



Telemedicine: Pediatric Applications

Bryan L. Burke Jr, MD, FAAP, R. W. Hall, MD, FAAP, the SECTION ON TELEHEALTH CARE

Telemedicine is a technological tool that is improving the health of children around the world. This report chronicles the use of telemedicine by pediatricians and pediatric medical and surgical specialists to deliver inpatient and outpatient care, educate physicians and patients, and conduct medical research. It also describes the importance of telemedicine in responding to emergencies and disasters and providing access to pediatric care to remote and underserved populations. Barriers to telemedicine expansion are explained, such as legal issues, inadequate payment for services, technology costs and sustainability, and the lack of technology infrastructure on a national scale. Although certain challenges have constrained more widespread implementation, telemedicine's current use bears testimony to its effectiveness and potential. Telemedicine's widespread adoption will be influenced by the implementation of key provisions of the Patient Protection and Affordable Care Act, technological advances, and growing patient demand for virtual visits.

abstract

I. INTRODUCTION

Definition

Telemedicine has been defined as “the use of medical information exchanged from one site to another via electronic communications to improve a patient’s clinical health status.”¹ Telehealth has historically had a broader definition, encompassing telemedicine’s clinical care for patients and tele-education, teleresearch, and disaster response. *Telemedicine* and *telehealth*, as commonly used today, can be considered synonymous.¹

History

Telecommunications has had a role in medical care at least since the Civil War, when the telegraph was used to transmit casualty lists and to order supplies.² The invention of the telephone and radio expanded medical telecommunications, and the telephone maintains a central role in medical communications. The earliest recorded reference to telemedicine involved teleradiology and the distant transmission and interpretation of radiographic images.³ The needs of the National Aeronautics and Space Administration drove the expansion of telemedical technology.⁴ In 1964, an interactive video linked the Norfolk State Hospital with the Nebraska

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Psychiatric Institute, at a distance of 112 miles. In 1967, Massachusetts General Hospital linked with Boston's Logan Airport to deliver medical care remotely.⁴ In 1989, doctors from Australia reported a successful link of an aerial ambulance team with their base hospital, a teaching hospital, and regional hospitals.⁵

Technological improvements have driven the rapid evolution of telemedicine. In 1969 the US Department of Defense constructed the Advanced Research Projects Agency Network, which later evolved into the Internet.⁶ In the 1970s, data transmission standard protocols, known as transmission control protocols and Internet protocols, were created. In the 21st century, Web 2.0 brought a new generation of Web development that allowed more social networking, folksonomy (a system for classifying, tagging, and categorizing content), interoperability (the ability of an electronic device to interact with another electronic device), collaboration, and communication. Web 2.0, characterized by dynamic content and the growth of social networks, also made Voice Over Internet Protocol possible, facilitating the growth of synchronous and asynchronous audiovisual (AV) communication.⁷ The mobile device industry has also increased access to both voice and video, enabling real-time discussions for clinicians to collaborate more effectively. These technological improvements have contributed to the rapid expansion of pediatric telemedicine.

Use of Telemedicine

Pediatricians can use telemedicine for a broad range of applications. Telemedicine can be used for tele-education, teleconsultation, telepractice, and teleresearch. Tele-education can be delivered through live interactive AV links, by live streaming video, and by viewing stored educational material. Tele-education programs allow physicians

to stay current, travel less often for continuing medical education (CME), obtain free CME, foster relationships between academic and community-based physicians, and establish widespread peer groups to learn from each other and from academicians.^{7,8}

Teleconsultation typically involves establishing a communication link between doctors who request consultations on patients under their care and experts located in distant medical centers. Such consults can occur through a live, interactive AV link or through store-and-forward technology. An example would be the storage of echocardiogram images for an expeditious, but not real-time, reading by a distant cardiologist. Teleconsultation works well for both acute and chronic disease management.⁹⁻¹⁴ Advantages of such consultations include increased access for the medically underserved, improved access for the rural and inner-city child, enhanced care through faster and more accurate assessment than can be provided by telephone consultation, and decreased cost to the health care system and the patient's family.

Telepractice involves establishing links between doctors and their patients who may be located in a child care center, preschool, school, or juvenile detention facility. Telepractice does not replace the in-person visit but rather adds to it. The advantages of such links include an enhanced medical home in which personal physicians care for children; reduced health care system costs, as well as fewer school absences for the children; less money spent by parents on travel; less time away from employment for parents; and less crowding in emergency departments.^{9,15-18}

Teleresearch involves the dissemination of translational research from the academic center to primary care physicians, the use of telemedicine to broaden a population base under study, and improved

collaboration between researchers within and between institutions. The rapid dissemination of translational research results has a high national priority.¹⁹ Telemedicine offers the best tool for such rapid dissemination.⁸

The use of telemedicine as an important mode of health care delivery has occurred in a number of settings, and the future holds promise for further expansion. Technological developments are increasing the number of tools that can be used for telemedical care while driving down the cost of these tools. In addition, government forces, such as legislation mandating telemedicine reimbursement, will drive the further development of telemedicine.^{9,15,17-21}

Patient Protection and Affordable Care Act

The Patient Protection and Affordable Care Act (ACA) contains 4 sections that promote the use of telemedicine, including establishing the Center for Medicare and Medicaid Innovation (CMMI) within the Centers for Medicare and Medicaid Services.²² Such an emphasis will promote telemedicine's use and expansion. The ACA contains several provisions to advance telemedicine and allows the new CMMI to explore and develop new care models that use technology, including electronic monitoring, across a variety of care settings. The law also directs the CMMI to study the use of entities located in medically underserved areas and facilities of the Indian Health Service to provide telehealth services in treating behavioral health problems and stroke and to study ways to improve the capacity of general medical practitioners and nonmedical providers to provide health services for patients with chronic and complex medical conditions.

For Medicaid, the law provides individual states with a "health home" option to better coordinate primary,

acute, behavioral, and long-term and social service needs for those who are chronically ill and allows states the option to use health information technology, including wireless patient technology, to improve service delivery and coordination across the care continuum. At the time this report was written, 11 states had taken advantage of the health home option, and more states may follow.

The ACA also includes opportunities for telehealth application for Medicare beneficiaries. The law requires accountable care organizations (ACOs) to create ways to promote evidence-based medicine and patient engagement, report on quality and cost measures, and coordinate care through the use of telehealth, remote patient monitoring, and other enabling technologies. The law also created the Independence at Home Demonstration Program, which allows the use of remote monitoring by what the program calls “home-based primary care providers” (ie, teams led by physicians and nurse practitioners delivering health care services in patients’ homes to adult patients with multiple chronic conditions).

II. TELE-EDUCATION

Provider Education

Live AV links create a virtual classroom, allowing real-time teacher–student interactions at a distance. Such links have been used to connect academic medical center physicians with community physicians and to offer current and cost-effective CME for local providers. Additionally, when conducted in a collegial fashion, instruction becomes more of a discussion between equals than a lecture from a “superior” to an “inferior.” The discussion allows the learner to ask questions, leading the teacher to better follow adult learning principles²³ while creating an academic and primary care virtual peer group. Even broader, as

community-based physicians listen to their peers’ questions and comments, a virtual peer group is created for the entire area served by the academic center. Live AV links also create the ability to distribute information quickly and accurately in response to disasters, acts of terror, and pandemics (such as the H1N1 influenza epidemic), providing an ideal platform for rapid dissemination of clinical guidelines and research for providers on the front line of pediatric care.^{8,24,25}

One-way streaming video links work well, although not as well as live AV links, because the interaction between teacher and student is limited. Although the student can watch the presentation in real time from a distant lecture site, the teacher cannot see or hear the student. However, the student can send instant messages to ask questions and make observations that the teacher can relay to the local and distant audiences.^{7,8}

Stored educational materials have the strong advantage of being accessible at any time. Although real-time discussion is impossible, the learner can e-mail questions and observations to the teacher, which does allow some interaction.^{8,26}

Patient and Family Education

Tele-education can also provide credible, reliable information to patients and families. Numerous Web sites, online books, and other applications exist that target the needs of patients and their families. In addition to the educational methods described previously, mobile phones are an additional method of delivering tele-education.^{27–29}

III. TELECONSULTATION

Inpatient

In urgent clinical situations, telemedicine consultations can enable pediatric subspecialists to extend the reach of their expertise to children receiving care in distant urban and

rural medically underserved regions. Telemedicine is increasingly used to provide specialty consultations to infants and children receiving care in community and rural hospitals. The use of live interactive videoconferencing, coupled with the optional use of peripheral devices, including stethoscopes, otoscopes and ophthalmoscopes, and ultrasonography machines, can simulate an in-person bedside consultation with a specialist. These applications are often used for patients with unanticipated specialty needs, including newborn infants delivered at level I or II nurseries, pediatric patients hospitalized without local access to pediatric specialists, and infants, children, and adolescents presenting to emergency departments with acute medical emergencies.^{13,30–32}

For pediatric patients located in hospitals with limited pediatric expertise, telemedicine can be used to access specialists who are not otherwise available in the community. The use of this technology overcomes the barriers of time and distance, allowing specialists, such as pediatric hospitalists, emergency medicine specialists, and critical care physicians, to bring their skills to the bedside of the child in need. Models of care include connecting community and rural nurseries to perinatal and neonatal specialists for general advice or assistance during emergencies.^{30,33} This assistance includes evaluations for critical illness,¹⁰ congenital heart disease,³⁴ genetic abnormalities,³⁵ and retinopathy of prematurity.³⁶ Telemedicine has also been increasingly used to provide other specialty consultations, including critical care and pharmacy services, to children hospitalized in general pediatric wards or nonpediatric intensive care units.^{13,14,32,37} The use of telemedicine in these situations has been shown to reduce unnecessary patient transports.³⁸ The final goal of this model of care is that hospitalized children are more often able to receive care in their local

communities, resulting in less disruption to the family.^{10,13,14,38-41} Telemedicine has even proven useful in areas that already have access to pediatric subspecialty care. Attending physicians at home can use telemedicine to help care for patients who are being treated by residents and fellows in teaching hospitals, allowing a quicker response time, backed up by attending physicians coming into the hospital at night if the patient's problems cannot be managed completely via a telemedical connection.⁴²

For infants, children, and adolescents who present to an emergency department that may lack pediatric expertise, telemedicine can be a useful tool to assist in the diagnostic workup, therapeutic plan, and decisions about disposition. Physical abuse cases provide an excellent model to demonstrate the ability of telemedicine to improve emergency department evaluation of pediatric patients.⁴³ Currently, more than 15 telemedical programs in various institutions throughout the United States are providing telemedicine consultations to pediatric patients in remote emergency departments. Similar to studies in adult emergency medicine for acute stroke patients, studies evaluating this model of care for pediatric patients suggest that telemedicine consultations can result in higher parent satisfaction, higher emergency department physician satisfaction, and higher quality of care.⁴⁴ Data also suggest that this model of care results in a reduction of unnecessary transports and an overall reduction in costs, given the lower rates of transport and less frequent use of helicopters.³⁸ Telemedicine has also been found to change newborn referral patterns and decrease infant mortality statewide.³³

Outpatient

Teleconsultation can be used for routine, less time-critical consultations. Such consultations can occur via a live AV link or through

store-and-forward technology. Although telemedicine can be used to provide outpatient teleconsultations for any subspecialty, pediatric dermatology provides a clear and well-documented example of the utility of both live and store-and-forward consultations.⁴⁵

Less urgent teleconsultations provide many of the same advantages as emergency and urgent critical care consultations. Patients can receive these consultations in their own medical home, thus increasing its utility and importance. Because local access to consultation makes appointments easier to keep, the consultant has less difficulty with patients who fail to keep their appointments, and local care providers can be included in the visits, increasing opportunities for care coordination and collaboration.^{11,12,35,46-52}

Telepractice

Children younger than 15 years old in the United States make an estimated 71 million office visits annually for acute problems, which are the leading cause of parents having to miss time from work.⁵³ Clearly, the social and economic burden associated with caring for ill children is substantial. Opportunities exist to rethink how and when children receive medical care.

Telemedicine encounters can facilitate care provided in the patient-centered medical home between primary care pediatricians and their established patients. Telepractice in the context of the medical home permits providers making decisions to have full access to the complete medical record and an established relationship, both of which are conducive to making appropriate care decisions for the patient on par with the level of care afforded during an in-person visit. In addition, telepractice in the context of the medical home has the advantage of being able to convert a tele-enabled visit into an in-person visit when

medically necessary. Typically, this is not possible with telehealth-only providers.

The health care market has seen a rapid expansion in the use of telehealth visits by standalone virtual providers such as those linked to retail-based clinics, entrepreneurs, or insurers whose business model is to provide health care services to patients via Web-based cameras on smartphones, laptop computers, tablets, or video kiosks⁵⁴. Typically these models do not have a previous physician-patient relationship, previous medical history, peripheral technology to facilitate a telehealth examination, or access to basic laboratory testing (eg, throat cultures, rapid strep tests, urine cultures). Despite these deficits, many telehealth-only providers diagnose and treat pediatric patients and prescribe antibiotics electronically, contrary to current recommendations from authoritative sources. These models of care provide episodic and fragmented medical care, which may lead to incomplete or redundant services, a potential waste of health care dollars. Few, if any, of these standalone telehealth providers report consistently notifying the patient's medical home of the care provided (Center for Telehealth and E-Law Summit Meeting, Washington, DC, November 2014).

Although such novelty care appeals to health care consumers because it can be faster, more convenient, and more affordable than an office visit, the potential erosion of recent advances in establishing pediatric medical homes is concerning. The effect on patient safety should telehealth-only care diminish the quality and continuity of care warrants close attention.

Telepractice in the pediatric medical home eliminates access barriers, increases consumer satisfaction, preserves the integrity of the pediatric medical home, and prevents the fragmentation of care common

with standalone direct-to-consumer telehealth care providers.⁵⁵ Medical home-based telehealth visits can reduce emergency department visits for nonurgent care, thus preventing overcrowding and waste of health care dollars.

Outpatient telemedicine programs have successfully connected pediatric offices to child care centers, preschools, schools, group homes, summer camps, and juvenile detention centers.^{18,56,57} Although providers historically have been based in university telemedicine centers, there is new emphasis on community-based health care providers delivering care directly to their patients. Outcome studies demonstrate high parent satisfaction, reduced absenteeism due to illness, reduced travel time and costs, high rates of visit completion via telemedicine, and reduced emergency department use for nonurgent conditions.^{16–18,21,57}

Telepractice can ease the delivery of chronic medical care for primary care providers and pediatric medical and surgical subspecialists. Conditions necessitating chronic care, including asthma, diabetes, genetic conditions, obesity, congenital cardiac conditions, epilepsy, and mental health disorders, have been shown to be telemedicine friendly.^{15,56,58–60} Provider satisfaction may increase as less time and money are spent traveling to satellite clinics and care coordination can be managed at shorter intervals.⁴⁷

As new models of payment for health care are explored in ACOs, telemedicine may play a bigger role in delivering cost-effective care across a defined population of children. This should help ACOs to deliver higher-quality care with greater access at lower costs.

IV. TELERESEARCH

Telemedicine research has become more sophisticated, progressing from

user satisfaction and validation surveys to more complex outcome studies. Key parts of the evaluation strategy advocated by the National Center for Research Resources include establishment of measurable outcomes, basic equipment descriptions, multisite trials, and economic evaluations.⁶¹ Other key focus areas include new technologies, evaluation of telehealth, innovation in education, innovation for improving access, tools for public health systems, and the development of national telehealth networks such as that of the Veteran's Administration.⁶⁰ More recently, noninferiority trials⁶² and other statistical methods have been used to evaluate telemedicine.⁶³ Noninferiority trials test whether a new experimental intervention is less efficacious than an active control already in use.

Telemedicine can be used in research to recruit study patients from the community, to study an intervention's usefulness in clinical care, and to disseminate translational research findings to community providers. Since its inception, more than 11 000 articles about telemedicine have been published, as referenced by the Ovid database. These publications include descriptive studies demonstrating feasibility, systematic reviews evaluating the use of telemedicine, and articles about the delivery of health care to the community. The American Telemedicine Association has identified 4 key areas for research: technical, clinical, human or ergonomics, and economic analysis.⁶⁴

Telemedicine has been used to improve recruitment of potential research subjects from community practices. Research in these settings has been challenging because of the lack of infrastructure, lack of funding to support the complex statistical analyses needed for this research, and inability to access medical records from community providers.⁶⁵ However, telemedicine has been used

to successfully recruit stroke patients for thrombolysis through telemedicine stroke networks. Recruitment of rural and minority populations for a telemedicine-based diabetes management intervention has been augmented by telemedicine in rural South Carolina,⁶⁶ and multicenter trials have used telemedicine technology to improve recruitment in distant sites and improve standardization, data dissemination, and monitoring.⁶⁷ Telemedicine and other strategies to improve patient recruitment can be implemented to facilitate this critical component of community-based research.⁶⁸

Translational research has been plagued by the lack of adoption of research findings by community providers. For example, regionalization of neonatal intensive care, which has long been known to improve outcomes, has not been accepted by some communities.^{69–71} This reluctance might be mitigated through telemedicine consultation, which can help community providers continue to care for neonates as appropriate for their nursery, transferring only patients who need a continuous, higher level of care.³³

Research of telemedicine technologies has included a number of innovative devices, such as robotics that assess patients at the bedside,⁷² stethoscopes,¹⁸ laryngoscopes,⁷³ and retinal devices.^{74,75} These technologies have typically been compared with a gold standard, using a standard statistical measure such as κ statistics and sensitivity and specificity measures. Several articles have reported on the technological component of telehealth, including infrastructure, support personnel, and information technology highways.^{76–79} Data on implementation research, focusing on whole telehealth systems rather than individual technological components, are still sparse.⁶¹

Tele-education research has tremendous potential. Innovative simulation techniques have provided a means to maintain competency in complex procedures such as surgical and intubation training.^{80,81} Tele-education has the potential to reduce duty hours for pediatric residents by restructuring workflow and incorporating community practitioners to shoulder some of the intensive care duties.⁸² Additional research is needed to evaluate the effectiveness of simulation technologies used in tele-education^{61,82} and develop guidelines and methods for simulation training in tele-education.⁸⁰

Access innovation is an important research focus, but it has been difficult to assess, primarily because it requires community engagement with academia. Although the randomized controlled trial has been the gold standard, researching access through randomized controlled trials is challenging, especially in underserved populations. The Health Resources and Services Administration has supported numerous programs to improve health care access. These initiatives have resulted in community health centers that have collaborated with academic institutions to study health care access, but research has been limited.⁶⁵ European studies are evaluating health care models that could potentially improve access through telemedicine.⁸³

Public health and emergency preparedness offer another possible avenue for telemedicine research. Important gaps remain regarding the effectiveness of telemedicine and national networks such as the Nationwide Health Information Network and the Public Health Information Network. Large database studies and collaboration with state health departments will be needed to determine the effectiveness of telehealth interventions.³³ Evaluation of telemedicine in larger populations

will require collaboration between various agencies such as the Health Resources and Services Administration, the Centers for Medicare and Medicaid Services, and the Centers for Disease Control and Prevention.⁸⁴

Major gaps exist in the comprehensive evaluation of a complete telehealth system, simulation technologies, strategies to improve patient outcomes through telemedicine in large populations, and knowledge on how best to train the next generation of telehealth providers. Effective research in telemedicine will require a team approach with collaboration between health care providers, policymakers, engineers, social scientists, health economists, community partners, and government agencies.

V. INFRASTRUCTURE

The technical needs of a telehealth program will depend on the type of telemedicine its organization intends to practice: synchronous or asynchronous. Synchronous or live telemedicine involves a real-time interaction between the participants at 2 or more sites. Asynchronous or store-and-forward telemedicine involves recording medical information at 1 site and then transmitting the recorded information to another site or sites for evaluation by a medical specialist at a later time.

Remote monitoring is an important area in telehealth, enabling the specialist to monitor patients in real time at hospitals and at home and offering patients self-monitoring for chronic diseases such as asthma, diabetes, or heart disease.^{32,85} Another rapidly growing area in telehealth is mobile health, which the NIH Consensus Group defines as the use of mobile and wireless devices to improve health outcomes, health care services, and health research.⁸⁶

Equipment

The equipment needed may range from dedicated turnkey videoconferencing units to software-based videoconferencing programs for computers or mobile platforms such as tablets and cell phones. The technology should be able to provide sufficient AV clarity needed for the patient's assessment and the ability for providers to communicate easily with each other. Depending on the needs of the telehealth program, the technologies should also be able to connect peripheral medical devices that may be hardwired or portable (eg, general examination camera, stethoscope, pulse oximeter, otoscope, ultrasonography device).⁸⁷

An important consideration when selecting technologies for the telehealth program involves the interoperability of the technology with existing telemedicine services and technologies. The recommended criteria for current technologies are H.323 compliance, live video resolution of $4 \times$ Common Intermediate Format (4CIF) (704×480) or higher, and an ability to connect at a minimum of 384 kilobits per second running 4CIF at 30 frames per second.⁸⁷ In addition, the technology should support H.264 video compression standard or better, H.261 video compression standard compatibility, and G.711 audio compression standard or better to ensure high-quality audio and video for the telemedicine interaction. The technologies should comply with current organizational, legal, and regulatory requirements and will change as technology develops.

Connection

The quality of a telemedicine interaction depends on the connection established between the sites involved in the call. Therefore, the organization should provide adequate bandwidth to support the needs of the telehealth program goals. The organization should be

able to provide point-to-point connectivity from within or outside the health care facility. Most telemedicine interactions now use Internet protocol using a high-speed Internet connection. On occasion, telemedicine interactions use an integrated services digital network connection when sites lack the infrastructure to support high-speed Internet connections. For a live interactive telemedicine link, a commonly suggested minimum speed is a 384-kilobits-per-second bidirectional connection between the sites.

Privacy and Security

Telemedicine interactions must comply with the Health Insurance Portability and Accountability Act (HIPAA) of 1996 and other regulatory requirements.^{88,89} A major goal of the HIPAA Security Rule is to protect the privacy of individuals' health information while allowing covered entities to adopt new technologies to improve the quality and efficiency of patient care. The Security Rule is designed to be flexible so a covered entity can implement policies, procedures, and technologies that are appropriate for that entity's size, structure, and consumers' protected health information risk.⁸⁹ Most telemedicine technologies create a point-to-point encryption between the devices involved in the interaction. Virtual private network tunnels are a common method used to facilitate the privacy of the Internet connection used for the telemedicine interaction. Although the security of the telemedicine interaction is determined by encryption and privacy of the Internet connection, each covered entity should ensure the security of protected health information by developing appropriate safeguards related to data integrity, access, and security tracking and reporting, similar or in line with their face-to-face patient encounters.

Barriers to Telemedicine

Telemedicine has had major success, as demonstrated by the exponential increase in the use of this technology in pediatrics over the past decade. It has been used successfully in neonatology,¹⁰ in critical care medicine,¹³ in ophthalmology for retinopathy of prematurity screening,⁹⁰ for following chronic diseases such as asthma⁹¹ and diabetes,¹⁵ in psychology,⁹² for outpatient care,¹⁷ in dermatology,⁹³ and in education.⁸ However, barriers to its use exist.⁹⁴ These include personal (provider and patient), technological, legal, administrative, and licensing barriers.⁹⁵

Personal barriers to telemedicine use relate to provider acceptance, patient acceptance, and personnel training. Provider acceptance has been the most difficult hurdle, with providers being more cautious than patients, although both groups are generally accepting of telemedicine.⁹⁶⁻⁹⁸ For example, Roberts et al⁹⁹ found that patients were generally accepting of telemedicine monitoring for chronic obstructive lung disease, but providers were concerned about inadequate training and technical problems. Provider acceptance hinges on ease of use and perceived usefulness, with perceived usefulness being the most important determinant.

Both perceived usefulness and ease of use are determined by training, system quality, information quality, and service quality.⁷⁶ For example, image quality must be adequate to make a diagnosis.¹⁰⁰ Echocardiography must be performed by someone trained to obtain a high-quality study, and the specialist must be well trained to interpret the image. If the study is not of sufficient quality, the specialist must demand a repeat study before making an interpretation. The electronic connection must be adequate to support the image, and information technology assistance should be

available for troubleshooting technical problems. Furthermore, the specialist must be readily accessible for primary providers needing immediate help. Physicians familiar with technology are more inclined to use telemedicine; therefore, this barrier may continue to decrease with increasing acceptance of all forms of technology.¹⁰¹

Provider education is also influenced by usefulness and ease of use.¹⁰² Training has a large influence on perceived ease of use. However, the necessity, frequency, and influence of ongoing training have not been well studied.¹⁰³ Breakdowns in training, systems, information, or service quality will deter providers from acceptance. Other factors related to provider acceptance include an unwillingness to accept change.

Patient barriers are related to concerns over perceived threats to privacy, disruptive changes to existing services, and concern over the ability to operate the technology.¹⁰⁴ In one study, the loss of face-to-face interaction was perceived as a limitation by 32% of older patients, although familiarity with the Internet mitigated those concerns.¹⁰⁵ Barriers to home telemedicine systems included lack of motor skills and technological complexity and lack of health literacy.¹⁰⁶ Difficulty in obtaining parental consent can be a barrier for children in a school or child care setting.¹⁰⁷ Finally, patients' fear of losing connectivity was cited by 1 qualitative study as a major obstacle in the United Kingdom, emphasizing the importance of information technology support.¹⁰⁴ When any electronic device is used, plans should be in place to deal with problems such as system failure, loss of power, or loss of connectivity. Telemedical informed consent should include this potential problem.

Technological barriers to telehealth adoption can usually be resolved but may entail increased infrastructure costs.⁹⁵ For example, adequate

bandwidth in rural areas can be an expensive hurdle. Because of their remote location, the Fiji and Cook islands would welcome telehealth, but inadequate bandwidth precludes its use.¹⁰⁸ As mobile technology use increases, reduced equipment costs will allow better access to higher bandwidth and increase patient access.

Legal barriers can be substantial. Liability in the context of telemedicine means the exposure of a physician to a claim for damages for alleged medical malpractice or negligence while providing telemedicine services. Telemedicine programs can mitigate their legal risk by having the program reviewed by an attorney familiar with telemedical law. The key liability issues in telemedicine are as follows:

- The physician–patient relationship. Extrapolating from case law on telephone use, it is reasonable to conclude that a physician–patient relationship has been established with both the on-site treating physician and the remote consultant during a telemedicine encounter if the remote consultant participates in the history, examination, diagnosis, and development of the treatment plan.¹⁰⁹
- Roles and communication responsibilities. The referring physician must explain to the patient why the referral is necessary and the factors on which the recommendation to use telemedicine are based.
- Patient abandonment. Once the physician–patient relationship has been established, steps must be taken to prevent patient abandonment. If the on-site physician has failed in his or her duty, the remote consultant may be held responsible for this omission, as has been found with telephone consultations.
- Technological failures. The liability for technology failures may be shared by all involved parties.

A supervising physician may be at risk for equipment failure, although the American Telemedicine Association has no record of any such lawsuit.

- Liability insurance. If a physician crosses a state line to practice telemedicine, he or she must determine whether malpractice insurance covers out-of-state telemedicine encounters and whether the coverage is sufficient for the distant state.
- Site of malpractice action. Crossing state lines telemedically raises jurisdictional issues. Conceivably, a telemedicine patient may be permitted to choose the jurisdiction for filing a malpractice claim (ie, in the patient's state of residence, the state where the physician is located, or the state where the physician has a telemedicine presence).
- Standard of care. The standard of care for telemedicine may vary depending on technological sophistication, available options, and patient expectations.¹¹⁰
- Informed consent. Special consent may be necessary regarding the risks associated with the use of telemedicine, including involvement of nonmedical staff, recording of the interaction, and the vulnerability of the equipment to failure.
- Security. Security policies and procedures for telemedicine systems must be designed and operated in compliance with the final HIPAA directive on the subject, titled "Standards for Privacy of Individually Identified Health Information" (published in 2002),¹¹¹ and applicable state laws governing patient confidentiality.
- Unknown legal risks associated with telemedicine.¹¹² The improved patient assessment allowed by an AV connection, as compared with a telephone connection, should lead to better patient

assessment and quicker, more accurate diagnosis and therapy, thus decreasing malpractice risk when a face-to-face encounter is impossible. This conjecture has not been proven. Telemedicine can also be used when face-to-face visits are possible, such as when the child is in school, allowing the parent to stay at work rather than bringing the child to the doctor's office during the day or to the emergency department in the evening. Whether telemedical care incurs more liability in this situation is unknown.

Concern exists that telemedicine liability will be similar to that in telephone cases. In a review by Katz et al,¹¹³ telephone malpractice cases were found to be costly, and injuries were sometimes catastrophic. The most common allegation was missed diagnosis (68%), sometimes leading to death. However, telemedicine should enable a more informed diagnosis than the telephone because of the visual cues afforded by this technology. Documentation will have to be the same as for face-to-face assessment to mitigate medical malpractice concerns. The majority of negligence cases seen thus far have involved telemedicine providers who prescribe medications across state lines without examining the patient.

The Joint Commission and now the Center for Medicare and Medicaid Services have accepted telemedicine applications within states as long as both originating and distant site providers are accredited by The Joint Commission or state credentialing agency.¹¹⁴ However, the use of interstate telemedicine often requires participants to be licensed in both states, which can be a formidable barrier, particularly for telemedicine providers who work in multiple states. Many states have recognized the value of allowing out-of-state physicians to share their knowledge and expertise and have therefore granted specific exceptions to their

licensing rules. Nevertheless, all states still have the authority to license and regulate the practice of medicine within their borders, and physicians who practice telemedicine must carefully follow the rules in each state that they “enter” electronically to provide medical care. In *Hageseth v Superior Court of San Mateo County* (2007),¹¹⁵ the California Court of Appeals held that an out-of-state physician who prescribed medications over the Internet to a California resident, without involving a licensed California doctor in the telemedicine consultation, could be prosecuted for the criminal violation of practicing medicine without a California license. In California, the out-of-state physician cannot meet patients in California, receive calls from patients in California, give medical orders, or have ultimate authority over the care or primary diagnosis of the patient. *Holzhauser v State Medical Board of Ohio* (2007)¹¹⁶ clearly stated that out-of-state physicians who provide telemedical services to Ohio residents must comply with all of the Ohio Medical Board’s physician rules, including the rule that “prohibits physicians from prescribing medications to a patient they have not personally examined and diagnosed.”

Administrative issues are a barrier for telehealth care. They include the need to provide information technology support, record storage, and provider training. Because this technology takes time and has the potential to attract more patients, physician time must be taken into consideration. Practice patterns may need to be redesigned, and time for training must be allotted for a successful program implementation.^{103,117,118} The declining yet substantial costs associated with this technology, as well as concern over payment for services, remain substantial barriers to implementing telemedicine on a large scale.^{104,119}

Past barriers of clinician and patient acceptance, technological barriers, and security still exist but have greatly diminished.¹⁰¹ Current barriers outlined in the literature include licensure, credentialing, and payment for services. More research exploring these barriers and the steps taken to overcoming them will lead to better provider acceptance, and legislative action can help overcome administrative and licensing issues.

VI. FINANCIAL IMPACT OF TELEMEDICINE: COST, EVALUATION, AND SUSTAINABILITY

Telemedicine has the potential to provide significant cost savings and financial gain even though the expense of a program may be substantial. Stakeholders (including public and private insurers as well as hospital systems) are interested in the overall economic impact of this technology. This process is complex, because multiple factors must be taken into account in evaluating a program. In the published literature, methodologic issues, such as failure to consider all costs, difficulty quantifying the economic benefit, and the perspective from which the economic benefits are considered, often hamper economic evaluations of telemedicine.^{120,121} Although use of technology has been shown to be cost effective in smaller studies with defined patient populations, these benefits may be limited by the barriers in our current health care system, such as reimbursement and credentialing costs.^{122–124} However, the choice of appropriate perspective and outcome measures, such as patient and parent convenience, travel, and time off from work, may lead to demonstration of substantial positive financial gains.⁵⁷ The practitioner seeking to evaluate the financial impact of a telehealth program should consider cost, return on investment, and sustainability. In addition, future research and interpretation of the literature will

require careful assessment of the methods used.

Costs

The cost of a telemedicine program varies substantially depending on the intervention used, such as inpatient versus outpatient, and the technology, such as mobile health versus videoconferencing. In assessing the costs, hardware at both the originating and distant sites must be included, along with annual depreciation and some estimate of future costs. Equally important considerations are software, information technology support, administration costs, training, licensing fees, software updates, and the time available to provide the services of both originating and distant site providers.^{9,125} Less easily quantified costs must also be considered. For example, one Australian group found more time was needed for a telemedicine visit than for an in-person visit, although other providers with more extensive experience have not found this to be the case.^{21,126}

Care must be taken in estimating costs, because even similar programs may have different estimations. Comparison of 2 ICU studies demonstrated an almost fourfold variability in estimated program costs, based on both the evaluation methods and the technology used.^{119,127}

Return on Investment

Comprehensive costs must be considered before a telemedicine program is adopted. Benefits will vary based on the perspective of the evaluation, whether provider, patient, health care institution, health care utilization researcher, policy analyst, or payer.¹²⁰ Direct billing, contract fees, and extramural funding are potential benefits to the institution, whereas travel,¹²⁸ days off from work, and convenience may be more important for patients. Providers may realize decreased need for specialty

office space.⁵⁷ Cost savings from decreased emergency department use and decreased hospital admissions may be significant.¹²⁹

Currently, a handful of commercially sustainable telemedicine ventures provide electronic visits to a variety of customers. Commercially sustainable telemedicine ventures are best exemplified in the provision of subspecialist services.¹³⁰ The best known of these are radiology services, such as NightHawk, and intensive care services, such as Visicu.¹³¹ Both of these ventures evolved into initial public offerings and were eventually merged into other for-profit health care companies (Virtual Radiologic and Phillips Healthcare, respectively).¹³² Specialists on Call is an example of a company that provides specialty services in neurology, psychiatry, and intensive care.

More recently, telehealth is expanding into the general pediatric market, with companies such as NuPhysicia providing video visits via immediate care centers located in Walmart stores, and Walgreens recently announced a similar program with MDLive.¹³³ Another interesting development has been the launch of for-profit companies such as MDLive, Doctors on Demand, and Teledoc. These privately held telehealth corporations deliver low-acuity visits via videoconferencing technology either by telephone only or combined AV computer-based encounters. Such visits generally are completely separate from the family's primary care provider's office; the primary care provider may or may not receive reports from these visits, resulting in fragmented care.

Four general funding mechanisms exist to provide services to those who want to gain access to these convenient but disconnected visit opportunities: contracting directly with an employer on behalf of employees and families, contracting with an insurance company to

directly provide services to people covered by insurance plans, selling a monthly subscription to families directly, and a pay-per-visit option in which people generally pay \$40 to \$45 per visit via credit card. These payment mechanisms usually do not involve the submission of a claim to an insurer but are based on a direct payment model. Families with limited means may not be able to afford these direct payment options. If proven true, such a limitation would create a medical justice issue.

Cost Evaluation

In interpreting the economic literature, studies may be influenced by the methods used.^{98,122,123,134} Because of the diversity of specialties involved in telemedicine, the technology used, local pricing and incentives, and the context of the research, generalizing the results is challenging.¹²² An international group of experts has described 19 principles that can be used to assess cost-effectiveness of health technology assessment.¹³⁵ Although no single study will be able to comply with all the principles, this list can be used to determine whether a careful economic evaluation has been performed.

Sustainability

The widespread implementation of telemedicine has been limited by the lack of proven sustainability. Business modeling is critical and should be implemented early in the course program development. Pilot projects funded by grant money may fail when criteria to justify additional financial support lack alignment with the original program and stakeholder goals,⁹⁸ illustrating the importance of aligning both the cost and benefit for all stakeholders and patients.¹³⁶

In the reported literature, telemedicine has demonstrated variable cost-effectiveness. In a systematic review of real-time video communication, 61% of the articles showed cost savings with technology,

whereas others showed similar or higher costs.¹²⁴ In home care videoconferencing, 1 of 9 studies demonstrated financial benefit.¹²⁰ Cost savings have been realized when telemedicine is used for case management in both adult and pediatric medicine for conditions such as asthma¹²⁹ and diabetes.¹³⁷ General pediatrics, pediatric dermatology, and adolescent psychiatry have shown variability in cost-effectiveness.^{11,138-140}

Payment is a key factor in determining sustainability for services. Although lack of payment has led to failure of some programs,^{141,142} perceptions may be changing. One encouraging study revealed that 43% of respondents in 1999 saw payment as a barrier to telemedicine service, but only 22% of respondents in 2004 reported payment as a barrier to sustainability.¹⁴³

Coding for telemedical care is remarkably straightforward. To the appropriate Current Procedural Terminology or HealthCare Common Procedure Coding System code, one simply adds the telehealth modifier "GT," which means "via interactive audio and video telecommunications system" (eg, 99201 GT). Payment policies are a different matter: They are still evolving and vary from state to state. Thus, no definitive statement about payment can be made that will be consistent and current. Three useful reference documents for payment are

- The American Telemedicine Association's Web site
- <http://www.americantelemed.org/policy/state-policy-resource-center>, a continually updated document
- The July 2014 report "State Telehealth Laws and Reimbursement Policies: A Comprehensive Scan of the 50 States and the District of Columbia"¹⁴⁴

Although each state's laws, regulations, and Medicaid program

policies differ significantly, certain trends are evident in the various policies. For example, live video Medicaid reimbursement continues to far exceed reimbursement for store-and-forward and remote patient monitoring. However, in recent months, and since the 50-state survey was first published in 2013, we have seen more states begin to expand telehealth policies and attempt to address barriers to its use. A few significant findings include the following:

- In comparison with 44 states last year, currently the Medicare programs in 46 states and Washington, DC reimburse for some form of live video.
- Since July 2014, 1 state (South Dakota) has removed reimbursement for store-and-forward from their Medicaid program, for a total of 9 state Medicaid programs that offer some reimbursement for store-and-forward (states that reimbursed only for teleradiology are not included in this count).
- Fourteen state Medicaid programs offer reimbursement for remote patient monitoring, compared with 10 states at the time this report was first published in 2013.
- Three state Medicaid programs (Alaska, Minnesota, and Mississippi) reimburse for all 3.

Since 2011, the number of states with telemedicine payment parity laws, which require private insurers to cover telemedicine-provided services comparable to in-person services, has doubled. Now 21 states have telemedicine payment parity laws for private insurance.

Revised policies on coding, billing, and payment are needed to ensure the financial sustainability of health care delivered via telemedicine. Payer education and policy advocacy are needed to enact appropriate valuation of these services in all settings to all

patients by all qualified providers within fee-for-service and alternative payment systems.

No single framework describes exactly what is needed to build and sustain a successful telehealth program. The following suggestions have proven helpful for many telemedical programs. First, ensure that the organization's leaders agree and are involved in project oversight. Second, the organization's information technology support staff must be involved. Third, clinician champions must be identified and supported. Fourth, specific goals must be agreed on by all. Finally, periodic evaluations and reviews to measure effectiveness and process improvement are important.

The Future

Telemedicine has many and diverse applications in pediatrics. As technology continues to improve and decrease in cost, telemedicine will improve research, education, access to care, emergency response, and the delivery of general and specialty pediatrics in diverse settings. It will also augment communication between families and medical professionals caring for their children, even in general pediatrics in community-based practice. The most significant barriers are payment, licensing across state borders, and liability. More research is needed to determine telemedicine's best uses, quality improvement and patient safety implications, and cost-effectiveness in alternative payment systems such as ACOs.

Telemedicine's greatest strength lies in its ability to overcome the barriers of distance and time to reach medically underserved populations. This strength should enable the use of telemedicine to expand in multiple pediatric settings.

LEAD AUTHORS

Bryan L. Burke Jr, MD, FAAP
R. W. Hall, MD, FAAP

SECTION ON TELEHEALTH CARE EXECUTIVE COMMITTEE, 2013–2015

Peter J. Dehnel, MD, FAAP
Joshua J. Alexander, MD, FAAP
Denise M. Bell, MD, FAAP
Maya Bunik, MD, MSPH, FAAP
Bryan L. Burke Jr, MD, FAAP
Joseph A. Kahn, MD, FAAP
Jeffery R. Kile, MD, MHA, FAAP

STAFF

Cathleen Guch, MPH
Julie Kersten Ake

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AMERICAN TELEMEDICINE ASSOCIATION PEDIATRIC SPECIAL INTEREST GROUP

Dale C. Alverson, MD, FAAP; Madan Dharmar, PhD; Julie Hall-Barrow, EdD; Neil Herendeen, MD, MMM, FAAP; James P. Marcini, MD, FAAP; Adam Rule, MBA; Kathleen A. Webster, MD, FAAP

ABBREVIATIONS

4CIF: 4 × Common Intermediate Format
ACA: Patient Protection and Affordable Care Act
ACO: accountable care organization
AV: audiovisual
CME: continuing medical education
CMMI: Center for Medicare and Medicaid Innovation
HIPAA: Health Insurance Portability and Accountability Act

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