Telehealth

18

Justin B. Starren, Thomas S. Nesbitt,
and Michael F. Chiang

After reading this chapter you should know the answers to these questions:

- What are the key informatics requirements for successful implementation of telehealth systems?
- What are some key benefits from and barriers to implementation of telehealth systems?
- What are the most promising application domains for telehealth?

18.1 Introduction

Complexity and collaboration characterize health care in the early twenty-first century. Complexity arises from increasing sophistication in the understanding of health and disease, wherein etiological models must take into account both molecular processes and physical environments. Collaboration reflects not only inter-professional collaboration, but also a realization that successful attainment of optimal well-being and effective management of disease processes necessitate active engagement of clinicians, lay persons, concerned family members, and society as a whole. This chapter introduces the concepts of **telemedicine** and **telehealth**, and illustrates how maturing computer networks like the Internet make possible the collaborations necessary to achieve the full benefits of our growing understanding of health promotion, disease management and disability prevention. Consider the following situation:

> Samuel is a 76 year-old man with coronary artery disease, poorly-controlled Type II diabetes, and high blood pressure. In the past, he has been unable to keep medical appointments consistently because of difficulty arranging transportation. He had a recent acute hyperglycemic episode that required hospitalization. After 4 days he is medically stable and ready for discharge. He is able to measure his blood glucose and can safely administer the appropriate dose of insulin. The nurse notes that Samuel sometimes has trouble calibrating his insulin dose to the blood glucose reading.

J.B. Starren, MD, PhD (✉)
Division of Health and Biomedical Informatics, Department of Preventive Medicine and Medical Social Sciences, Northwestern University Feinberg School of Medicine, 750 N. Lake Shore Dr., Chicago, IL 60611, USA
e-mail: justin.starren@northwestern.edu

T.S. Nesbitt, MD, MPH
Department of Family and Community Medicine, School of Medicine, UC Davis Health System, 4610 X Street, Suite 3101m, Sacramento, CA 95817, USA
e-mail: thomasnesbitt@ucdmc.ucdavis.edu

M.F. Chiang, MD, MA
Department of Ophthalmology & Medical Informatics and Clinical Epidemiology, Oregon Health & Science University, 3375 SW Terwilliger Boulevard, Portland, OR 97239, USA
e-mail: chiangm@ohsu.edu

This chapter is adapted from an earlier version in the third edition authored by Patricia Flatley Brennan and Justin B. Starren.

E.H. Shortliffe, J.J. Cimino (eds.), *Biomedical Informatics*,
DOI 10.1007/978-1-4471-4474-8_18, © Springer-Verlag London 2014

18.1.1 Telemedicine and Telehealth to Reduce the Distance Between the Consumer and the Health care System

Historically, health care has usually involved travel. Either the health care provider traveled to visit the patient, or more recently, the patient traveled to visit the provider. Patients with diabetes, like Samuel, typically meet with their physician every 2–6 months to review data and plan therapy changes. Travel has costs, both directly, in terms of gasoline or transportation tickets, and indirectly, in terms of travel time, delayed treatment, and lost productivity. In fact, travel has accounted for a significant proportion of the total cost of health care (Starr 1982). Because of this, both patients and providers have been quick to recognize that rapid electronic communications have the potential to improve care by reducing the costs and delays associated with travel. This has involved both access to information resources, as well as direct communication among various participants, including patients, family members, primary care providers and specialists.

As is the case with informatics, the formal definitions of telemedicine and telehealth tend to be very broad. **Telemedicine** involves the use of modern information technology, especially two-way interactive audio/video communications, computers and telemetry to deliver health services to remote patients and to facilitate information exchange between primary care physicians and specialists at some distance from each other (Bashshur 1997). **Telehealth** is a somewhat newer and broader term referring to remote health care that includes clinical services provided using telemedicine, as well as interactions with automated systems or information resources. Because of its broader scope, we are using the term telehealth in this chapter.

As is the case with Biomedical informatics, there are many different sub-domains within telehealth. For nearly every clinical domain, there is a "tele-X" or "X telehealth", where X is the clinical domain. Examples include: **Teleradiology** (see Sect. 18.3.4.1); **Teleophthalmology** (see Sect. 18.3.4.2); **Telepsychiatry** (see Sect. 18.3.5.1); and, **telehealth** (see Sect. 18.3.5.3). Some subdomains do not fit neatly into this naming paradigm. **Correctional Telehealth** (see Sect. 18.3.5.2) refers to the location of the patient in a correctional institution. It is discussed separately because of the different business model, and the fact that it represents an early and sustained success. **Remote Intensive Care** (see Sect. 18.3.5.5) is the term used to describe the use of telehealth technologies in an ICU setting. **Teleconsultation** is a general term describing the use of telehealth technologies to support discussions between clinicians, or between a clinician and a patient. The archetypal teleconsultation occurs when the patient and the generalist clinician are in a rural or remote location and a specialist is at a distant tertiary referral facility. **Telepresence** (see Sect. 18.3.6) refers to high-speed, multi-modality telehealth interactions, such as **Telesurgery**, that gives the feeling of "being there".

It is clear from the definition above that there is considerable overlap between telehealth and Biomedical informatics. In fact, one will frequently find papers on telehealth systems presented at Biomedical Informatics conferences and presentations on informatics at telehealth and telemedicine meetings. Some groups, especially in Europe, have adopted the rubric **health information and communication technology** (HICT). The major distinction is one of emphasis. Telehealth and telemedicine emphasize the distance, especially the provision of care to remote or isolated patients and communities. In contrast, Biomedical Informatics emphasizes methods for handling the information, irrespective of the distance between patient and provider.

Consumer health informatics (CHI) is a related domain that bridges the distance between patients and health care resources, and that typically emphasizes interactions with computer-based information such as websites or information resources. Collectively, CHI and telehealth deliver health care knowledge and expertise to where they are needed, and are ways to involve the patient as an active partner in care. Despite their similarities, CHI and telehealth come from very different historical foundations. Telehealth derived from traditional patient care, while CHI derived from the self-help movements of the 1970's. Largely owing to this historical separation, practitioners and researchers in the two fields tend to come from different backgrounds. For these reasons, we are presenting CHI and telehealth as two distinct, but closely related domains (see Chap. 17 for more on CHI).

18.2 Historical Perspectives

The use of communication technology to convey health-related information at a distance is nothing new. The earliest known example may be the use of so-called "leper bells" carried by individuals during Roman times. Sailing ships would fly a yellow flag to indicate a ship was under quarantine and awaiting clearance by a doctor, or a yellow and black "plague flag" to indicate that infected individuals were on board. By some accounts, when Alexander Graham Bell said "Mr. Watson. Come here. I need you" in 1876, it was because he had spilled acid on his hand and needed medical assistance. In 1879, only 3 years later, the first description of telephone use for clinical diagnosis appeared in a medical journal (Practice by Telephone 1879).

18.2.1 Early Experiences

One of the earliest and most long-lived telehealth projects is the Australian Royal Flying Doctor Service (RFDS), founded in 1928. In addition to providing air ambulance services, the RFDS provides telehealth consultations. These consultations first used Morse Code, and later voice, radio communications to the remote sheep stations in the Australian outback. Lay people played a significant role here, clearly communicating their concerns and clinical findings to the RFDS and carefully carrying out instructions while awaiting, if necessary, the arrival of the physician. The RFDS is most famous for its standardized medical chest, introduced in 1942. The chest contains diagnostic charts and medications, identified only by number. This allowed the consulting clinician to localize symptoms by number and then prescribe care, such as "take one number five and two number fours."

Modern telehealth can be traced to 1948 when the first transmission of a radiograph over a phone line was reported. Video-based telehealth can be traced to 1955 when the Nebraska Psychiatric Institute began experimenting with a closed-curcuit video network on its campus. In 1964 this was extended to a remote state mental health facility to support education and **teleconsultation**. In 1967, Massachusetts General Hospital (MGH) was linked to Logan International Airport via a microwave audio-video link (Bird 1972; Murphy et al. 1973). In 1971 the National Library of Medicine began the Alaska Satellite Biomedical Demonstration project linking 26 remote Alaskan villages utilizing NASA satellites (Hudson and Parker 1973)

The period from the mid 1970's to the late 1980's was a time of much experimentation, but few fundamental changes in telehealth. A variety of pilot projects demonstrated the feasibility and utility of video-based telehealth. The military funded a number of research projects aimed at developing tools for providing telehealth care on the battlefield. The early 1990's saw several important advances. Military applications developed during the previous decades began to be deployed. Military **teleradiology** was first deployed in 1991 during Operation Desert Storm. Telehealth in military field hospitals was first deployed in 1993 in Bosnia. Several states, including Georgia, Kansas, North Carolina and Iowa implemented statewide telehealth networks. Some of these were pure video networks, based on broadcast television technology. Others were built using evolving Internet technology. During this same period, correctional telehealth (see Sect. 18.3.5.2) became much more common. For example, in 1992 East Carolina University contracted with the largest maximum-security prison in North Carolina to provide telehealth consultation.

Telehealth projects in the early 1990s continued to be plagued by two problems that had hampered telehealth since its inception: high cost and poor image quality. Both hardware and **high-bandwidth** connections were prohibitively expensive. A single telehealth station typically cost over $50,000 and connectivity could cost thousands of dollars per month. Most programs were dependent on external grant funding for survival. Even with this, image resolution was frequently poor and **motion artifacts** were severe.

The Internet revolution that began in the late 1990s drove fundamental change in telehealth. Advances in computing power both improved image quality and reduced hardware costs to the point that, by 2000, comparable systems cost less than a tenth of what they had a decade earlier. Improvements in **image compression** made it possible to transmit low-resolution, full-motion video over standard telephone lines, enabling the growth of telehome care. With the increasing popularity of the World Wide Web, high-bandwidth connections became both more available and less expensive. Many telehealth applications that had relied on expensive, dedicated, point-to-point connections were converted to utilize commodity Internet connections. The availability of affordable hardware and connectivity also made access to health-related electronic resources from the home, school or work place possible and fueled the growth of consumer health information (see Chap. 17).

18.2.2 Recent Advances in Medical-Grade Broadband Technology

As telemedicine applications are being increasingly used in critical medical situations such as emergency care and remote surgery applications, quality of service (QOS) becomes extremely important. It is important to note that optimally provisioning a network for medical-grade QOS does not simply imply that the network will provide "quality" in the sense of reliability, consistency and bandwidth performance, although these characteristic are certainly important requirements. Any network, no matter the bandwidth available, can become congested – overwhelmed with the volume of traffic to the extent that sessions are interrupted and data lost. Bandwidth availability limitations are particularly prevalent in rural locations where high-capacity circuits may be unavailable or prohibitively expensive.

Newer network routing technologies such as **multiprotocol label switching** (MPLS) can, in addition to providing superior network throughput performance, permit explicit prioritization of clinical traffic while simultaneously providing access to lower priority administrative and other non-clinical traffic. The individual data packets of high priority traffic (e.g., telehealth or patient monitoring sessions) are "tagged" with a numerical priority flag. As the QOS-tagged packets traverse the network, each routing/switching device recognizes the priority tag and preferentially processes and forwards the packets. This explicit QOS combined with advanced security and privacy features within a broadband network has been characterized as "Medical Grade" broadband.

18.3 Bridging Distance with Informatics: Real-world Systems

There are many ways to categorize telehealth resources, including classifications based on participants, bandwidth, information transmitted, medical specialty, immediacy, health care condition, and financial reimbursement. The categorization in Table 18.1 is based loosely on bandwidth and overall complexity. This categorization was chosen because each category presents different challenges for informatics researchers and practitioners.

A second categorization of telehealth systems that overlaps the previous one is the separation into synchronous (or real-time) and asynchronous (or **store-and-forward** systems). Video conferencing is the archetypal synchronous telehealth application. Synchronous telehealth encounters are analogous to conventional office visits. Telephony, chat-groups, and **telepresence** (see Sect. 18.3.6) are also examples of synchronous telehealth. A major challenge in all synchronous telehealth is scheduling. All participants must be at the necessary equipment at the same time.

Store-and-forward, as the name implies, involves the preparation of a dataset at one site that is sent asynchronously to a remote recipient. Remote interpretation, especially teleradiology, is

Table 18.1 Categories of telehealth and consumer health informatics

Telehealth category	Bandwidth	Applications
Information resources	Low to moderate	Web-based information resources, patient access to electronic medical records
Messaging	Low	E-mail, chat groups, consumer health networks, personal clinical electronic communications (PCEC)
Telephone	Low	Scheduling, triage
Remote monitoring	Low to moderate	Remote monitoring of pacemakers, diabetes, asthma, hypertension, Congestive Health Failure (CHF).
Remote interpretation	Moderate	PACS, remote interpretation of radiographic studies and other images, such as dermatologic and retinal photographs.
Videoconferencing	Low to high	Wide range of applications, from low-bandwidth telehome care over telephone lines, to high-bandwidth telementoring and telepsychiatry
Telepresence	High	Remote surgery, telerobotics

the archetypal example of store-and-forward telehealth. Images are obtained at one site and then sent, sometimes over very low bandwidth connections, to another site where the domain expert interprets them. Other examples of store-and-forward include access to Web sites, e-mail and text messaging. Some store-and-forward systems support the creation of multimedia "cases" that contain multiple clinical data types, including text, scanned images, wave forms and videos.

18.3.1 The Forgotten Telephone

Until recently, the telephone was a forgotten component in teleheath. The field of telemedicine and telehealth focused on video and largely ignored the audio-only telehealth. Few studies were done and few articles written. This is paradoxical given that up to 25 % of all primary care encounters occur via the telephone. These include triage, case management, results review, consultation, medication adjustment and logistical issues, like scheduling. In part, this can be traced to the fact that telephone consultations are not reimbursed by most insurance carriers.

More recently, increased interest in cost control through case management has driven renewed interest in use of audio-only communication between patients and providers. Multiple articles have appeared on the value of telephone follow-up for chronic conditions. Several managed care companies have set up large telephone triage centers. The National Health Service in the UK is investing £123 million per year in NHS Direct, a nation wide telephone information and triage system that handles 27,000 calls per day. With some insurance providers reimbursing for e-mails and text messaging, providers are asking why not reimburse for telephone calls also.

18.3.2 Electronic Messaging

Electronic text-based messaging has emerged as a popular mode of communication between patients and providers. It began with patients sending conventional e-mails to physicians. The popularity of this grew so rapidly that national guidelines were developed (Kane and Sands 1998). However, e-mail has a number of disadvantages for health related messaging: delivery is not guaranteed; security is problematic; e-mail is transient (there was no automatic logging or audit trail); and the messages are completely unstructured.

To address these limitations, a variety of Web-based messaging solutions, called **personal clinical electronic communications**, have been developed (Sarkar and Starren 2002). Because the messages never leave the Web site, many of the problems associated with conventional e-mail are avoided. Web-based messaging is a standard feature of **patient portals** see Chap. 17) associated with many EHRs. The inclusion of messaging as a Meaningful Use requirement for Certified EHRs is expected to significantly increase the use of web-based messaging to provide telehealth (Fig. 18.1).

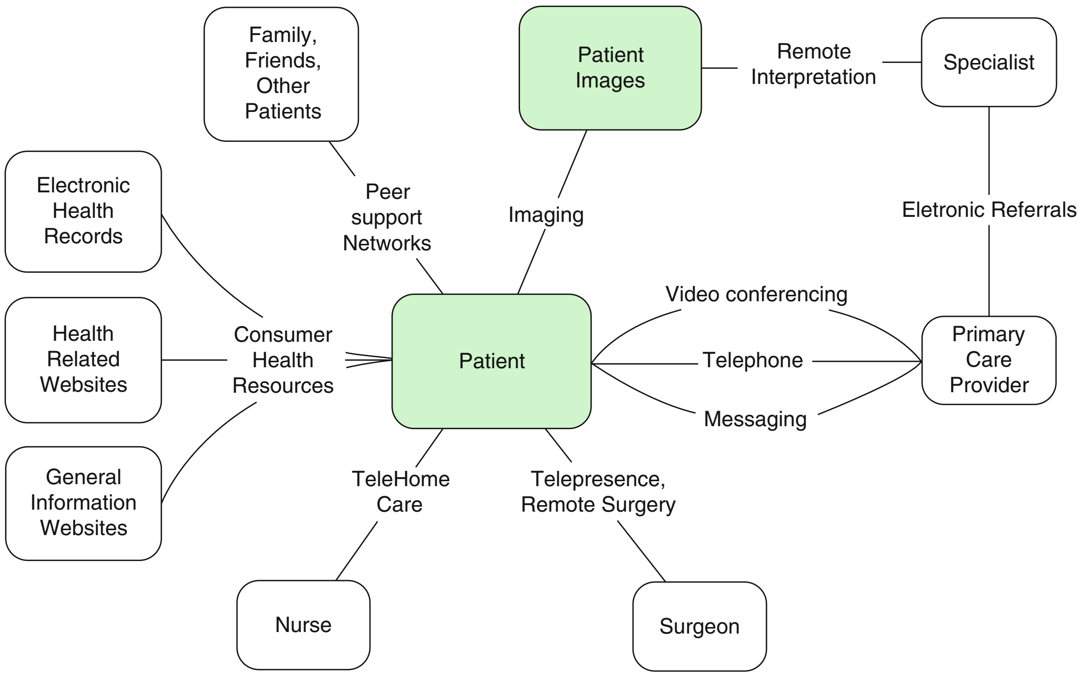

Fig. 18.1 Connections. The figure shows different ways that electronic communications can be used to link patients with various health resources. Only connections directly involving the patient are shown (e.g., use of the EHR by the clinician is not shown). Some of the resources, such as Web sites or telehome care, can be accessed from the patient's home. Other resources, such as remote surgery or imaging, would require the patient to go to a telehealth-equipped clinical facility

18.3.3 Remote Monitoring

Remote monitoring is a subset of telehealth focusing on the capture of clinically relevant data in the patients' homes or other locations outside of conventional hospitals, clinics or health care provider offices, and the subsequent transmission of the data to central locations for review. The conceptual model underlying nearly all remote monitoring is that clinically significant changes in patient condition occur between regularly scheduled visits and that these changes can be detected by measuring physiologic parameters.

The care model presumes that, if these changes are detected and treated sooner, the overall condition of the patient will be improved. An important distinction between remote monitoring and many conventional forms of telemedicine is that remote monitoring focuses on management, rather than on diagnosis. Typically, remote monitoring involves patients who have already been diagnosed with a chronic disease or condition. Remote monitoring is used to track parameters that guide management. Any measurable parameter is a candidate for remote monitoring. The collected data may include continuous data streams or, more commonly, discrete measurements.

Another important feature of most remote monitoring is that the measurement of the parameter and the transmission of the data are typically separate events. The measurement devices have a memory that can store multiple measurements. The patient will send the data to the caregiver in one of several ways. For many studies, the patient will log onto a server at the central site (either over the Web or by direct dial-up) and then type in the data. Alternately, the patient may connect the measurement device to a personal computer or specialized modem and transfer the readings electronically.

More recently, a variety of monitoring devices have been developed that either connect directly to mobile telephones or transmit the data to the mobile phone using Bluetooth wireless. The mobile phone then transmits the data to a provider for review. A major advantage of direct electronic transfer is that it eliminates problems stemming from manual entry, including falsification, number preference and transcription errors. The role of mobile telephones in providing health services has grown so rapidly that a new term **mobile health** (or "mHealth") has been coined. The term appeared first, one time, in 2004 in PubMed. All of the other mentions have been since 2009.

Any condition that is evaluated by measuring a physiologic parameter is a candidate for remote monitoring. The parameter most measured in the remote setting is blood glucose for monitoring diabetes. A wide variety of research projects and commercial systems have been developed to monitor patients with diabetes. Patients with asthma can be monitored with peak-flow or full-loop **spirometers**. Patients with hypertension can be monitored with automated blood pressure cuffs. Patients with congestive heart failure (CHF) are monitored by measuring daily weights to detect fluid gain. Remote monitoring of pacemaker function has been available for a number of years and has recently been approved for reimbursement. Home coagulation meters have been developed that allows the monitoring of patients on chronic anticoagulation therapy. See Chap. 19 for more on patient monitoring systems.

Several factors limit the widespread use of remote monitoring. First is the question of efficacy. While these systems have proven acceptable to patients and beneficial in small studies, few large-scale controlled trials have been done. Second is the basic question of who will review the data. Research studies have utilized specially trained nurses at centralized offices but it is not clear that this will scale up. Third is money—for most conditions, remote monitoring is still not a reimbursed activity.

18.3.4 Remote Interpretation

Although Samuel was diagnosed with Type II diabetes over 20 years ago and realizes that visual loss can be a serious complication, he has only rarely received dilated eye exams for retinopathy screening. There is no eye doctor conveniently located near his home, and he feels that the appointments are always too long and that he has no problems such as blurred vision. However, his primary care doctor has recently implemented a new retinal screening machine in the office. During a routine medical examination, Samuel receives a retinal photograph from an office technician that is then interpreted by a remote ophthalmologist. Samuel is told that he has high-risk diabetic retinopathy that requires treatment to prevent visual loss. He is emergently referred to an ophthalmologist, who performs a successful laser procedure to treat the diabetic retinopathy.

Remote interpretation is a category of store-and-forward telehealth that involves the capture of images, or other data, at one site and their transmission to another site for interpretation. This may include radiographs (*teleradiology*), photographs (*teledermatology*, *teleophthalmology*, *telepathology*), wave forms such as ECGs (e.g. *telecardiology*), and text-based medical data.

The store-and-forward telehealth modalities have benefited most from the development of the **commodity Internet** and the increasing availability of affordable high bandwidth connections that is provides. The shared commodity Internet provides relatively high bandwidth, but the available bandwidth is continuously varying. This makes it much better suited for the transfer of text-based data and image files, rather than for streaming data or video connections. Although image files are often tens or hundreds of megabytes in size, the files are typically transferred to the interpretation site and cached there for later interpretation. From a logistical perspective, multiple remote interpretations may be batched and performed together, thereby providing important workflow and convenience advantages over traditional medical examinations or real-time video telehealth paradigms.

18.3.4.1 Teleradiology

By far, teleradiology is the largest category of remote interpretation, and probably the largest category of telehealth. Teleradiololgy (along with telepathology) represents the most mature clinical domain in telehealth. With the deployment of **picture archiving and communications systems** (PACS) that capture, store, transmit and displays digital radiology images, the line between teleradiology and conventional radiology is blurring. In fact, routine medical care in radiology and pathology is increasingly being delivered primarily through "telehealth" strategies (Radiology image management is discussed in more detail in Chap. 20).

Many factors have contributed to the more rapid adoption of telehealth in domains such as radiology and pathology. One important factor is the relationship between these specialists and their patients. In both domains, the professional role is often limited to the interpretation of images, and the specialist rarely interacts directly with the patient. To patients, there is therefore little perceived difference between a radiologist in the next building and one in the next state.

An important factor driving the growth of teleradiology is that it is reimbursable by insurance payers. Because image interpretation does not involve direct patient contact, few payers make any distinction about where the interpretation occurred. Rapid dissemination of teleradiology systems has also been supported by widespread adoption of vendor-neutral image storage and transmission standards such as **Digital Imaging and Communication in Medicine** (DICOM; discussed in more detail in Chaps. 7 and 20). Finally, numerous evaluation studies have demonstrated that digital image interpretation by through teleradiology has comparable, or potentially even better, accuracy and efficiency compared to traditional film-based radiological examination (Franken et al. 1992; Reiner et al. 2002; Mackinnon et al. 2008).

18.3.4.2 Teleophthalmology

Another area of remote interpretation that is growing rapidly is teleophthalmology, particularly for retinal disease screening. As one example, diabetic retinopathy (retinal disease) is a leading cause of blindness that can be treated if detected early. However, it has been found that nearly 50 % of diabetics are non-compliant with guidelines recommending annual screening eye examinations (Brechner et al. 1993). Systems have been developed that allow nurses or technicians in primary care offices to obtain high quality digital retinal photographs. These images are sent to regional centers for interpretation. If diabetic retinopathy is identified or suspected, the patient is referred for full ophthalmologic examination.

Large-scale operational systems have been implemented by the Veterans Health Administration and by other institutions, particularly in areas with limited accessibility to eye care specialists (Cavalleranno et al. 2005; Cuadros and Bresnick 2009). In fact, remote interpretation of retinal images by certified reading centers, when taken after dilation of the eyes using standard photographic protocols originally developed for clinical research trials, has been demonstrated to classify diabetic retinopathy more accurately than traditional dilated eye examination. This is likely because retinal abnormalities found on photographs may be reviewed in more detail than what is generally feasible during traditional eye examinations.

As another example of teleophthalmology, retinopathy of prematurity (ROP) is a leading cause of blindness in premature infants, and hospitalized infants are examined regularly to identify treatment-requiring disease. However, these examinations are logistically difficult and time consuming, and the number of ophthalmologists willing to perform them has decreased. As a result, systems have been developed in which trained nurses capture retinal photographs and transmit them to experts for remote interpretation (Fig. 18.2) (Richter et al. 2009).

18.3.5 Video-based Telehealth

To many people telehealth is videoconferencing. Whenever the words "telehealth" or "telemedicine" are mentioned, most people have a mental image of a patient talking to a doctor over some type of synchronous video connection. Indeed, most early telehealth research did

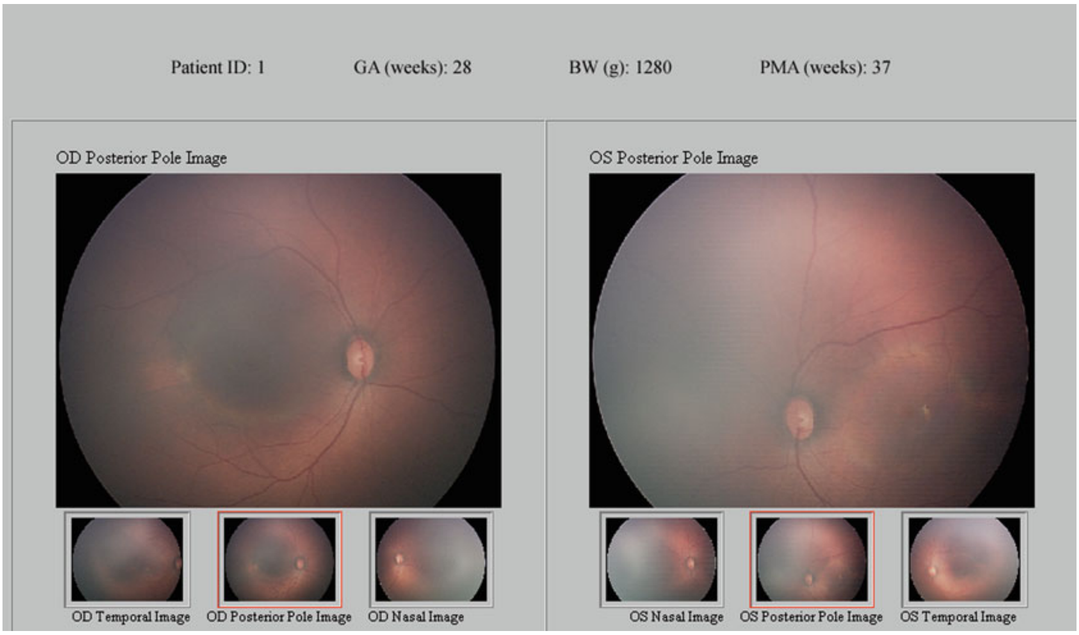

Fig. 18.2 Store-and-forward telemedicine system for ophthalmic disease, in which a remote grader interprets retinal images, along with relevant clinical data, captured by a nurse. Three images from different areas of the patient's right eye (*OD*) and left eye (*OS*) are displayed. Diagnosis and recommendations are then sent back to the local site (Source: Chiang .2007. *Archives of Ophthalmology*, *125*(11), 1531. Copyright © (2007) American Medical Association. All rights reserved)

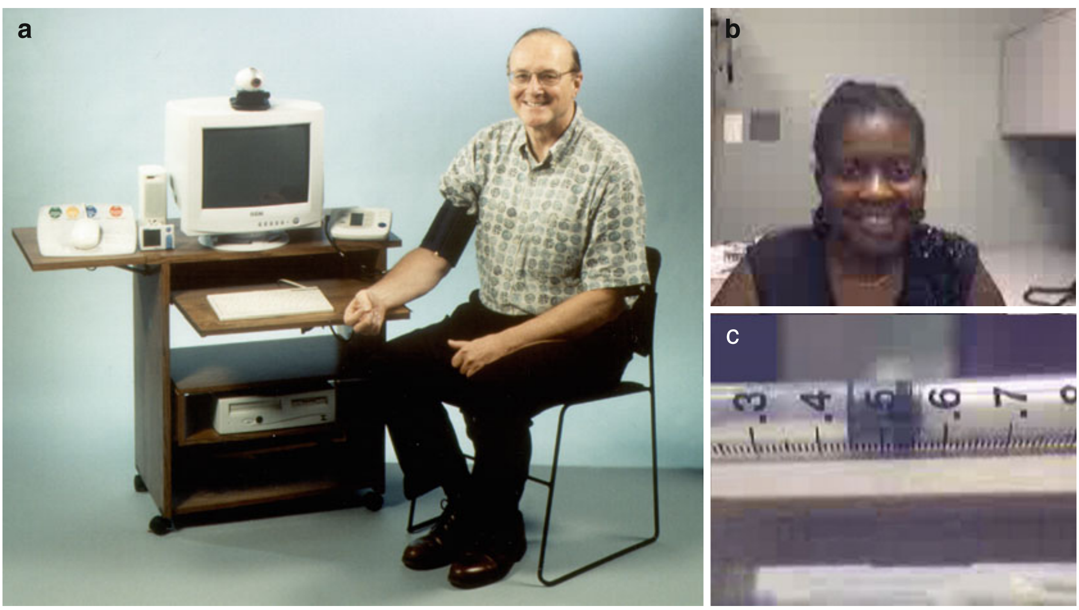

Fig. 18.3 Plain old telephone service (POTS)–based home telehealth. Panel (**a**) shows the IDEATel Home Telemedicine Unit. Panel (**b**) shows a typical full-motion video image transmitted over POTS. Because of frame-to-frame compression, images of nonmoving objects can be of even higher quality. Many home telehealth systems are also equipped with close-up lenses to allow providers to monitor medications or wounds. Panel (**c**) shows a close-up video image of a syringe indicating that the patient has drawn up 44 units of insulin. The small markings are roughly 0.6 mm apart (Source: Starren 2003, reproduced with permission)

focus on synchronous video connections. For many of the early studies, the goal was to provide access to specialists in remote or rural areas. Nearly all of the early systems utilized a hub-and-spoke topology where one hub, usually an academic medical center, was connected to many spokes, usually rural clinics.

Many of the early telehealth consults involved the patient and the primary care provider at one site conferring with a specialist at another site. Most of the state-wide telehealth networks operated on this model. This was so engrained in the telehealth culture, that the first legislation allowing Medicare reimbursement of telehealth consults required a “presenter” at the remote site.

This requirement for a “presenter” exacerbated the scheduling problem. Because synchronous video telehealth often uses specialized videoconferencing rooms, the televisits need to be scheduled at a specific time. Getting the patient and both clinicians (expert and presenter) at the right places at the right time has forced many telehealth programs to hire a full-time scheduler. The scheduling problem, combined with the advent of more user-friendly equipment, ultimately led Medicare to drop the presenter requirement. Even so, scheduling is often the single biggest obstacle to greater use of synchronous video consultations.

A second obstacle has been the availability of relevant clinical information. Because of the inability to interface between various EHRs, it was not unusual for staff to print out results from the EHR at one site and then to fax those to the other site prior to a synchronous video consultation.

Unlike store-and-forward telehealth, synchronous video requires a stable data stream. Although video connection can use conventional phone lines (commonly referred to as **plain old telephone service**, or POTS) that provide 64 bits-per-second (64 kbs) transmission speed, diagnostic quality video typically requires at least 128 Kbs and more commonly 384 Kbs (see Chap. 5). In order to guarantee stable data rates, synchronous video in clinically critical situations still relies heavily on dedicated circuits, either **Integrated Service Digital Network** (ISDN) connections or leased lines. Within single organizations, or in consultative or educational settings, Internet Protocol (IP) based video conferencing has become the dominant modality.

Synchronous video telehealth has been used in almost every conceivable situation. In addition to traditional consultations, the systems have been used to transmit grand rounds and other educational presentations. Video cameras have been placed in operating rooms at hub sites to transmit images of surgeries for educational purposes. Video cameras have been placed in emergency departments and operating rooms at spoke sites to allow experts to “telementor” less experienced physicians in the remote location. Video cameras have also been placed in ambulances to provide remote triage.

More recently, the growing popularity of mobile devices is creating potential for new strategies involving real-time video communication between patients and health care providers. This is especially promising because mobile networks are low-cost and widely-available for consumers, and because they are increasingly accessible even in developing countries. However, health information exchange using mobile networks raises concerns about privacy, security, and compliance with **Health Insurance Portability and Accountability Act** (HIPAA). With appropriate encryption settings, wireless video communication using mobile device applications may be HIPAA-compliant (e.g. FaceTime; Apple Computer, Cupertino, CA). In the future, these mobile technologies may provide opportunities for greater communication between patients and providers.

Prior to the adoption of IP-based videoconferencing, programs begun with grant funding ended soon after the grant funding ended. Even after the advent of IP-based conferencing, many programs have struggled. This is in spite of the fact that Medicare has begun reimbursing for synchronous video under limited circumstances.

Some rural health care providers, such as the Marshfield Clinic in Wisconsin, have integrated synchronous telehealth into their standard care model to provide routine specialist services to outlying location. Some categories of synchronous video telehealth have developed sustainable models: telepsychiatry, correctional telehealth; home telehealth, emergency telehealth, and remote intensive care.

18.3.5.1 Telepsychiatry

In many ways, psychiatry is the ideal clinical domain for synchronous video consultation. Diagnosis is based primarily on observing and talking to the patient. The interactive nature of the dialog means that store-and-forward video is rarely adequate. Physical examination is relatively unimportant, so that the lack of physical contact is not limiting. There are very few diagnostic studies or procedures, so that interfacing to other clinical systems is less important. In addition, state offices of mental health deliver a significant fraction of psychiatric services, minimizing reimbursement issues. This is illustrated by two projects. In 1995, the South Carolina Department of Mental Health established a telepsychiatry network to allow a single clinician to provide psychiatric services to deaf patients throughout the state (Afrin and Critchfield 1997). The system allowed clinicians, who had previously driven all over the state, to spend more time in patient care and less time traveling.

The system was so successful that it was expanded to multiple providers and roughly 20 sites. The second example comes from the New York State Psychiatric Institute (NYSPI), which is responsible for providing expert consultation to mental health facilities and prisons throughout the state. As in South Carolina, travel time was a significant factor in providing this service. To address the problem, the NYSPI created a videoconference network among the various state mental health centers. The system allows specialists at NYSPI in New York City to provide consultations in a timelier manner, improving care and increasing satisfaction at the remote sites.

18.3.5.2 Correctional Telehealth

Prisons tend to be located far from major metropolitan centers. Consequently, they are also located far from the specialists in major medical centers. Transporting prisoners to medical centers is an expensive proposition, typically requiring two officers and a vehicle. Depending on the prisoner and the distance, costs for a single transfer range from hundreds to thousands of dollars. Because of the high cost of transportation, correctional telehealth was economically viable even before the advent of newer low cost systems.

Correctional telehealth also improves patient satisfaction. A fact surprising to many is that inmates typically do not want to leave a correctional institution to seek medical care. Many dislike the stigma of being paraded through a medical facility in prison garb. In addition, the social structure of prisons is such that any prisoner who leaves for more than a day risks losing privileges and social standing. Correctional telehealth follows the conventional model of providing specialist consultation to supplement to on-site primary care physicians. This has become increasingly important with the rising prevalence of AIDS in the prison population.

18.3.5.3 Home Telehealth

> After Samuel misses two scheduled visits, the Diabetes Educator calls see what is the matter. Samuel explains that it is a 1-h drive from his home to the diabetes center, that his daughter had trouble taking time off from work to drive him, and that he would have difficulty leaving his wife home alone because she has been ill recently. The Diabetes Educator notes that Samuel lives in a rural area and is eligible to receive educational services via teleheath. She signs Samuel up to receive a Home Telehealth Unit and schedules delivery. The unit is initially difficult for him to use because he is not familiar with computer systems. However, after this initial learning process, Samuel rarely misses a video education session. At one visit, Samuel complains that his children and wife are always "on his case" about his injections. The nurse schedules the next video visit during an evening when Samuel's daughter can attend. She also schedules Samuel to have a video visit with the dietician.

Somewhat paradoxically, one of the most active areas of telehealth growth is at the lowest end of the bandwidth spectrum—telehealth activities into patients' homes. In the late 1990s, many believed that home broadband access would soon become ubiquitous and a number of vendors abandoned POTS-based systems in favor of IP-based video solutions. The broadband revolution was slower than expected, especially in rural and economically depressed areas most in need of home telehealth services. A few research projects paid to have broadband or ISDN installed in patients' homes. In response to this, the American Telemedicine Association released new guidelines for Home Telehealth in 2002 in which synchronous video is provided over POTS connections.

Most vendors have returned to POTS-based solutions and a number of new products have appeared in the past 3 years. In addition to video, the devices typically have data ports for connection of various peripheral devices, such as a digital stethoscope, glucose meter, blood pressure meter, or spirometer. Although the video quality would not be adequate for many diagnostic purposes, it is adequate for the management of existing conditions. Figure. 18.3 shows actual POTS video quality.

Home telehealth can be divided into two major categories. The first category, often called **telehome care**, is the telehealth equivalent of home nursing care. It involves frequent video visits between nurses and, often homebound, patients. With the advent of prospective payment for home nursing care, telehome care is viewed as a way for home care agencies to provide care at reduced costs. As with home nursing care, telehome care tends to have a finite duration, often focused on recovery from a specific disease or incident. Several studies have shown that telehome care can be especially valuable in the management of patients recently discharged from the hospital and can significantly reduce readmission rates.

The second category of home telehealth centers on the management of chronic diseases. Compared with telehome care, this type of home telehealth frequently involves a longer duration of care and less frequent interactions. Video interactions tend to focus on patient education, more than on evaluation of acute conditions.

Fig. 18.4 Emergency telemedicine care system, in which a remote expert performs videoconsultation with a local physician or nurse (University of California, Davis Health System, 2010, reproduced with permission)

The largest such project to date is the Informatics for Diabetes Education and Telemedicine (IDEATel) project (Starren et al. 2002). Started in 2000, the IDEATel project was an 8-year, $60 million demonstration project funded by the Center for Medicare and Medicaid Services (CMS, formerly the Health Care Financing Administration, or HCFA) involving 1665 diabetic Medicare patients in urban and rural New York State. In this randomized clinical trial, half of the patients received Home Telemedicine Units (HTU) (Fig. 18.3), and half continued to receive standard care.

At peak, 636 patients were actively using the HTU's. In addition to providing 2-way POTS-based video, the HTU allowed patients to interact in multiple ways with their online charts. When patients measure blood pressure or fingerstick glucose with devices connected directly to the HTU, the results were automatically encrypted and transmitted over the Internet into the Columbia University Web-based Clinical Information System (WebCIS; Hripcsak et al. 1999) at New York Presbyterian Hospital (NYPH) and to diabetes-specific case management software. Nurse case managers monitored patients by viewing the uploaded results, participating in bulletin board discussions, videoconferencing, and answering e-mailed questions daily. The case manager received an alert when a patient's transmitted values exceed set thresholds.

An important distinction between telehome care and disease management telehealth is that interactions in the former are initiated and managed by the nurse. Measurements, such as blood pressure, are typically collected during the video visit and uploaded as part of the video connection. For disease management, the HTU also needs to support remote monitoring, patient-initiated data uploads and, possibly, Web-based access to educational or disease management resources.

A project that reversed the conventional notion of home telehealth was the Baby CareLink project (Gray et al. 2000). This project focused on very low birth weight infants who typically spend months in neonatal intensive care units (NICU). The project used high-speed (ISDN) video connections to connect from the NICU into the parents' home. This allowed parents who could not visit the NICU regularly to maintain daily contact with their infants. The video connection was supplemented by communication and educational material on a project Web site.

18.3.5.4 Emergency Telemedicine

> Samuel develops slurred speech and weakness on the right side of his body. His daughter, who is with him at the time, calls 911. The ambulance crew notifies the emergency room that they are in route with a possible stroke victim. On arrival, the rural emergency department (ED) physician does a quick evaluation and connects via telemedicine with a stroke neurologist at an academic health center. The neurologist talks with the Samuel and his daughter, and participates in the examination with the ED physician. Following laboratory work and a CT negative for hemorrhage, the ED physician again consults with the neurologist who confirms the diagnosis of ischemic stroke and institutes thrombolytic therapy via pre-arranged protocol. Samuel is transferred to the intensive care unit for close monitoring of his diabetes, hypertension, and evolving stroke.

"Just in time" consultation in the emergency setting potentially represents one of the most beneficial uses of telehealth (Fig. 18.4). Emergency telemedicine has been used in a variety of ways and has demonstrated significant benefits, including in such area as tele-trauma care, burn care, and critical care pediatric specialists consulting on critically ill or injured children (Ricci et al. 2003; Saffle et al. 2009; Heath et al 2009). Telehealth in the emergency setting is likely to have the greatest benefit when time-limited critical decision making by a specialist physician regarding a specific intervention is necessary.

An important and increasingly frequently used application demonstrating this is in the evaluation and treatment of the stroke patient. Best practice management of ischemic stroke in appropriate patients now includes the use of thrombolytic therapy such as tissue plasminogen activator (tPA), which has been shown to have statistically significant clinical and financial benefits. Recommendations and drug labeling limit the use of intravenous tPA to within 3 h of when the patient was last seen as well or had witnessed onset of symptoms.

This therapy, however, has significant complications, particularly in patients with hemorrhagic rather than ischemic events – requiring urgent specialty consultation, along with rapid expert interpretation of imaging and laboratory work. Many settings lack the specialty expertise to have on-site "stroke teams" to accomplish best practice. Telemedicine can bring specialty expertise to a remote location for emergency evaluation of the patient directly, while transmit images and laboratory work for immediate interpretation.

This model of care, first called "telestroke" care by Levine and Gorman, has been increasingly used throughout the country (Levine 1999). The efficacy of this model, compared to traditional telephone consultation, was evaluated by Meyer et al. (2008). These investigators found that telestroke care resulted in more accurate decision making than did telephone consultation.

Based on a comprehensive review of evidence, the American Heart Association and American Stroke Association have recommended that "whenever local or on-site acute expertise or resources are insufficient to provide around-the-clock coverage for a health care facility, telestroke systems should be deployed to supplement resources at participating sites" (Schwamm et al. 2009). This comprehensive and detailed report makes other recommendations in support of telemedicine in the area of stroke care.

18.3.5.5 Remote Intensive Care

> Samuel was admitted to the intensive care unit (ICU) in his local hospital with the diagnosis of stroke, diabetes and hypertension. He is being treated with thrombolytic therapy. During the night, Samuel's blood pressure begins to rise significantly above the recommended level for patients under treatment with thrombolytic therapy. This is quickly recognized by a remote tele-ICU team that provides coverage for all of the ICU beds in Samuel's rural hospital. This remote intensive care team has complete access to Samuel's electronic health record and bedside monitors and they also have video and audio connectivity into the room. The remote critical care team is able to quickly connect to Samuel's room and do a neurological exam with the assistance of the on-site nursing team. They determine that the exam is unchanged from the emergency room. They are able to order appropriate medications, recommend more frequent neurological checks, and directly follow his blood pressure response.

Consultation models in the in-patient setting using telemedicine in a variety of specialties have been reported. including intensive care where timely consults are often essential (Assimacopoulos et al. 2008; Marcin et al. 2004). Although, these consultation models in critical care have shown benefit, a comprehensive multi-modality model has becomeh more common. This is often referred to as tele-ICU, and is defined as care provided to critically ill patients with at least some of the managing physicians and nurses in a remote location.

Some of the initial work in this area, done by Rosenfield and Bresslow in the Sentara Health System, demonstrated improved mortality, reduced lengths of stay and decreased costs (Rosenfeld et al. 2000). Remote intensive care has grown significantly over time with an estimated 10 % of all ICU beds in the U.S. covered under this model of care, in large part due to a shortage of critical care physicians Typically, a single "Command Center" can cover multiple intensive care units over a large geographic region creating significant efficiencies and economies of scale.

This model of care integrates several of the technologies discussed in this book and is primarily enabled using electronic health records, evidenced based decision support tools, connections to bedside monitoring systems and audio/video based telemedicine into patient rooms. Most commonly, critical care health professionals co-manage care from a Command Center led by board-certified critical care physicians. Protocols and treatments reviews for patient management are incorporated into the care process using data from the monitoring and alert systems that indicate when changes in care should take place. The goal is to assure adherence to best practice, achieve shorter response times to alarms, abnormal laboratory values and more rapid initiation of life saving interventions (Lilly et al. 2011).

Recent studies have shown mixed results in terms of the benefits of tele-ICU. Morrison and colleagues studied mortality, length of stay, and total cost in 4,088 patients admissions at two metropolitan hospitals. Age, gender, race/ethnicity, trauma status, **APACHE III** score, and physician utilization of the eICU were included as covariates. In this study, the investigators did not find a reduction in mortality, length of stay, or hospital cost attributable to the introduction of the eICU (Morrison 2009). In a study by Thomas in 2009, the investigators found that although remote monitoring of ICU patients was not associated with an overall improvement in mortality or LOS, there was a significant interaction between the tele-ICU intervention and severity of illness ($P < .001$), in which tele-ICU was associated with improved survival in sicker patients but with no improvement or worse outcomes in less sick patients (Thomas et al. 2009).

In a more recent study, Lilly et al. reported that in a single academic medical center, implementation of tele-ICU was associated with reduced mortality and LOS, as well as lower rates of preventable complications (Lilly et al. 2011). Further research is needed in this area to determine the benefits of tele-ICU and the specific components that account for these benefits.

18.3.6 Telepresence

Telepresence involves systems that allow clinicians to not only view remote situations, but also to act on them. The archetypal telepresence application is telesurgery. The most basic surgical telepresence systems simply permit two-way audio-video communications, by which remote surgeons can observe, teach, and collaborate with local surgeons while they operate on patients.

More advanced surgical telepresence systems allow procedures to actually be performed remotely. Although largely still experimental, a trans-Atlantic gall bladder operation was demonstrated in 2001 (Kent 2001). The military has funded considerable research in this area in the hope that surgical capabilities could be extended to the battlefield. Telepresence requires high bandwidth, low **latency** connections. Optimal telesurgery requires not only teleoperation of robotic surgical instruments, but also accurate **force feedback** (or **haptic feedback**) that requires extremely low network latencies. Accurate millisecond force feedback has been historically limited to distances under 100 miles. The endoscopic gall bladder surgery mentioned above is an exception to this general principle because that specific procedure relied almost exclusively on visual information. It used a dedicated and custom configured 10 Mb/s fiberoptic network with a 155 ms latency.

Providing tactile feedback over large distances actually requires providing the surgeon with simulated feedback while awaiting transmission of the actual feedback data. Such simulation requires massive computing power and is an area of active research. Telesurgery also require extremely high-reliability connections. Loss of a connection is an annoyance during a consultation; it can be fatal during a surgical procedure.

Robotic surgery systems have been commercially available since the early 2000s. In these systems, surgical instruments and a camera are introduced into the patient through small incisions. The surgeon controls these instruments remotely, while he or she is viewing a magnified three-dimensional camera image of the patient's anatomical structures. These systems are currently being used in some medical centers for small-incision surgery, typically performed by surgeons seated adjacent to their patients. The increasing availability and use of these robotic surgery systems creates possibilities for an increasing number of telesurgery applications.

To date, robotically-assisted surgery has been most common in fields such as cardiothoracic surgery, gynecology, and urology. Potential advantages of remote robotically-assisted surgery may include smaller incisions, improved anatomic visualization, and finer control of surgical instrumentation. Several clinical studies comparing robotically-assisted surgery with traditional surgery have suggested that the outcomes are similar (Allemann et al. 2010; Ficarra et al. 2009). However, additional research is required to determine the optimal role of robot-assisted surgery and its applications to telesurgery.

A novel form of telepresence gives clinicians the ability to not only to see, but also to walk around. Since the early 2000s, a commercially-available system has combined conventional

Fig. 18.5 Telehealth robot. This is controlled by a remote clinician, and includes videoconferencing and remote monitoring capabilities. In this example, physician is speaking with a nurse while conducting remote patient rounds (Source: InTouch Health, reproduced with permission)

video telehealth with a remote controlled robot (Fig. 18.5). It allows clinicians to literally make remote video rounds. A frequent problem with telehealth systems is having the equipment where it is needed. With this system, the telehealth equipment is literally able take itself to wherever it is needed. Remote monitoring may be also performed by interfacing digital devices such as stethoscopes or imaging systems to the remote-controlled robot. These remote-controlled systems are most often used by physicians and nurses to examine patients in nursing homes or other long-term facilities, improve health care access in rural areas, and perform post-operative examinations. It is too early to tell whether this model of telepresence will become widely adopted, but, like many earlier innovative systems, it raises many interesting questions.

18.4 Challenges and Future Directions

As telehealth evolves from research novelty to being a standard way that health care is delivered, many challenges must be overcome. Some of these challenges arise because the one patient, one doctor model no longer applies. Basic questions of identity and trust become paramount. At the same time, the shifting focus from treating illness to managing health and wellness requires that clinicians know not only the history of the individuals they treat but also information about the social and environmental context within which those individuals reside. In the diabetes example, knowledge of the family history of risk factors, diseases, and the appropriate diagnostic and interventional protocols, aid the clinical staff in providing timely and appropriate treatment.

18.4.1 Challenges to Using the Internet for Telehealth Applications

Because of the public, shared nature of the Internet, its resources are widely accessible by citizens and health care organizations. This public nature also presents challenges to the security of data transmitted along the Internet. The openness of the Internet leaves the transmitted data vulnerable to interception and inappropriate access. In spite of significant improvements in the security of Web browsing several areas, including protection against viruses, authentication of individuals and the security of email, remain problematic.

Ensuring every citizen access to the Internet represents a second important challenge to the ability to use it for public health purposes. Access to the Internet presently requires computer equipment that may be out of reach for persons with marginal income levels. Majority-language literacy and the physical capability to type and read present additional requirements for effective use of the Internet. Preventing inequalities in access to health care resources delivered via the Internet will require that health care agencies work with other social service and educational groups to make available the technology necessary to capitalize on this electronic environment for health care.

As health care becomes increasingly reliant on Internet-based telecommunications technology, the industry faces challenges in insuring the quality and integrity of many devices and network pathways. These challenges differ from previous medical device concerns, because the diversity and reliability of household equipment is under the control of the household, not the health care providers. There is an increased interdependency between the providers of health services, those who manage telecommunication infrastructure and the manufacturers of commercial electronics. Insuring effective use of telehealth for home and community based care requires that clinical services be supported by appropriate technical resources.

18.4.2 Licensure and Economics in Telehealth

Licensure is frequently cited as the single biggest problem facing telemedicine involving direct patient-provider interactions. This is because medical licensure in the United States is state-based, while telemedicine frequently crosses state or national boundaries. The debate revolves around the questions of whether the patient "travels" through the wire to the clinician, or the clinician "travels" through the wire to the patient. Several states have passed legislation regulating the manner in which clinicians may deliver care remotely or across state lines. Some states have enacted "full licensure models" that require practitioners to hold a full, unrestricted license in each state where a patient resides. Many of these laws have been enacted specifically to restrict the out-of-state practice of telemedicine. To limit Web-based prescribing and other types of asynchronous interactions, several states have enacted or are considering regulations that would require a face-to-face encounter before any electronically delivered care would be allowed. In contrast, some states are adopting regulations to facilitate telehealth by exempting out-of-state physicians from in-state licensure requirements provided that electronic care is provided on an irregular or episodic basis. Still other models would include states agreeing to either a mutual exchange of privileges, or some type of "registration" system whereby clinicians from out of state would register their intent to practice via electronic medium.

At the same time, national organizations representing a variety of health care professions (including nurses, physicians and physical therapists) have proposed a variety of approaches to these issues. While the existing system is built around individual state licensure, groups that favor telemedicine have proposed various interstate or national licensure schemes. The Federated State Board of Medical Examiners has proposed that physicians holding a full, unrestricted license in any state should be able to obtain a limited telemedicine consultation license using a streamlined application process. The American Medical Association is fighting to maintain the current state-based licensure model while encouraging some reciprocity. The American Telemedicine Association supports the position that—since patients are "transported" via telemedicine to the clinician—the practitioner need only be licensed in his or her home state. The National Council of State Boards of Nursing has promoted an Interstate Nurse Licensure Compact whereby licensed nurses in a given state are granted multistate licensure privileges and are authorized to practice in any other state that has adopted the compact. As of 2002, 19 states had enacted the compact.

The second factor limiting the growth of telehealth is reimbursement. Prior to the mid-1990s there was virtually no reimbursement for telehealth outside of teleradiology. At present Medicare routinely reimburses for synchronous video only for rural patients. Nineteen states provide coverage for synchronous video for Medicaid recipients. Five states also mandate payments by private insurers. A few insurers have begun experimenting with reimbursement for electronic messaging and online consultation, although this has been limited to specific pilot projects. Although teleradiology is often reimbursed, payments for other types of store-and-forward telehealth or remote monitoring remain rare. Few groups have even considered reimbursement for telehealth services that do not involve patient-provider interaction. An expert system could provide triage services; tailored on-line educational material, or customized dosage calculations. Such systems are expensive to build and maintain, but only services provided directly by humans are currently reimbursed by insurance.

Historically, patients have been perceived as reluctant to pay directly for telehealth services, especially when face-to-face visits were covered by insurance. This may be changing. The Marshfield Clinic in Wisconsin has reported that many patients are willing to pay a small technology fee ($10–20) to avoid a several hour drive to see the specialist face-to-face. Private companies have begun providing direct-to-patient video consults utilizing normal Web browsers and Flash™ video at a charge of $45 for 10 min and have placed video stations in workplaces and pharmacies. Some insurers have begun reimbursing for such visits when a patient's primary clinician is not available.

Finally, home telehealth monitoring may reduce the health care costs associated with unreimbursed hospital readmissions. For example, some insurance payers do not reimburse for hospital readmissions that occur within 30 days of discharge, and there are anecdotal reports of health systems paying for 32 days of home monitoring post-discharge. Determining whether, and how much, to pay for telehealth services will likely be a topic of debate for years to come.

18.4.3 Logistical Requirements for Implementation of Telehealth Systems

Telehealth systems must be carefully evaluated before implementation for routine use in individual disease situations, to ensure that they have sufficient diagnostic accuracy and reproducibility for clinical application. Appropriate training and credentialing standards must be developed for personnel who capture clinical data and images from patients locally, as well as for physicians and nurses who perform remote interpretation and consultation. Clear rules and responsibilities must be developed for remote patient management, including the appropriate response for situations in which data are felt to be of insufficient quality for telehealth. Guidelines for medicolegal liability must be established. Software that displays clinical information required for remote management, and that integrates into existing workflow patterns and maximizes efficiency through good usability principles will be required. Methods for providing added value from technology toward telehealth diagnostic systems through strategies such as links to consumer health resources or computer-based diagnosis may be explored (Koreen et al. 2007). Finally, studies have suggested that patient satisfaction with telehealth systems is high (Lee et al. 2010). However, the practitioner-patient relationship is fundamental to health care delivery, and mechanisms must be developed that this bond is not lost from telehealth.

18.4.4 Telehealth in Low Resource Environments

In many parts of the developing world, the density of both health care providers and of technology is quite low. Thus, the demand for telehealth is high, but the ability to deliver it is challenged. Many of these regions have largely skipped traditional land-line telephony and moved directly to cellular infrastructure (Foster 2010). This, combined with advances in low-cost laptop computers that do not depend on stable power-grids, has allowed the development of a wide variety of telehealth and tele-education applications. The majority of these are based on an asynchronous model. Transport media range from standard broadband in the urban areas, to satellite connections, to cellular data, to **SMS messaging**. The largest group of applications focuses on the provision of remote consultations for difficult cases using computer-based systems, while general health education and remote data collection have been the primary applications using cellular telephony applications. However, the development of smart mobile telephones with high-resolution cameras is rapidly blurring this distinction. The e-book by Wootton provides an overview of this domain (Wootton 2009) and Foster focuses on the role of mobile telephones (Foster 2010).

18.5 Future Directions

Telehealth validation studies across a range of clinical domains have demonstrated good diagnostic accuracy, reliability, and patient satisfaction. Based on these results, numerous real-world telehealth programs have been implemented throughout the world. In the long term, successful large-scale expansion of these programs will require addressing the above challenges.

Beyond these practical factors, traditional medical care uses a workflow model based on synchronous interactions between clinicians and individual patients. The workflow model is also a sequential one in that the clinician may deal with multiple clinical problems or data trends but only within the context of treating a single patient at a time. Medical records, both paper and electronic, as well as billing and administrative systems all rely on this sequential paradigm, in which the fundamental unit is the "visit." Advances in telehealth are disrupting this paradigm. Devices have been developed that allow remote electronic monitoring of diabetes, hypertension, asthma, congestive heart failure (CHF), and chronic anticoagulation. As a result, clinicians may become inundated by large volumes of electronic results. This may mean that clinicians will no longer function in an assembly-line fashion, but will become more like dispatchers or air-traffic controllers, electronically monitoring many processes simultaneously. Clinicians will no longer ask simply, "How is Mrs. X today?" They will also ask the computer "Among my 2,000 patients, which ones need my attention today?" Neither clinicians, nor EHRs, are prepared for this change.

Perhaps the greatest long-term effect of the information and communication revolution will be the breaking down of role, geographic, and social barriers. Medicine is already benefiting from this effect. Traditional "doctors and nurses" are collaborating with public health professionals, and anyone with computer access can potentially communicate with patients or experts around the world. The challenge will be to facilitate productive collaborations among patients, their caregivers, biomedical scientists, and information technology experts.

Suggested Readings

Bashshur, R.L., Shannon, G.W., Krupinski, E.A., Grigsby, J., Kvedar, J.C., Weinstein, R.S., et al. (2009). National telemedicine initiatives: Essential to healthcare reform. *Telemedicine and e-Health*, 15, 600–610. This paper discusses cost-benefit tradeoffs associated with telemedicine within the context of large-scale efforts promoting health care reform in the United States.

Gray, J.E., Safran, C., Davis, R.B., Pompilio-Weitzner, G., Stewart, J.E., Zaccagnini, L., et al. (2000). Baby CareLink: Using the internet and telemedicine to improve care for high-risk infants. *Pediatrics, 106*, 1318–1324. Families of very-low-birthweight babies use interactive television and the world-wide-web to monitor the babies' progess while in hospital and to receive professional coaching and support once the babies return home.

Richter, G.M., Williams, S.L., Starren, J., Flynn, J.T., & Chiang, M.F. (2009). Telemedicine for retinopathy of prematurity diagnosis: Evaluation and challenges. *Survey of Ophthalmology*, 54, 671–685. This article reviews the potential benefits and implementation challenges associated with the use of store-and-forward telemedicine for an ocular disease affecting infants hospitalized in neonatal intensive care units.

Schwamm, L.H., Holloway, R.G., Amarenco, P., Audebert, H.J., Bakas, T., Chumbler, N.R., et al. (2009). A review of the evidence for the use of telemedicine within stroke systems of care: A scientific statement from the American Heart Association/American Stroke Association. *Stroke*, 40, 2616–2634. This is a systematic evidence-based review of scientific data examining the use of telemedicine for stroke care delivery by two major medical organizations. Published studies are categorized according to their level of certainty and class of evidence.

Shea, S., Weinstock, R.S., Teresi, J.A., Palmas, W., Starren, J., Cimino, J.J., et al. (2009). A randomized trial comparing telemedicine case management with usual care in older, ethnically diverse, medically underserved patients with diabetes mellitus: 5 year results of the IDEATel study. *Journal of the American Medical Informatics Association: JAMIA, 16*, 446–456. This paper describes an evaluation study examining the effectiveness of home telemedicine for clinical case management in a group of over 1,600 medically-underserved patients with diabetes mellitus.

Questions for Discussion

1. Telehealth has evolved from systems designed primarily to support consultations between clinicians to systems that provide direct patient care. This has required changes in hardware, user

interfaces, software, and processes. Discuss some of the changes that must be made when a system designed for use by health care professionals is modified to be used directly by patients.

2. There are many controversies regarding reimbursement for telemedicine services. Imagine that you are negotiating with an insurance carrier to obtain reimbursement for a store-and-forward telemedicine service that you have developed. The medical director of the second insurance payer states: "Telemedicine seems like 'screening' rather than a mechanism for delivering health care. This is because you are simply using technology to identify patients who need to be referred to a real doctor, rather than providing true medical care. Therefore we should only reimburse a very small amount for these screening services." In your opinion, is this a legitimate argument? Explain.
3. Using telehealth systems, patients can now have interaction with a large number of health care providers, organizations and resources. As a result, coordination of care becomes increasingly difficult. Two solutions have been proposed. One is to develop better ways to transfer patient-related information among existing EHRs. The other is to give the give the patient control of the health record, either by giving them a smart card or placing the records on a central web site controlled by the patient. Assume and defend one of these perspectives.