in youth have shown some promise in maintaining engagement, using text messages, games, e-mails, and social media to promote active and ongoing participation. Within mHealth, the need for parental involvement is less clear: In one study, parent-focused mHealth interventions for adolescent obesity and overweight did not demonstrate a reliable impact on patients' dietary or physical outcomes [75], although another study implementing a caregiver strengthened the effect over communications to child patients alone [76].

Diabetes mellitus

Because some of the risk factors for managing overweight overlap with the risk factors for managing insulin-dependent diabetes mellitus (IDDM), those lessons may be transferable in effective diabetes telecare. In addition, there is diabetes-specific evidence that a telemedicine visit does not show significant difference from an in-person visit in managing behavioral aspects of IDDM [77].

Where behavior management for IDDM may differ from overweight is the opportunity for remote physiologic monitoring. In one study, patients and their families manually documented and e-mailed readings from a glucose monitor 5 times daily, receiving text messages or e-mails if values were critically out of range: This intervention resulted in decreased hemoglobin A1c levels and improved diabetes control, although the manual data entry was difficult for patients and families to adhere to [78]. In another study the use of continuous glucose monitoring, mediated by an insulin pump that concurrently alerted the patient and notified the treatment team of out-of-range values while simultaneously managing the correction, led to overall improvement in diabetes control that was safe and well accepted by patients [79].

Oncology

The role of telecare in improving outcomes for pediatric oncology patients has likewise been explored. These patients often experience mental and physical fatigue during and after chemotherapy treatments, and telecare technologies may have a role in supporting and empowering patients to better manage their care.

A survey of oncologists generally favored the idea of telecare, and the specific use of mobile oncology applications by patients, as a mechanism for monitoring side effects of chemotherapy and providing quicker response from the oncology team, while limiting patient inconvenience [80]. The use of an electronic checklist to support symptom identification and management was found to be associated with increased patient-clinic communication and satisfaction, and was strongly correlated with improved outcomes, without increasing costs

[81]. One study found that more than half of patients reported taking their scheduled medication immediately on receipt of a reminder from a smartphone-based application [82]. However, the evidence that real-time monitoring of symptoms decreases morbidity and unplanned admissions is limited and anecdotal [83].

Real-time video telephony has been suggested as a cost-effective and convenient means for providing clinical and psychosocial support for pediatric oncology patients [84]. In a Brazilian study on telecare for patients with acute lymphoblastic leukemia, implementation of an online meeting program resulted in decreases in overall mortality, early death, and relapses [85].

In areas of future interest, the use of video, electronic games, and mobile health applications are speculated to have a neurobiological role in encouraging resilience and empowerment in pediatric patients with cancer [86], and the use of mHealth technology for e-learning, promoting exercise, tracking behaviors, and supportive gaming are areas of promise [87].

Telehealth in public health: protecting populations

An important focus of public health is the protection of populations from disease and disability. Specific to child health, public health may include educating patients and families, screening for preventable or correctable conditions, and protection from infectious diseases.

Audiometric screening

Telehealth for audiometric screening is not well explored in the United States, where most newborns receive a hospital-based screening at birth, and screening for acquired hearing loss is available as a Medicaid-covered benefit through the Early and Periodic Screening, Diagnosis, and Treatment (EPSDT) Program, as well as through school-based programs. However, teleaudiometry–generally the use of a computer-based or tablet-based application to administer a hearing screening–is of significant interest internationally, where access to formal audiometric screening is limited, and often relies on questionnaire-based parental assessments [88].

Teleaudiometry is comparable in effectiveness with sweep audiometry in detecting hearing deficit, and may be feasible and cost effective as an initial screen in remote settings [89]. The audiologist may participate directly in the screening administering the examination remotely in real time using videoconferencing [90], or via a store-and-forward model where a trained assistant mediates an otoscopic examination and audiometric testing, with results later evaluated by the audiologist [91]. Although less common, teleaudiometry has sometimes included screening for other auditory conditions, such as tinnitus [92].

When an audiologist is not available to interpret a screening, a tablet-based hearing screening test can be used effectively for initial screening [93]. Smartphone-based hearing screening has been used by community health care workers to detect unidentified hearing loss at early childhood development centers [94]. In India, remote screening via auditory brainstem response has been facilitated by trained village health

workers, with detection rates comparable with in-person screening, and with improved follow-up that has been attributed to geographic convenience [95].

After a hearing deficit is identified, teleaudiometry may also be used to validate the intervention. For example, in pediatric patients with cochlear implants, several visits to the cochlear implant center are required in the first year of use, and once or twice yearly thereafter, to assure ongoing effectiveness. Real-time, videoconference-mediated testing of cochlear implants did not reveal significant differences between remote and in-person testing, although the quality of the testing equipment and environment sometimes affected speech perception remotely [96].

Dental health

Like hearing screening, dental examinations are an EPSDT benefit, although individual states vary in their coverage, and many dentists opt not to participate in EPSDT programs. Beyond the EPSDT benefit, California requires an oral health assessment to be performed by a licensed dentist or registered dental hygienist (RDH) before, or soon after, school entry. Given significant unmet demand for pediatric dentists, the use of teledentistry (a form of teleconsultation using video and information communication technologies in real time or asynchronously) may provide an opportunity for an RDH to conduct initial dental screening and consult with a dentist on the need for additional referral. Although an area of practical interest with anecdotal successes, teledentistry-assisted use of RDHs has a limited evidence base and faces opposition from other dental care providers as hurdles to wider implementation [97].

Home-visitation programs

Public health nurse home-visitation programs can protect the health and well-being of at-risk children [98], some of whom may be medically complex. These programs are often grant funded, and many are subject to resource constraints or workforce limitations to providing direct care. Although there is sparse evidence of the use of telehealth technology in home-visitation programs, there is some evidence of success with medically complex children: Nursing televisits have been shown to result in fewer unplanned clinical visits [99] and lower rates of hospitalization and greater caregiver satisfaction [100]. This effective use of telecare may be appropriate to extend the reach of public health nurse home-visitation programs that educate caregivers and monitor at-risk children. The use of real-time audio/video has been discussed as an adjunct to social worker visits, to facilitate more frequent public health nursing assessments of children in foster care [101].

Tuberculosis control

Directly observed therapy (DOT) is a public health strategy to ensure patient adherence to treatment of tuberculosis. In DOT, patients meet with health workers, daily or several times per week, at a special public health clinic or via a community worker home visit; in either setting, health workers observe

patients taking tuberculosis medication and enquire about side effects. This is a resource-intensive approach for health departments and can also be inconvenient for patients.

Video DOT (VDOT) is a form of telehealth that uses video in place of in-person visits and may be conducted asynchronously or in real time. In a study in New York City, the use of real-time, scheduled VDOT permitted workers to see the same number of patients as they would have in the clinic, and twice as many as they would have seen on home visits, with similar treatment completion outcomes in both scenarios [102]. In a similar California-based study, some patients recommended (and often preferred) real-time VDOT over DOT, with VDOT having higher adherence at lower cost than DOT [103]. Asynchronous VDOT, with videos reviewed daily, has also been shown to be feasible, and have high rates of patient approval and adherence [104].

Most studies on VDOT have involved management of adult patients. However, the lessons of VDOT may also be applicable to children, with strategies focused on scheduling VDOT asynchronously or synchronously before or during school hours to better monitor compliance.

Sexual health

There is some evidence of the effectiveness of telehealth applications to improve adolescent sexual health. For example, a rural, school-based telehealth education program was found to be effective in teaching reproductive health to female students, including those engaged in high-risk sexual activity, as evidenced by the increased use of condoms and hormonal contraceptives, and increased rates of human papillomavirus vaccination [105]. In another study of patients 16 years of age or older, a telehealth program was used to confirm *Chlamydia* diagnosis and initiate treatment, including partner notification and capture of surveillance data, with treatment outcomes similar to those for in-person care [106].

Although there are some states that specifically prohibit its use for abortion, telemedicine has been used in adult populations to access medications to terminate pregnancy, with outcomes comparable with in-person care [107]. It has been proposed that this type of telemedicine could be expanded to improve access to medical termination for women living in remote areas [108], and that such access would reduce terminations in the second trimester [109]. A telemedicine visit resulting in medical abortion has been shown to have similar efficacy, with no increased risk of adverse events, when compared with in-person abortion [110]. In jurisdictions where adolescents may consent to care regarding their sexual health, these applications of telehealth may reduce barriers to intervention.

Telepractice: transforming the physician-patient relationship

The previous telehealth examples have focused on pediatric specialties, and noteworthy examples of their use of technology to support teleconsultation or telecare. Telehealth is increasingly being used to support the traditional physician-patient interaction in several pediatric specialty areas.

Neonatology

The use of telehealth in the neonatal period has been previously highlighted under cardiology and ophthalmology consultations, but the applications in neonatology span many telehealth categories and neonatal phases of care.

Neonatology has made use of asynchronous teleconsultation from the early 1990s to meet the increased demand for specialty evaluation created by conditions of prematurity [111], but synchronous teleconsultation has also been shown to be effective, with the neonatologist as either the requestor or the consultee. For example, real-time video teleconsultations, with the specialist observing remotely and the neonatologist on-site in the NICU to adjust the position of the camera or the patient, have been used to conduct genetic and neurologic evaluations, allowing identification of more than 90% of abnormalities—with implications for use as a screening, if not diagnostic, tool [112]. In the counter example, when a community hospital seeks a teleconsultation with a remote neonatologist, it is more likely to adhere to standard measures of neonatal care and have higher-quality resuscitations of preterm neonates [113]; these positive impacts have been found to be greater when the teleconsultation is used earlier in the evaluation.

Telehealth technologies are increasingly used for RPM in the practice of neonatology. The extensive use of telemetry in the NICU provides opportunities to monitor patient status remotely, and the introduction of audiovisual equipment provides opportunities for real-time observation of the neonate. In one study, robots were used to convey a live audiovisual feed to a neonatologist rounding remotely: no significant differences were noted in care or outcomes when compared with an on-site neonatologist, except for interruptions caused by the mobility of the robot or issues with the Internet connection. This use of robots was positively received by parents and NICU staff, with potential implications for the timing and frequency of daily patient rounds [114]. In another NICU study, telemedicine respiratory assessments were well correlated with in-person evaluation, and respiratory therapists found the careful use of the telemedicine technology to be acceptable, suggesting the incorporation of tele-auscultation to further augment assessments [115].

Telehealth may serve additional uses outside of the NICU. For example, after the neonate is discharged from the NICU, the use of an informational Web site and videoconferences with families was shown to decrease emergency hospital visits in this population; families expressed satisfaction with this use of telecare, and perceived that they had more scheduled appointments than necessary when compared with other families without access to telecare [116]. In another example, telehealth may have a role in the immediate prenatal period, as prenatal telemonitoring [117] and telemedicine obstetric consults [118] have both been used to decrease the incidence of very-low-birth-weight deliveries.

Neurology

Telehealth has demonstrated effectiveness across the spectrum of pediatric neurology, from diagnosis to ongoing management.

For institutions without a pediatric neurologist, teleconsultation is an important path to access this expertise. Consultation by telephone alone has proved effective to pediatricians in managing neurologic cases and reducing unnecessary admissions or transfers to tertiary care hospitals [119]. Other types of neurology consultations may be conducted effectively asynchronously or synchronously. In one study, electroencephalograms (EEGs) were made available securely over a virtual private network, expanding access to EEG review services and reducing waiting time for consultation by half, at a comparable unit cost per EEG [120]. In another study, videoconferencing was evaluated as a mechanism for physical examination to diagnose a rare neurologic condition (Batten disease): Using a standardized scale, a nonphysician in-person examination was observed by an in-person rater, and a remote rater participating via teleconference, with high inter-rater reliability [121].

For patients already under the care of a pediatric neurologist, telehealth may have a role in the management of various neurologic conditions. For example, in the management of stable epilepsy, no significant difference was noted in the number of breakthrough seizures for patients who were followed telephonically or in person, allowing telephonic review to be considered with selected patients for whom access may be an issue [122]. In a telecare example, the use of text message reminders improved the education of patients with epilepsy, and compliance with both drug-taking and clinic appointments, with high patient acceptability [123]. In the management of migraines, RPM focused on adherence to preventive treatment and lifestyle may improve outcomes: In one study, the electronic monitoring of bottle-cap opening was associated with significantly higher adolescent adherence to medication regimen than self-reported rates without monitoring (75% vs 64%) [124].

Mental health

In a study of Medicaid telemedicine claims between 2008 and 2009, nearly 95% were associated with a psychiatric or behavioral health diagnosis, mostly bipolar disorder or attention-deficit disorder [125]. As the number of child and adolescent psychiatrists, particularly in rural or underserved communities, does not meet projected needs, tele-mental health (TMH) services can be an effective approach to provide direct patient care via telephone or videoconferencing, or teleconsultation to pediatricians, with additional services as needed in other settings such as schools or home [126]. The use of TMH can improve access simply by eliminating clinician travel time, increasing the opportunities for unscheduled visits during times of urgency or crisis [127].

Therapist-guided cognitive behavioral therapy (CBT) delivered via the Internet as texts or streaming media may provide an alternative to in-person care in addressing somatic complaints such as chronic pain, and psychiatric conditions including anxiety [128] and depression [129]. More research is needed with regard to the safety, efficacy, and effectiveness of mHealth CBT applications before supporting their stand-alone use for children and

adolescents, but they may have a role as extenders of relationships with mental health professionals [130].

Telehealth may have a role in supporting timely assessment of developmental disorders, whereby early intervention may be critical. For example, the mean time between evaluation, diagnosis, and intervention for autism spectrum disorder may exceed a year [131]. In one evaluation model, the use of in-home, parent-recorded video was demonstrated to be an effective complement to traditional in-office assessment of autism [132], and was speculated to improve the efficiency of diagnosis [133].

Rheumatology

There is approximately one board-certified pediatric rheumatologist for every 1000 children with a rheumatologic condition in the United States, with more than half of the states having between zero and 2 of these specialists, as many are geographically concentrated in urban centers or at academic institutions [134].

This challenge in access has generated interest in offering telemedicine as a practice option, although a survey of pediatric rheumatology practices found that only 3 of 77 had ever used telemedicine [135].

In a study comparing families seen at an in-person pediatric rheumatology clinic in Missouri with families seen at a telemedicine outreach clinic more than 150 miles away, telemedicine visits were shown to mitigate the burden of time and cost, with no change in clinical outcomes [136]. Patient preference may play an important role in the acceptability of this mode of care, as another study showed that an overwhelming majority (95%) of patients' families preferred in-person pediatric rheumatology visits to telemedicine, even when travel was noted to be inconvenient (more than 3 hours) [137]. However, in a study from Chile, where some patients with juvenile idiopathic arthritis (JIA) live in remote areas with limited access to health care of any kind, telemedicine was used as a tool to support diagnosis and ongoing follow-up, with the number of patients requiring specific referral for in-person care decreasing from 10 to 1. In contrast to the aforementioned United States findings, the advantages of this telemedicine outreach model were seen by both patients and their parents to outweigh the disadvantages [138].

The use of a single, integrated pediatric rheumatology questionnaire to track parent- and child-reported outcomes for JIA, juvenile dermatomyositis, and juvenile autoinflammatory diseases has been shown to be effective in guiding patient self-management, documentation of change in health, assessment of therapeutic interventions, and verification of satisfaction with outcomes [139]. Where telemedicine via videoconferencing is not available, this telecare approach may be a useful option to support the management of patients already under care.

Telepractice: changing the game for general pediatric care

General pediatricians have long participated in the art of telepractice: from asynchronous review and triage of telephone messages, to real-time calls

back to families and phoned-in prescriptions, the concept of telehealth is not a new one. Some pediatricians may even entrust patients and families with their mobile phone numbers for on-demand, synchronous care. With the convergence of enabling technologies, increasing reimbursement opportunities, and consumer demand, the stage is set for a formal telemedicine role in general pediatrics, especially for acute care.

With the rapid proliferation of DTC telemedicine in the United States, it is natural to think about the role that telemedicine may play in pediatric urgent care visits. When compared with traditional office or ED visits, telemedicine visits have been increasingly identified and promoted as a cost-effective alternative to in-person care [140], making virtual urgent care an increasingly attractive proposition for health plans and employers. In adult studies, patients have reported high satisfaction with these visits, rating convenience and perceived quality of care as important factors [141]. Such quality of care, however, may simply be perceived.

Respiratory tract infections (RTIs) are the predominant reason for a DTC telemedicine visit: One study of RTI visit-length data found that DTC visits were shorter when antibiotics were prescribed and longer when nonantibiotics were prescribed, compared with visits with no prescriptions, suggesting that DTC prescriber incentive to increase patient volume could come at the expense of antibiotic stewardship [142]. In a follow-up study of patients surveyed for these RTI visits, patients rated DTC prescribers (whether for antibiotics or nonantibiotics) higher than DTC nonprescribers [143]. Specific to pediatrics, children seen at DTC visits for acute respiratory infections were more likely to receive antibiotics, and in a manner more likely to deviate from guidelines, than children at their primary care provider (PCP) or traditional urgent care visit [144]. More generally, when a national DTC vendor was compared with traditional physician offices, the DTC approach trailed in measures of access and quality [145].

DISCUSSION

Telehealth approaches by specialty

The effectiveness and applicability of a telehealth approach varies widely by pediatric specialty, care delivery setting, and patient preference.

Asynchronous specialty teleconsultation has long been a stalwart of pediatric telehealth, as demonstrated in cardiology, ophthalmology, nephrology, and dermatology. Real-time teleconsultation has been effective in improving outcomes in the evaluation of the acutely ill child in the ED setting as well as in the NICU.

Early efforts in managing chronic conditions via telecare have relied on active patient participation with Web sites, whereby adherence to the intervention is not readily sustained over time. The use of RPM and mHealth applications have shown some promise for telecare, as they may require less active patient engagement while providing real-time intervention in the form of education, reminders, or real-time consultations as needed.

The use of telehealth in public health has been shown to be effective in audiology screening and tuberculosis control, overcoming geographic and resource limitations to detect and treat conditions. Evidence of the effective use of telehealth in other areas of public health is limited but may be helpful in expanding the reach of dental screening and home-visitation programs, as well as providing population-based health education. The most significant constraint to the public health application of telehealth is the reliance on core public funding or external grant funding to evolve and sustain innovative programs.

Perhaps the greatest interest in telehealth is in telepractice/telemedicine, where each specialty is unique in the opportunities that it may successfully exploit. Neonatology has historically been a technologically advanced specialty, which has translated well across the spectrum of telehealth applications. The nature of observation and communication in mental health and development are amenable to the use of evidence-based screening tools and videoconferencing or even telephony. Telemedicine is effective in rheumatology practice, although this is one identified specialty with a specific patient preference for in-person visits.

Telehealth in general pediatrics

The use of DTC is more likely in nonmetropolitan communities and in children without preventive care visits, and when compared with children receiving acute care with their PCP, children with DTC visits were also more likely to have had urgent care and ED visits [146]. In an analysis of commercial claims data, it was estimated that 12% of DTC visits replaced visits to other providers, and 88% represented new utilization, without the touted decrease in overall cost [147]. The records from these visits may not be readily captured into the EHR system of the patient's medical home, if the practice is even aware that the DTC visit occurred. Given the popularity of urgent care visits in the pediatric population, as some DTC service vendors begin to establish (or partner with) brick-and-mortar urgent care centers, there is a risk that children and families may never have–or even depart from–a pediatric medical home.

The AAP supports the pediatric medical home as the optimal location for children to receive acute, nonemergent care, acknowledging that families may take advantage of other services for convenience of access or cost [148]. Digital communication has been shown to provide the most benefit when there is an existing relationship between the patient and the clinical team [149]. To maximize opportunities for families to keep care within the pediatric medical home, pediatric practices may need to establish urgent care telemedicine as a core offering. One study estimated that approximately 85% of sick visits in a pediatric practice could be completed using a telemedicine model that offers only simple office testing and albuterol administration [150], suggesting that urgent care telemedicine in the context of a pediatric medical home could be a viable alternative to in-person acute care. It has also been suggested that a robust pediatric urgent care telemedicine practice

could provide teleconsultations to augment acute care needs where access to health professionals might be limited, such as athletic tournaments or at schools [151]. At present, Medicaid reimbursement for real-time telemedicine exceeds reimbursement for store-and-forward and RPM; as states expand their policies and reimbursements to specifically support telecare or asynchronous telepractice, there may be opportunities for innovation in pediatric practice to extend core telehealth offerings [152]. The AAP provides resources for practices interested in providing telehealth services [153], including practice transformation [154].

Telemedicine practice considerations

Although telemedicine platforms have become cost accessible for even smaller pediatric practices, there are numerous additional considerations before implementing telemedicine in a practice, including licensure, liability, privacy and security, technology, and workflow.

As originating and remote sites may be in different states, multistate licensure may be a consideration for practices with a catchment area that straddles state lines, or where patients travel out of state. The Interstate Medical Licensure Compact is an agreement between 29 states and 1 territory and their respective Medical and Osteopathic Boards that qualifies licensed physicians to practice medicine in participating states in the Compact, if eligibility requirements are met [155].

Although medical malpractice insurance is essential to any practice, telemedicine adds complexity to the liability coverage required. Telemedicine services may be excluded by some carriers; moreover, coverage may be defined by the state where the physician is licensed rather than the originating site, with premiums based on time worked in each state, and additional coverage for privacy and security exposure over the Internet.

Practices should resist the temptation to use social media applications as their entrée into telemedicine. Although social media may offer video-chat technologies, these applications are not usually encrypted, and are not compliant with the Health Insurance Portability and Accountability Act of 1996 (HIPAA); in addition, cloud service providers are generally not covered under HIPAA [156]. Although there are mechanisms to send encrypted e-mail to personal e-mail accounts, asynchronous communications with patients should be limited to secure messaging, preferably associated with the telemedicine platform or an EHR patient portal.

When evaluating a telemedicine platform, it would ideally integrate with the practice's EHR: lack of integration may lead to redundant documentation in separate systems, or having separate information silos for documentation, ordering, and billing for telemedicine and in-office visits.

The telemedicine platform should be suitable for a wide range of user skills, for both the physician and the patient population, to ensure that telehealth interactions are reliable, error-free, efficient, and without undue delay or interruption. In a heuristic evaluation of 4 telemedicine software platforms, 46

unique issues were uncovered for potential usability problems with existing user interfaces [157]. In offices with multiple concurrent telemedicine visits, or simply limited broadband Internet capacity, performance issues may be encountered as network-reliant applications compete for bandwidth.

Each practice should carefully consider the implications of its telemedicine scheduling structure and staffing model, as there is no one-size-fits-all model for success. With regard to scheduling, use of telemedicine may be ad hoc (akin to the model of responding to telephone messages) or have dedicated spots in the schedule. Telemedicine encounters in a general pediatrics practice should be reserved for acute care and follow-up of established patients only, with new patients having in-person visits. When visits are scheduled, some physicians may prefer dedicated blocks of telemedicine visits, whereas others may prefer virtual visits to be interspersed with in-office visits. Telemedicine visits may be an option to establish, or augment existing, urgent care hours on evenings and weekends. Depending on the videoconferencing and other technologies used, a dedicated space may be required for telemedicine visits, or may even be desired when the physician's office is in a shared, highly interruptive, or otherwise unsuitable space; if the dedicated space is an examination room, this should also be factored into scheduling.

With regard to staffing, when there are dedicated telemedicine blocks scheduled, physicians may choose to share in telemedicine responsibilities covering "shifts"; larger practices may have the flexibility to assign or dedicate certain physicians to telemedicine, especially when other physicians in the practice are not comfortable with virtual visits.

Telemedicine may provide work flexibility that supports physicians who are temporarily or permanently unable to practice medicine in a traditional setting full time, as well as moonlighting opportunities. For physicians who have become disenchanted with the practice of medicine, telemedicine may allow for reduction in workload without abandoning practice altogether. On the other hand, there may also be physicians who have no desire to practice telemedicine, but are compelled to do so by their employers or the demands of the health care environment. With cross-cutting subspecialties such as sports medicine, adolescent medicine, and even clinical informatics, some have proposed that telehealth should become its own medical specialty or subspecialty, certifying "medical virtualists" who will spend most or all of their time delivering competent and compassionate care at the "webside" [158]. More research is required to determine whether telemedicine subspecialists in the primary care disciplines can mitigate inequities in telemedicine clinical practice and outcomes.

Physicians should remain cognizant of the impact of these technologies on the physician-patient relationship, and maintaining continuity of care and minimizing the risk for patient abandonment [159]. Indiscriminate use of telehealth technologies for delicate patient revelations may result in perceptions of care as insensitive or unethical [160].

SUMMARY

Advances in technology, access to care, service reimbursement, and consumer demand have been primary drivers for pediatric telehealth. In some specialties, telehealth is used across all phases of care from diagnosis to follow-up. Teleconsultation has been successful in closing gaps in access to pediatric specialists, and telecare may create opportunities to more closely monitor and intervene in the health of the pediatric patient, extending the concept of the medical home to a patient "health home."

While there is limited, context-specific evidence that telehealth improves health outcomes when compared with direct, in-person care, the expanding consumer demand for telemedicine may have disruptive effects on the practice of pediatrics and the urgency with which practices choose to adopt telehealth technologies. The effectiveness and applicability of a telehealth approach varies by pediatric specialty, care delivery setting, and patient preference; in addition, there are licensure, liability, privacy and security, technology, and workflow considerations that may affect implementation. Whether implementing telehealth in a general or specialty pediatrics practice, the diversity of previous experiences may inform appropriate uses that are suitable for the needs of an individual practice.

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