California HealthCare Foundation

Health Care Unplugged:
The Evolving Role of Wireless Technology

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by
Richard Adler, M.B.A.

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About the Authors

Richard Adler is principal of People & Technology, a research and consulting firm in Cupertino, California, and a research associate at the Institute for the Future, Palo Alto, California.

About the Foundation

The **California HealthCare Foundation,** based in Oakland, is an independent philanthropy committed to improving California's health care delivery and financing systems. Formed in 1996, our goal is to ensure that all Californians have access to affordable, quality health care. For more information about CHCF, visit us online at www.chcf.org.

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I. Introduction

The world is in the midst of a wireless communications revolution. The most visible aspect of this global revolution is the explosive growth of cell phones, both in the United States and abroad. Other key elements of the revolution include advances in short- and medium-range digital networks that expand the power of cell phone networks, in sensors that enable remote monitoring, and in the batteries that power portable devices.

Together, these innovations are creating a pervasive broadband wireless environment that can support a wide range of new uses. While most wireless applications to date have focused on providing mobile communications, information, and entertainment, a growing number of applications related to health are appearing. These applications hold the potential to improve health care delivery, reduce costs, increase the efficiency and effectiveness of health care providers, and make services more convenient for patients.

Wireless technology enables clinicians to monitor patients remotely and give them timely health information, reminders, and support—in short, to greatly extend the reach of health care, ultimately making it available anywhere, anytime.

However, if this potential is to be realized, a number of issues must be addressed. These include health industry issues, such as uncertainty about provider reimbursement, unproven clinical benefits, a health system that is not well-configured for wireless innovations, and concerns about maintaining privacy and security; technological issues, such as potential information overload for providers and a lack of standards; and issues arising from a fragmented cell phone market and differences between that market and the health care market.

This report is based on interviews with more than two dozen researchers, clinicians, and application developers, and on a review of a broad range of published papers and articles, Web resources, and other materials. The report begins with an overview of the global wireless revolution in terms of who is using the technology and how the technology is evolving. It then describes a variety of

wireless health care applications that are currently available or under development; considers the impact these advances could have on providers, patients, and payers; and discusses key unresolved issues. The report concludes with a brief look at some likely future developments and their implications for health care.

II. The Wireless Revolution

The Growth of Cell Phones

Cell phones were first introduced in the United States in the mid-1980s. During the last two decades, they have evolved from being a novelty to being a necessity for a substantial majority of Americans. In 1984, there were just 340,000 cell phone subscribers in the United States. By 1990, more than 5 million cell phones were in use; in 2006 the number had grown to 233 million, and nearly three-fourths of Americans older than 18 had one.[1]

There are now more than 2.5 billion cell phone users around the globe, which means that more than one-third of the world's population is using the devices.[2] The United States lags behind many other nations in terms of cell phone penetration and the range of available services.[3] In about two dozen European and Asian countries, the number of cell phones in use is now greater than the number of people in those countries.[4]

Global cell phone penetration is continuing to grow rapidly; the number of users worldwide is expected to exceed 3 billion by the end of 2007.[5] Developing countries may be experiencing the greatest cell phone impact. Millions of people in rural areas of Africa, India, China, and elsewhere who never had access to traditional phone service are now communicating via cell phones. In these countries, the cell phone is also becoming the primary Internet access device for many people. India is adding more than 6 million cell phone subscribers each month, and China, where two of the three largest mobile phone companies in the world are located, now has more than 500 million subscribers.[6]

As the popularity of cell phones has increased, so has their functionality. Cell phones are doing much more than simply providing mobile voice communications; they also have become a platform for delivering a growing variety of applications. A recent report describes some of the many ways that people around the globe are using cell phones:

> In India, worshippers send text prayers to the temple of a Hindu god. In China, coupons received on cell phones are redeemable at McDonald's. In Singapore, drivers can pay tolls and buy tickets with a mobile device. In South Korea, an online

dating service sends a text message when a person matching your profile is nearby. In Los Angeles, high school students flirt, make dates, and carry on courtship rituals in electronic form. People in 22 countries cast 680 million text-message votes for contestants during the most recent season of American Idol. In Bangladesh, farmers use mobile devices to learn the true market value of their produce. In Stockholm, customers use mobile phones to find nearby restaurants. A British mobile carrier lets subscribers point their cell phones to the sky to identify constellations… In the U.S., MasterCard has introduced a service through which customers can call a phone number, input their location, and receive a text message directing them to the nearest ATM.[7]

As these examples illustrate, the cell phone is rapidly evolving from a device just for making mobile voice calls into something much more versatile: a personal, portable, multipurpose, multimedia computing and communications device. A good example of the current state of the art is Apple's iPhone, introduced in June 2007. In addition to serving as a conventional mobile phone, the iPhone can be used to store and play music and videos; take, store, and view photos; keep track of contacts and appointments; find a location on a map; send and receive email; and surf the Web.

Cell Phone Networks

Cell phones communicate over networks that allow users to connect with virtually any other phone in the world. These networks operate through a series of local antennas that wirelessly connect local users to the telephone switches and "long lines" that provide global coverage. By the end of 2006, there were nearly 200,000 cellular antennas in the United States that provide access across much, though not all, of the country.[8]

Cell phone networks have evolved through several generations, each faster and more robust than the previous one. The first-generation (1G) networks were analog; the second-generation (2G) networks are digital. The latter enable users to transmit text and still images, and to download music and ringtones.

Recently introduced 3G networks enable high-speed communications capabilities such as Web surfing and downloadable video. Data transmission speeds will continue to increase as newer broadband networks are introduced. The next generation (3.5G and 4G) of all-digital networks now being rolled out will support live, two-way video communications on cell phones.

In a number of ways, cell phone networks outside the United States are more advanced than American networks; those in many other countries are more pervasive and offer higher speeds, a greater variety of services, and lower costs. In addition, most of the rest of the world uses a single cell phone standard, which permits widespread interoperability, while U.S. carriers use several different network standards, which hinders interoperability.

As cell phone networks become more pervasive and more capable, they are creating opportunities to deliver mobile health care applications.

Demographics of U.S. Cell Phone Users

Cell phone ownership in the United States has been increasing steadily among all age groups, and a majority of Americans now use cell phones. However, usage is still more widespread among younger than older people. A 2006 national survey by the University of Michigan found that cell phone penetration was more than 70 percent among Americans 18 to 49 years old, compared to about 60 percent among those 50 to 69 years old. Among those older than 69, penetration was 44 percent, which is still reasonably high—certainly much higher than it was even a few years ago.[9]

Age is also related to the use of more advanced cell phone features, including features that can support health-related applications. For example, the University of Michigan survey found that while

more than 80 percent of users 18 to 27 years old knew how to send and receive simple text messages on a cell phone, fewer than half of adults between 50 and 59—and only about one-fourth of those 69 or older—knew how to use text messaging.[10]

There are even greater differences among age groups in terms of their ability to send and receive more complex multimedia messages such as video clips. Thirty-seven percent of mobile phone users ages 18 to 27 could send a multimedia message compared to 17 percent of users 50 to 59 years old and just 7 percent of those 69 or older.[11]

Related Technologies

Part of the potential value of cell phones for delivering health-related applications is their ability to leverage several related technologies, including short- and medium-range wireless networks and miniaturized sensors, which also are evolving rapidly. Also important is battery technology; it plays a role in determining which mobile applications are feasible.

Combinations of these technologies are creating a variety of opportunities for remotely monitoring patients' physiological functions and for providing information to and support for patients in managing their own health.

Short- and Medium-Range Wireless Networks

A variety of short-range (up to 10 meters) digital network technologies have liberated computers and other devices from being tethered to wires and cables. Perhaps the most familiar example is Bluetooth, a widely used technology that links wireless headsets to cell phones. Bluetooth can also transmit data from a physiological monitor on the body to a nearby external receiver.[12]

Wireless fidelity (Wi-Fi) is a medium-range network standard that enables laptop computers and other devices to connect wirelessly to the Internet from "hot spots" in millions of homes, offices, and public facilities at distances of up to 1,000 meters. This standard has evolved through several generations, each operating faster and over a greater range than prior generations. Nearly all recent laptop computers and many other mobile devices, including a growing number of cell phones, have built-in Wi-Fi receivers.

Some medical devices use Wi-Fi to link monitoring sensors to a nearby receiver that can connect to a long-range cell phone network for transmitting data to a remote site, such as a doctor's office.

Sensors

Miniature sensors are available that can accurately monitor a variety of physiological functions, including physical activity, respiration, body temperature, heart rate, muscle function, blood glucose levels, and oxygen saturation. Increasingly, many sensors are small enough to be worn on or implanted in the body. When their output is linked to external networks, the sensors provide opportunities for remote patient monitoring.

A critical element in the effectiveness of sensors is the accompanying software that processes their output and aids interpretation of the data they generate by tracking trends or detecting important events. Thanks to hardware and software improvements, the accuracy and sensitivity of sensors have been steadily increasing while their size and cost have been declining.

Batteries

Portable wireless devices depend on batteries to power their operations. Bigger batteries provide more energy, but they may not meet the size and weight requirements of many portable devices.

Although research is leading to improvements in battery performance, no major breakthroughs appear likely in the near future. Much of the recent gain in the performance of portable devices such as cell phones and health monitoring devices has been achieved by reducing their power needs rather than increasing the capacity of batteries.

III. Wireless Health Care Applications

Cell Phone Attributes

Cell phones have four attributes that make them particularly well-suited for delivering health care applications. Cell phones are:

- **Personal.** Because each phone is associated with a particular person, applications can be targeted to that individual.
- **Ubiquitous.** Cell phone owners typically take their phone wherever they go. Therefore, continuous physiological monitoring is possible anywhere, and information and services can be delivered when and where they will be most effective.
- **Connected.** Cell phones offer direct links to vital information and caregivers, and to peer groups that can provide social support.
- **Increasingly intelligent.** Many cell phones are essentially small computers that can capture, store, and process information. Imbedded algorithms enable the phones to handle large amounts of data and to identify significant trends and events.

Because of their pervasiveness and low cost, cell phones and other wireless technologies are particularly well-suited for supporting the treatment of chronic diseases, which typically must be managed over an extended period. These technologies make it possible for health care providers to monitor patients' health and to track and guide their self-care beyond the clinical setting, potentially improving outcomes and reducing health care costs.

The Demographic Imperative

The aging of the U.S. population and the increasing occurrence of chronic diseases are creating an urgent need for better tools to monitor patients' health status and help them manage their health.

Thirty-eight percent of Americans, or 125 million people, have at least one chronic condition, while 11 percent have three or more. The likelihood of having at least one chronic condition increases with age: Fewer than 10 percent of Americans younger than 44 years old have a chronic disease, compared to 23 percent of those between the ages of 44 and 64, 34 percent of those from age 65 through 74, and 45 percent of those 75 years or older.[13]

Caring for patients with chronic conditions accounts for more than four-fifths of all health care expenditures, or more than $1.4 trillion annually—an amount that is projected to increase by at least 25 percent over the next two decades as the baby boomers age.[14]

Better chronic disease care could produce substantial cost savings. For example, among the 10 percent of Americans older than 65 who have three or four chronic conditions, an estimated 40 percent of hospitalizations could be prevented through appropriate outpatient care.[15]

Many of the wireless applications described in this report were designed to improve chronic disease care. Those for remotely monitoring physiological conditions can give clinicians detailed and timely information about a patient's illness, while other applications can support and encourage patients to do a better job of managing their own health.

The Emergence of Wireless Health Care

In the last few years, dozens of health-related applications for cell phones and other wireless technologies have been introduced in the United States and elsewhere. Many have been developed in foreign countries where cell phone use is more common and, in many cases, cell phone networks are more pervasive and more advanced than they are in the U.S.

Most of these applications are relatively new, and evidence from controlled trials regarding their effectiveness is limited. Moreover, applications that work well in other countries may be less viable in the United States because of differences in health care and technological infrastructures.

While it is too early to say which applications will enter the mainstream or when, their number and variety illustrate the potential of wireless technologies to expand the reach of health care and deliver more effective and more timely services. These technologies could benefit patients, providers, and payers by:

- Increasing the convenience of diagnostic procedures while improving the speed and accuracy of diagnoses, particularly in detecting intermittent problems that more limited, short-term clinical tests may miss.
- Supporting continuous monitoring of patients' chronic conditions, thus enabling providers to detect and respond to problems as they occur, which reduces costly medical complications.
- Reminding patients to keep medical appointments and helping them to comply with prescribed medical regimens.
- Encouraging better patient self-management of chronic conditions via timely, personalized feedback about the patient's health status and support for self-care.
- Increasing providers' efficiency and effectiveness by giving them access to current information on patients' health and a convenient way to deliver appropriate advice and support.
- Enabling earlier hospital discharges while maintaining a high level of patient surveillance through remote monitoring.
- Providing a new channel for targeted public health campaigns, particularly those aimed at groups such as young people, who are generally difficult to reach through conventional campaigns.

Although these benefits seem compelling, realizing them will require significant investments in new technology. To justify such expenditures, proponents will have to document that wireless health care applications actually produce better health outcomes cost-effectively.

In addition, integrating wireless applications into health care will require new procedures and processes entailing significant changes in how physicians and other providers do their jobs, a prospect that is likely to meet resistance. Finally, a number of technological, regulatory, economic, and structural issues (discussed later in this report) will have to be addressed before wireless technologies become part of mainstream medical care.

Types of Applications

There are two major categories of wireless applications for health care: (1) applications that monitor physiological functions (in cardiac and diabetic patients, for example) and send the information to physicians; and (2) applications that provide information and feedback directly to patients, thus encouraging them to pay attention to and take a more active role in managing their health.

Monitoring applications vary in terms of the physical placement of the sensors they employ. They also differ in terms of the direction of information flow and the types of communication they use. Table 1 summarizes these capabilities.

Table 1. Types of Wireless Heath Care Applications*

	SENSOR PLACEMENT			INFORMATION FLOW			COMMUNICATIONS TYPE			
	Portable	Wearable	Implantable	Upstream	Downstream	2-Way	Data	Text	Multimedia	2-Way Video
Physiological Monitoring										
Cardiac	C	C	C	C			C			
Glucose	C		F	C			C			
Vital signs	C	C	F	C			C			
Patient Communication and Support										
Appointment reminders					C			C		
Health education and promotion					C	F		C	F	F
Patient compliance					C			C		
Patient engagement						C	C	C	F	F
Remote consultations						C				F

*C = current use, F = future use.

Monitoring applications, such as those for heart function, blood glucose level, and vital signs, rely on sensors that are portable, wearable, or implantable. Communications for these applications are typically "upstream" (from patient to provider); they offer opportunities for faster and more accurate diagnoses, particularly of intermittent problems, and for more rapid response to medical emergencies.

In contrast, patient communication and support applications—for appointment reminders, health education and promotion, and the like—are primarily "downstream" (from provider to patient), although more advanced applications may involve two-way communication. Many of these are based on text messaging on cell phones using short message service. Newer applications make use of multimedia message service or two-way video on more advanced phones.

Physiological Monitoring Applications

Applications that enable remote monitoring of various physiological functions are among the most mature wireless applications. They make it possible to move beyond short-term testing of patients in artificial—and sometimes stressful—clinical settings to longer-term, continuous monitoring of patients as they go about their daily activities. The result may be more accurate and up-to-date diagnoses that can improve the management of patients' health problems.

The Food and Drug Administration has approved several of these applications, which are available commercially. Others are still under development or awaiting FDA approval.

Portable Physiological Monitoring Applications

These typically involve lightweight portable external devices connected to sensors placed on or near the body for wirelessly transmitting monitoring data to a base station or a remote monitoring service. They include applications for:

Cardiac monitoring. When it was introduced in 1947, the battery-powered Holter monitor improved cardiac diagnosis by enabling continuous recording of heart function outside the clinical setting. Patients typically wear the monitor, which includes a set of electrodes attached to their chest and a recording device, for a period of up to 24 hours, and then return it to their physician for an analysis of the readings.

Mobile Cardiac Outpatient Telemetry (MCOT) System

The MCOT system from CardioNet uses a lightweight, three-lead sensor connected to a small electrocardiogram monitor attached at the belt. When the system detects an abnormal event, such as an arrhythmia, it automatically transmits the data to a service center where the results are evaluated and then reported to the patient's physician.

At home, the MCOT system connects to a standard phone line. Elsewhere, its monitor transmits data to the service center via a wireless network.

Patients typically use the MCOT monitor for 13 days; some use it for up to a month. Studies have shown that this type of extended monitoring can detect sporadic problems that short-term monitoring often misses, providing clinicians with more accurate information for determining appropriate treatments.

More than 80,000 patients have used CardioNet's device since it received FDA approval in 2002.[16] Uses include primary diagnosis, post-procedure monitoring, and titration of drugs for controlling heart rate.

Image source: Tim Gee, Medical Connectivity Consulting, www.medicalconnectivity.com

Newer devices, such as the CardioNet MCOT system (see box), take ambulatory monitoring a step further by adding wireless communications capabilities, which enable clinicians to learn about problems much sooner than they would without the devices. Research has shown that extended cardiac monitoring can detect a greater range of problems than shorter-term diagnostic techniques can, and that rapid detection and treatment of heart attacks saves lives. A device called Vitaphone, with sensors integrated into a standard cell phone, can take an electrocardiogram reading at any time. In addition, the Vitaphone's GPS capability can automatically identify a patient's location if medical assistance is necessary.

Blood glucose monitoring. If not properly controlled, diabetes can lead to a variety of serious problems, including heart disease, stroke, blindness, kidney failure, pregnancy complications, and limb amputations. Although the disease is preventable and controllable, its incidence is expected to continue growing and perhaps accelerate, given Americans' poor diet and lack of exercise.

To avoid complications, diabetics must carefully monitor and control their blood sugar levels. Conventional glucose meters have become smaller and more accurate over time, and the most recent generation of "smart meters" can store multiple results and display them in chart form, giving patients more information about their condition.[17]

GlucoPhone

Developed by HealthPia, a South Korean firm, the LG GlucoPhone combines a standard glucose meter with a cell phone to enable round-the-clock clinical support for diabetics.

The patient places a small blood sample on a test strip, inserts the strip into a reader integrated into the phone's battery pack, and views the results on the phone's screen. The results are also sent automatically to an online medical management database and, at the user's discretion, can be forwarded to a personal physician, family member, or caregiver.

The GlucoPhone, already in use in South Korea, received FDA approval in June 2006.

Image source: HealthPia America

Wireless applications can help diabetics and their care providers manage the disease even better. For example, the GlucoPhone (see sidebar on page 10) enables users to send their monitoring data to an online repository and immediately share it with clinicians, who can track patients' health status and, if necessary, recommend changes in medication. It is likely that future generations of glucose meters will incorporate similar wireless capabilities.

Multiple vital signs monitoring. Many patients, particularly those who are elderly, have more than one health problem or chronic condition. Wireless systems under development can monitor multiple physiological functions, providing a broader spectrum of information that gives clinicians greater opportunities to manage the whole patient rather than individual health problems. Multifunction monitors like these may supplement or even replace some clinical services, and may help reduce costs as a result of more timely treatments, earlier hospital discharges, or fewer emergency room visits.

Wearable Physiological Monitoring Applications

An emerging type of remote monitor is garments such as the SmartShirt (see sidebar) that incorporate strategically placed sensors and a wireless transmitter to send monitoring data to an external receiver. These garments automatically collect data on multiple vital signs and enable wearers to engage in normal activities.

Implantable Physiological Monitoring Applications

These wireless devices are intended for longer monitoring use—in some cases, for the patient's lifetime.

Wireless pacemakers and defibrillators. Implanted in the chest, pacemakers use electrical pulses to regulate heart rhythm, and defibrillators provide an electric shock to restore normal heartbeat. Pacemakers and defibrillators save lives by responding instantly to abnormal cardiac activity and restoring normal heart function.

Advanced versions of pacemakers and defibrillators, such as the Cylos DR-T (see sidebar on page 12), can wirelessly send cardiac monitoring data to a service center or a physician. They can also track their own performance to detect malfunctions.

Because wireless pacemakers and defibrillators deliver critical information quickly, most if not all future cardiac implants will likely include wireless capabilities. In September 2006, a task force of the Heart Rhythm Society recommended that "device manufacturers develop and utilize wireless and remote monitoring technologies to identify abnormal device behavior as early as possible and reduce underreporting of device malfunctions."[18]

Blood glucose monitors. Diabetics typically must monitor themselves several times a day by taking a small blood sample through a finger stick, then inserting the sample into a meter to get a glucose reading. Diabetics who fail to follow a strict regimen

SmartShirt

The cotton fabric of the Sensatex SmartShirt contains a conductive fiber system that monitors heart rate, respiration, and body temperature. The system wirelessly sends data via Bluetooth to a base station to be collected and stored for later analysis.

Potential applications for the shirt, which is intended for short-term diagnostic use and mostly restricted to research applications because of its high cost, include remote monitoring of postoperative and chronic disease patients, elderly persons at home, and soldiers in the field.

Image source: Sensatex

Cyclos DR-T Implantable Pacemaker

The Cyclos DR-T, a self-tracking, FDA-approved pacemaker from the German firm Biotronik, has a small transmitter that sends information to a "patient device" (similar to a cell phone) located within six feet of the patient. The device then transmits the information to a service center.

In a cradle at home, the Cyclos DR-T recharges and communicates with the outside world over a conventional phone line. Away from home, it can communicate wirelessly for up to 25 hours without recharging.

Normally, the device transmits a report to the service center once a day. But if it detects any abnormal cardiac rhythm or technical malfunction, the pacemaker immediately sends a "special event" message. In addition, a patient who becomes aware of an abnormal symptom can trigger a report transmission by passing a small magnet over the pacemaker.

Image source: Biotronik

of regularly sampling their blood run the risk of a "crash" that can lead to serious medical problems. Moreover, fluctuations in glucose levels that are out of the normal range can result in long-term complications.

Efforts are under way to automate the sampling process by means of implantable wireless devices that provide continuous blood glucose readings. More frequent measurements increase the likelihood of detecting and correcting changes that less frequent monitoring may miss.

Patient Communication and Support Applications

In addition to supporting remote monitoring, cell phones and other wireless devices can expand the opportunities for patients and providers to communicate with each other. Via simple text messaging, emerging applications in this category can remind patients about appointments, promote compliance with drug regimens, and deliver information and encouragement to help patients manage their health.

Such applications not only enable providers to communicate more frequently with patients, but also—at least in theory—to deliver health-related messages at precisely the times when, and places where, they can have the greatest impact. The goal is better patient outcomes and lower health-related cost.

Few applications of this type have undergone controlled experiments to determine their effectiveness, and published reports in peer-reviewed journals are scant. Most have been developed and implemented outside the United States in regions such as Europe and Africa, where cell phones are more pervasive and text messaging is more common.

Appointment Reminders

Reminding patients of upcoming appointments by sending text messages to their cell phones is a relatively simple, straightforward application that could improve administrative efficiency and increase the effectiveness of physicians' time. This could generate substantial savings for health care providers.

A 2005 survey by the British Institute of Healthcare Management found that patients in Great Britain who missed general practitioner, practice nurse, and hospital appointments cost the National Health Service about $1.58 billion a year. In one pilot study, missed clinic appointments among dermatology patients declined by 50 percent among those who received appointment reminders via text message. Other pilot studies reported up to 40 percent reductions in missed appointments among hospital outpatients who received such reminders.[19]

Health Education and Promotion

Young people are among the most active users of cell phones and text messaging. Given that health educators have had difficulty reaching this group through conventional channels, campaigns that deliver messages by cell phone may be a promising alternative.

In 2006, the San Francisco Department of Public Health introduced SexInfo, a free service that answers youths' questions about sexual health via text messaging and provides the location, phone numbers, and operating hours of local clinics.[20] Most such efforts have not been systematically evaluated.

Public Health Alerts

Text messaging also can help track disease outbreaks and provide timely alerts regarding potential health hazards. For example, during the 2003 SARS outbreak in Hong Kong, a local cell phone company provided subscribers with access to a government database of buildings where the disease had been reported. This service leveraged the GPS capability of cell phones to pinpoint a subscriber's location in order to determine which buildings in the database were nearby.[21]

Other applications provide warnings of dangerous levels of air pollution in London and of impending natural disasters, such as tsunamis in Southeast Asia.

Compliance Reminders and Treatment Support

Noncompliance with drug regimens is a serious, widespread problem. Surveys have found that only about half of all patients adhere to a regimen after they leave the doctor's office with a prescription. Forgetfulness is the most common reason for noncompliance.[22]

Full compliance with prescription drug regimens can prevent further medical problems. By one estimate, up to 10 percent of hospital admissions and up to 23 percent of nursing home admissions could be avoided if people took their drugs as directed.[23] A potentially powerful use of text messaging is to remind patients—particularly those with chronic conditions—to take their medications as directed.

Projects such at 8TDAZE (see sidebar) provide patients with reminders to follow a treatment plan.

8TDAZE

In 2006, the drugmaker PediaMed launched a "mobile compliance campaign" called 8TDAZE in the United States. The campaign involved a prescription acne treatment for teenagers.

Participants received text messages on their cell phones reminding them to apply the treatment regularly.[24]

Patient Engagement

The U.S. medical system simply does not have enough resources to deliver all of the care that the millions of people with chronic conditions need. In addition, to the degree that these conditions are related to lifestyle factors such as diet, exercise, and smoking, it is ultimately up to patients to take responsibility for their own choices and to provide appropriate self-care.

If care for chronic conditions is to improve significantly, patients must be more actively engaged in managing their own health on a daily basis. To that end, a number of applications, such as Asthma Assistant (see box on page 14), have been developed that use two-way wireless communication to support patients, track their health status, and motivate them to change their behavior.

Asthma Assistant

BeWell Mobile, a start-up company in San Francisco, is developing wireless applications for chronic disease care based on the principles of "persuasive technology" formulated by B.J. Fogg at Stanford University.[25]

Not far from Stanford, the San Mateo Medical Center is pilot-testing BeWell Mobile's first application, Asthma Assistant. Thirty young patients with severe and persistent asthma record their symptoms each day in an "electronic asthma diary" by answering 20 questions on cell phones provided by the researchers. Results go to an online storage site and to health care providers, who recommend changes in medication if necessary. Both patients and physicians can see how well the patients are doing by reviewing trend data in graphic form.

Initial results indicate that compliance with prescribed drug regimens doubled, from about 40 percent to 80 percent, among the participants. Furthermore, patients who typically go to the emergency room three to five times a year to receive treatment for severe asthma attacks did not make any ER visits and did not miss any school or work days during the first six months they participated in the pilot.[26]

BeWell Mobile is developing a similar application for adult diabetics.

Doctor–Patient Communications

Today, about one-quarter of physicians use email to communicate with patients[27] and a number of services have been introduced that provide phone access to a physician or an advice nurse.

Live, two-way video consultations would be an even more direct, immediate, and robust way for patients to connect with health care professionals. In effect, such applications would bring the benefits of telemedicine, which traditionally has required expensive, special-purpose equipment and networks, down to the level of the individual patient.

3G Doctor offers such consultations (see sidebar). However, while they could help physicians provide more timely diagnoses and make health care more convenient and satisfying for patients, live video calls would require changes in how medical practices are organized. These sessions would have to be scheduled, whereas physicians can use email, an asynchronous medium, at their convenience.

3G Doctor

This service, which started in the United Kingdom in late 2006, enables patients to consult with physicians using the video capabilities of advanced 3G phones.

Patients first complete a Web-based "instant medical record" containing key data about their health status; the participating physician can access the data at the time of the video consultation, which costs about $50. Afterward, a written report summarizing the doctor's recommendation is available for download by the patient.

IV. Issues and Implications

Numerous issues must be addressed if mobile technologies are to gain a firm foothold among providers and patients. These issues include the role of wireless innovations in health care, technological hurdles, a fragmented cell phone market, and differences between that market and the health care market.

Nevertheless, some experts believe that wireless health care applications are promising. For example, Arnold Milstein, M.D., the U.S. Health Care Thought Leader at Mercer Human Resource Consulting, has pointed out that the current health care system "relies on patients intuiting when they need care, making phone calls, coming in to see the doctor periodically. When you think about how quickly and subtly human physiology can change, it's clear that there's a role for cost-effective remote patient monitoring devices."

Momentum for wireless applications in health care is being driven by five primary forces:

- As wireless devices and networks become more versatile and capable, they offer expanded opportunities to link patients continuously to the health care system. Remote monitoring, particularly of patients with chronic conditions and of those recovering from major medical procedures, enables providers to rapidly identify signs of abnormal function and provide timely intervention to avoid larger problems. Indeed, wireless applications may be the most cost-effective way to manage millions of chronically ill patients.
- Providing medical information to consumers via cell phones and other wireless devices is a logical next step in the evolution that began with such content becoming available on the Internet. Because cell phones are personal and ubiquitous, they offer the ability to deliver health-related information whenever and wherever it can be most effective.
- As people become more aware of environmental health risks, such as contamination or infectious disease in food, water, and air, they are likely to be receptive to technologies that quickly alert them to potential hazards.

- As sensors become ever smaller, more reliable, and less power-hungry, ultimately they will probably be incorporated into wearable or implantable devices that function for an extended period of time, perhaps for a patient's lifetime.
- A world of pervasive wireless networks and remote sensors could make it possible to move from a health care system that primarily provides episodic treatment of acute problems to one that is better able to manage chronic conditions continuously. As remote delivery of health care services becomes more feasible, the locus for diagnosis and treatment of many medical conditions will shift from traditional settings such as clinics and hospitals to the patient's location.

Health Industry Issues

Uncertainty about Reimbursement

"Probably no topic is more often identified as an 'issue' or a 'barrier' to innovation, demand, and investment in telehealth than reimbursement for encounters," the U.S. Department of Commerce noted in a 2004 report.[28] The reimbursement issue also applies to wireless encounters between patients and providers.

Typically, consumers themselves pay for tools that promote general fitness or health, like the people in the United Kingdom who use 3G Doctor. But the available market research indicates that interest among consumers in paying for health services delivered by cell phone is limited.[29] Securing reimbursement from the government, private insurers, or other third-party payers—which together cover nearly 90 percent of all U.S. health care costs—will be necessary if wireless applications are to become an integral part of the larger health care landscape.

In the absence of appropriate reimbursement policies, innovative applications are likely to meet resistance even if they improve efficiency. A recent study of email communications between doctors and patients found that, although email was recognized as an efficient way to reduce office visits, some doctors were reluctant to use it because "in non-capitated systems, an overall reduction in office visit rates may not be financially advantageous."[30]

The willingness of insurers, including Medicare, to pay for telemedicine has gradually increased in the last decade. For example, as part of the Medicare Modernization Act of 2003, the Centers for Medicare & Medicaid Services established the Medical Technology Council to reduce the time it takes Medicare to make coverage decisions regarding telemedicine and other new technologies.

Reimbursement policies vary among states and private insurers. California, Oklahoma, Texas, and Kentucky require insurers to reimburse for telemedicine, while most other states have no explicit policy governing this issue. Private insurers, according to a 2002 study conducted in 25 states, reimbursed about half of the telemedicine programs surveyed, and only one insurer specifically prohibited reimbursement.[31] Exactly what percentage of telemedicine applications are actually reimbursed is unknown.

Unproven Benefits

As noted earlier, many wireless applications for health care are quite new or have undergone only small-scale pilot testing. Clinical evidence showing that they improve health, cut costs, or offer other benefits is sparse.

Remote monitoring will most likely demonstrate its value in cardiac care. However, in March 2007 an FDA advisory panel did not recommend approval of Medtronic's implantable hemodynamic monitor for patients who face potential heart failure. The panel cited a lack of evidence showing that the benefits of surgically implanting a device that only monitors cardiac function, and does not also serve as a pacemaker or defibrillator, outweighed the risks.[32]

Over time, remote monitoring and patient support applications will likely find useful roles in managing a range of chronic conditions. But to date, results from relatively few rigorous clinical tests have been mixed. Nor have new applications, such as those for supporting young asthmatics or diabetics, clearly proved they significantly change health behavior.

Documenting the benefits of wireless applications will be critical if these tools are to gain wider acceptance in health care. As Henry W. Osowski, senior vice president for business development at SCAN Health Plan, explained: "Health care payers and providers don't buy technology. They don't even buy 'solutions.' They buy outcomes. They are looking to provide quality of care and will only be interested in tools that can show that they improve quality in a cost-effective way."

A challenge for application developers will be determining which patients can or cannot benefit from the use of wireless technologies, and matching applications and technologies to individuals' capabilities and needs.

Health System Not Configured to Use Wireless Applications

Warren Taylor, M.D., medical director for chronic conditions management at Kaiser Permanente, has observed that "IT gadgets and systems are great, but it is still people and processes that provide health care."[33] To benefit from wireless applications, the health care system will have to adapt to new technological opportunities and reorganize around providing continuous treatment for chronic conditions rather than episodic treatment for acute conditions.

The current system is not well-configured to meet the health care needs of an aging population. Wireless tools can help correct this shortcoming, but their impact will be limited unless the tools are linked to other, more far-reaching changes in the way care is delivered and paid for. Several efforts are under way to bring about such changes.

For example, a disease management industry has emerged in the last two decades that specializes in providing care for chronic conditions. The goal of disease management programs, which now account for $1 billion in annual expenditures,[34] is to foster better long-term outcomes while controlling the cost of supporting chronically ill patients. These programs typically use the most efficient resources available to maintain contact with patients for the purpose of tracking their health status and providing them with education and support. Most insurers now pay for such third-party services,[35] which are likely to adopt wireless applications that prove cost-effective.

One disease management company, Alere Medical, remotely monitors patients using a device called the DayLink monitor. Initial results from a recent field trial by Alere and Health Net of Arizona showed that diabetic patients who received support through the monitor reduced medical costs by up to 40 percent compared to a control group.[36]

Another health care initiative that would support greater use of wireless applications is the "medical home" model proposed by the American Academy of Family Physicians and the American College of Physicians. Under this model, every patient would have an ongoing relationship with a primary care physician responsible for ensuring that all of the patient's health care needs are met, either by providing the care directly or coordinating care with other professionals. The proposed model states that reimbursements should "recognize the value of physician work associated with remote monitoring of [patients'] clinical data using technology."[37]

In 2006, Congress passed legislation that funds a Medicare Medical Home Demonstration Project. Physicians participating in the project are authorized to use "remote monitoring…to monitor and track the health status of patients and provide patients with enhanced and convenient access to health care services."[38]

As chronic care becomes more sophisticated and more efficient, remote monitoring and support applications—including the wireless variety—are likely to become more common. But this probably will not occur quickly. A challenge for many start-up companies that have innovative solutions but limited resources will be to survive a potentially long period of application development, testing, refinement, and gradual acceptance.

Privacy and Security

A perennial concern in health care is safeguarding the privacy and security of patient information. Among the questions that wireless technologies raise are: How can patients and providers be sure that only authorized persons will receive such information? How can they be sure the information is transmitted accurately? What happens if a wireless device that contains sensitive data is misplaced, lost, or stolen? Solutions that address these questions are partly regulatory, partly technological, and partly behavioral.

Wireless technologies must meet privacy and security provisions in the Health Insurance Portability and Accountability Act of 1996. An example of HIPAA-compliant policies that govern wireless health care applications is the set of policies at Yale University:

- If protected health information is stored on a device, the data should be encrypted and access should be password-protected.
- Authentication should be ensured before transmission and data should be encrypted during transmission.
- To protect data if a device is lost or stolen, there should be user ID and password-level security, user/device validation during synchronization, and encryption of data stored on the device.[39]

Technologies already exist to provide these safeguards. Many companies have adopted stringent privacy and security measures to protect sensitive cell phone communications among their employees. But vulnerabilities remain.

Information on cell phones can be compromised if the owner does not properly secure it and their phone ends up in the wrong hands. Yet people tend not to use privacy and security measures that are too complex. Surveys consistently show that many users do not properly manage passwords or turn on encryption and other security measures, or they are too casual about these tasks.[40] Such functions must be easy for consumers to understand and use, and people need to be aware of how important it is to actually use them.

Implantable wireless devices such as pacemakers, defibrillators, and radio frequency identification (RFID) chips pose particularly challenging privacy and security concerns because it is not easy to turn them off or shield them from unauthorized monitoring. At the very least, patients should be aware in advance that while wireless implants can be beneficial, they entail real privacy and security risks.

Technological Issues

Potential Information Overload

Remote monitoring of potentially millions of patients might generate vast amounts of data that could swamp providers, who already are grappling with the output from current information-intensive medical technologies. Potential solutions include linking remote monitors to special-purpose services that receive and manage monitoring data on physicians' behalf; configuring electronic medical records so they automatically receive and store information from remote monitoring devices; and designing patient monitoring systems that process data locally and only send concise summaries to clinicians or alert them when something goes awry.

Lack of Standards

Most of the technologies and applications described in this report are stand-alone tools, yet many patients have multiple medical problems that could require multiple monitoring devices. A lack of technological standards means some applications may not be compatible with others or will work only on one

type of cell phone. Equally important is ensuring that data generated by remote monitoring devices are encoded in standardized forms (such as Health Level 7), allowing the information to be stored and managed in different types of repositories. Several efforts are under way to develop standards for wireless health communications.[41]

Cell Phone Market Issues

Incomplete Coverage

No cell phone network offers seamless coverage across the entire United States. Many rural areas of the country lack coverage, and even in major metropolitan areas, service is poor or nonexistent in some locations. Although the reach and quality of service will continue to improve, it is not likely to become as pervasive or reliable as traditional phone service—or as widespread as cell phone service in many other countries—in the near future.

While these limitations may not be problematic for all wireless health care applications, they are a concern regarding critical applications. As Joseph Kvedar, M.D., director of the Center for Connected Health in Boston, noted: "If one text message out of a hundred messages between friends goes astray, it probably doesn't matter. But if one heart reading for a cardiac patient is not delivered correctly, someone could die." At a minimum, devices must be able to store data or messages when they are offline and to deliver them when connectivity is restored to ensure that essential information is not lost.

Network Fragmentation

Cell phone networks in the United States are fragmented and restrictive. Individual carriers decide which content will be available on their networks, and most provide their own gateways to the Internet. While customers can generally access online services outside the carrier's "walled garden," such access is usually more difficult. A uniform network would help alleviate this problem. Furthermore, U.S. carriers control which handsets can be used on their networks.

The Mismatch Factor

The highly competitive cell phone market is growing and changing rapidly; the health care market, in contrast, is evolving at a much slower pace, in part because new medical products must first undergo careful testing, and because innovations may alter the relationship between patients and caregivers. This market mismatch complicates the health system's adoption of wireless technologies and applications.

Another problematic mismatch is between cell phone penetration, which declines as the age of potential users increases, and the prevalence of chronic disease, which increases with the age of potential users of this technology.[42] Older people, who in theory could benefit greatly from wireless tools, are the least likely to own a cell phone, the least likely to believe they need one, and, in many cases, the least able to afford one.

V. Developments on the Horizon

RFID Chips

In 2006, Blue Cross Blue Shield of New Jersey began testing implantable RFID chips in a group of several hundred, chronically ill elderly patients.

The chips, which are about the size of a grain of rice and implanted in a simple outpatient procedure, can be used to quickly identify patients and locate their electronic medical records in case of an emergency.

Image source: Verichip

Technological advances in cell phones and cell phone networks, hand-held devices, sensors, and batteries will continue to further expand the capabilities of wireless health care applications in the years ahead.

Networks, Cell Phones, and Hand-Held Devices

Next-generation 3.5G and 4G networks and cell phones are under development that will transmit information faster than current systems can. In effect, they will erase the distinction between cell phone networks and high-speed Internet networks. An application that benefits from such advanced networks is an experimental Canadian system that uses GPS-enabled smart phones to track the daily activities and health status of diabetic patients in order to correlate fluctuations in their blood glucose levels with their travel, exercise, work patterns, and medication and food intake.[43]

Other cutting-edge, hand-held wireless devices include advanced smart phones, such as the Apple iPhone; ultra-mobile personal computers designed primarily for Internet access rather than voice communications; portable media players that connect to the Internet to download video content; and lightweight devices designed specifically to support health care applications.

Sensors

As sensors become smaller, more accurate, and more versatile, they will make it easier for patients to wear—and more feasible for physicians to implant—physiological monitors, including RFID chips (see sidebar).

Another emerging type of sensor uses radio, radar, or infrared waves to monitor physiological functions—of babies in their cribs, for example—from a distance, without physical contact. Contactless sensors are being developed that measure functions such as body temperature, heart rate and function, and muscle and nerve function.

Mobile Peer-to-Peer Communications

A final development to watch is the growth of mobile, peer-to-peer, health-related communications among patients that may or may not involve traditional providers.

Nanosensors and Biochips

Over time, nanotechnology—electronic devices and circuits built at the molecular level by manipulating individual atoms—may produce even smaller and more sophisticated sensors for implantation.

Researchers at the University of Alberta are developing a wireless microsensor based on nanotechnology that can be incorporated into an artificial hip or knee joint replacement to monitor bone healing after surgery. Powered by joint movement, the microsensor measures the growth of bone and its attachment to the implant, which are important in stabilizing the joint. To conserve power, the microsensor remains dormant until a signal from an external reader prompts it to transmit data.[44]

OrthoMEMS, a start-up affiliated with the Cleveland Clinic, is developing a tiny, externally powered device that monitors loads within musculoskeletal tissue and links to "micro-electronic mechanical systems" that adjust orthopedic implants. The first application will work with implants for treating the back pain caused by degenerative disc disease.[45]

Other researchers are creating "biochips" that integrate living cells with electronics for monitoring specific tissues or organ systems. For example, an implantable biosensor from Physiologic Communications, a start-up affiliated with the University of Rochester Medical Center, will track changes in blood proteins that signal potential heart problems.[46]

A number of Web sites, such as DailyStrength.org, enable individuals to exchange information about specific health topics. At WhoIsSick.org, people can report illness occurrences in their community that are automatically displayed on a Google map.

VI. Conclusion

Mobile applications could have a substantial impact on health care. In particular, they may become a vital tool for improving chronic disease management.

But realizing their potential will require significant changes in the way care is structured and how medical services are delivered and reimbursed. The pace of these larger systemic changes will likely be more influential than technological progress in determining how quickly wireless health care applications enter the mainstream.

Appendix: Interviewees

Rifat Atun, M.D.
Director, Center for Health Management
Tanaka Business School
Imperial College London

Peter Boland
Director, business development
BeWell Mobile

David Doherty
Chief executive officer
3G Doctor
United Kingdom

Sean T. Doherty
Associate professor, Department of Geography and Environmental Studies
Wilfrid Laurier University
Waterloo, Ontario, Canada

Rushika Fernandopulle, M.D.
Co-founder
Renaissance Health

B.J. Fogg
Director, Persuasive Technology Laboratory
Stanford University

Conor Heneghan
Chief scientific officer
BiancaMed

Donald Jones
Vice president, business development
Qualcomm

Iarla Kilbane-Dawe
Forecasting manager
Cambridge Environmental Research Consultants

Tae Kim
Director of operations and distribution
HealthPia America

Allan Korn, M.D.
Senior vice president and chief medical officer
Blue Cross Blue Shield Association

Vincent Kuraitis
Principal
Better Health Technologies

Joseph Kvedar, M.D.
Founder and director
Partners Telemedicine

William Lalinde
Business manager, Motohealth
Motorola

David Lansky
Executive director
Personal Health Technology Initiative
Markle Foundation

Michael Liebhold
Director
Institute for the Future

John Mascheni
Associate director, vertical data sales
Verizon Wireless

Rajiv Mehta
President
Zume Technologies

Jonathan Mesinger
Clinics manager
San Mateo Medical Center

William Montgomery
Vice president, health care
Sprint

Henry W. Osowski
Senior vice president for business development
SCAN Health Plan

Max Stachura, M.D.
Director, Center for Telehealth
Medical College of Georgia

Ivo Stivoric
Chief technology officer
BodyMedia

James Sweeney
Chairman and chief executive officer
CardioNet

Ryan Sysko
Chief executive officer
WellDoc

Sebastian Tanguay
General manager
Myca

Endnotes

1. Cellular News. "2.5 Billion Mobile Phones in Use." September 8, 2006 (www.cellular-news.com/story/19223.php).
2. Ibid.
3. Mace, M. "European vs. American mobile phone use." Mobile Opportunity. September 5, 2006 (mobileopportunity.blogspot.com/2006/09/european-vs-american-mobile-phone-use.html).
4. Central Intelligence Agency. *The World Factbook*. Washington, D.C.: U.S. Government Printing Office, 2006.
5. Ridley, K. "Global mobile phone use to pass 3 billion." Reuters U.K.: June 27, 2007 (uk.reuters.com/article/technologyNews/idUKL2712199720070627).
6. Kanellos, M. "How many new cell phone accounts are opened in China a day?" San Francisco: CNET News: May 31, 2007 (www.news.com/8301-10784_3-9724502-7.html?part=rss&subj=news).
7. Lasica, J.D. *The Mobile Generation.* Washington, D.C.: Aspen Institute Communications and Society Program, 2007.
8. CTIA, "Wireless Quick Facts." Washington, D.C.: December 2006 (www.ctia.org/media/index.cfm/AID/10323).
9. Department of Communications Studies, University of Michigan. *On the Move: the Role of Cellular Communications in American Life*. May 2006 (141.211.177.75/UofM/Content/comm/document/OnTheMove.pdf).
10. Ibid.
11. Ibid.
12. The Federal Communications Commission has reserved two portions of the electromagnetic spectrum specifically for unlicensed, short-range wireless medical communications. The Medical Implant Communication Service (MICS) is a low-power, radio band (402–405 MHz) designated for short-range wireless communications from implanted devices such as pacemakers and defibrillators to external receivers. MedRadio, which operates in bands adjacent to MICS, is reserved for wireless communications from wearable medical devices.
13. National Academy on an Aging Society. *Chronic Conditions: A Challenge for the 21st Century.* November 1999 (www.agingsociety.org/agingsociety/pdf/chronic.pdf).
14. Anderson G.F. and K.B. Wilson. *Chronic Disease in California. Facts and Figures*. California HealthCare Foundation, Oakland, CA: 2006 (www.chcf.org/topics/download.cfm?pg=chronicdisease&fn=ChronicDiseaseFactsFigures06%2Epdf&pid=478698&itemid=125683).
15. Ibid.
16. Sweeney, J.M. "Healthcare Unbound's Transition to Mainstream Medicine." Presentation at Healthcare Unbound, San Francisco: July 16–17, 2007.
17. See, for example, the LifeScan OneTouch UltraSmart blood glucose meter at www.lifescan.com/products/meters/ultrasmart.
18. Heart Rhythm Society. *Recommendations from the Heart Rhythm Society Task Force on Device Performance Policies and Guidelines.* August 2006 (www.hrsonline.org/uploadDocs/HRSTaskForceRecsFull.pdf).
19. Atun, R.A., S.R. Sittampalam, and A. Mohan. "Uses and Benefits of SMS in Healthcare Delivery." Discussion Paper V, Tanaka Business School, Imperial College London: January 2005 (www3.imperial.ac.uk/portal/pls/portallive/docs/1/5375912.PDF).
20. Levine, D., "Using Technology to Promote Sexual Health," in *Mobile Persuasion,* ed. B.J. Fogg and D. Eckles, Stanford, CA: Stanford Captology Media, 2007, 15–18.
21. Wong, M. "Phone company offers location-based SARS updates." Associated Press: April 22, 2003.
22. Merck & Co. "Compliance with Drug Treatment." In *The Merck Manuals Online Medical Library,* Whitehouse Station, NJ (www.merck.com/mmhe/sec02/ch016/ch016a.html).
23. Strandberg, L.R. "Drugs as a reason for nursing home admissions." *American Health Care Association Journal* 1984;10(4): 20–23. Schering Laboratories. *The Forgetful Patient: the High Cost of Improper Patient Compliance*. Schering Report IX. 1987.
24. Cosmetics Design.com. "Text message prompts for PediaMed acne treatment." Montpellier, France: July 27, 2005 (www.cosmeticsdesign.com/news/printNewsBis.asp?id=61552).

25. Fogg, B.J. *Persuasive Technology: Using Computers to Change What We Think and Do*. San Francisco: Morgan Kaufmann Publishers. 2003. A new book edited by Fogg and Dean Eckles (*Mobile Persuasion: 20 Perspectives on the Future of Behavior Change.* Stanford, CA: Stanford Captology Media: 2007) contains essays on BeWell Mobile and several other health-related applications (www.mobilepersuasion.com).

26. BeWell Mobile. *2006 Asthma Project Metrics* (unpublished report).

27. Center for Studying Health System Change. "Physician–patient email disconnect." September 21, 2006 (www.hschange.com/CONTENT/876/).

28. U.S. Department of Commerce. *Innovation, Demand and Investment in Telehealth*. February 2004 (www.technology.gov/reports/TechPolicy/Telehealth/2004Report.pdf).

29. See, for example, Enpocket. "Enpocket Mobile Media Monitor reveals what 3G will mean for UK consumers." December 14, 2004 (www.enpocket.com/news/press-releases/enpocket-mobile-media-monitor-reveals-what-3g-will-mean-for-uk-consumers).

30. Zhou, Y.Y., T. Garrido, H.L. Chin, and others. "Patient access to an electronic health record with secure messaging: Impact on primary care utilization." *American Journal of Managed Care* 2007;13:418–424 (www.ajmc.com/Article.cfm?Menu=1&ID=3340).

31. U.S. Department of Commerce. *Innovation, Demand and Investment in Telehealth.* February 2004 (www.technology.gov/reports/TechPolicy/Telehealth/2004Report.pdf).

32. Feder, B.J. "A remote heart monitor fails to impress an F.D.A. panel." *The New York Times*, March 2, 2007 (www.nytimes.com/2007/03/02/business/02device.html?ex=1187841600&en=0e16de96eba67d02&ei=5070).

33. Taylor, W. "Healthcare Unbound—the Payer Perspective." Presentation at Healthcare Unbound, San Francisco: July 16–17, 2007.

34. Matheson, D., A. Wilkins, and D. Psacharopoulos. *Realizing the Promise of Disease Management*. Boston Consulting Group: February 2006 (www.bcg.com/publications/files/Realizing_the_Promise_of_Disease_Management_Feb06.pdf).

35. Ibid.

36. Jacobs R & McGarry M. "Empowering patients to manage their diabetes: Results from a data-driven diabetes disease management program." Presentation at Healthcare Unbound, San Francisco: July 16–17, 2007.

37. American College of Physicians. "Joint Principles of the Patient-Centered Medical Home." March 2007 (www.acponline.org/hpp/approve_jp.pdf).

38. American College of Physicians. "Tax Relief and Health Care Act of 2006 and other changes affecting 2007 Medicare payments." December 21, 2006 (www.acponline.org/hpp/sgr2007faq.pdf).

39. ITS Office of Information Security, Yale University. "Mobile technology and security." January 2007 (www.yale.edu/its/mobile-technology/security.html#pdadep).

40. RSA Security. *The 2nd Annual RSA Security Password Management Survey*. 2006 (www.rsa.com/press_release.aspx?id=7296).

41. Among the efforts to develop standards for wireless health care communications are these: (1) A working group in the Bluetooth Special Interest Group is creating a profile that would specify how medical devices should communicate via Bluetooth with cell phones, PCs, and other electronic tools (www.bluetooth.com); (2) the Continua Health Alliance, which comprises more than 100 health, telecommunications, and electronics companies, is developing interoperability guidelines for wireless health communications. Its initial focus is on applications for chronic disease management, aging-related health monitoring, and support for health and fitness (www.continuaalliance.org); (3) IBM and the University of Florida are collaborating on developing open source hardware and software standards to facilitate communications between medical monitoring devices and data repositories (www.infoworld.com/article/07/07/24/IBM-U-of-Florida-team-on-healthcare_1.html).

42. Forty-five percent of people who are 75 years old or older are physically limited to some degree because of chronic health problems, compared to 23 percent of people in the 45 to 64 age range. Trupin, L. and D.P. Rice. "Health status, medical care use, and number of disabling conditions in the United States." *Disability Statistics Abstract*, No. 9. U.S. Department of Education, National Institute on Disability and Rehabilitation Research: September 1995.

43. Doherty, S. and P. Oh. "An automated monitoring system of patients' daily life and physiological conditions." Presentation at the Partners Telemedicine symposium, Boston: September 18–19, 2006.

44. "New biomedical device uses nanotechnology to monitor hip implant healing, may reduce wait time." *Science Daily.* October 24, 2006 (www.sciencedaily.com/releases/2006/10/061018094008.htm).

45. "Smart implant systems for spine and orthopaedic applications." *Wireless Healthcare.* Herstford, U.K.: November 30, 2006 (www.wirelesshealthcare.co.uk/wh/news/wk49-0003.htm).

46. "Cardiologist's 'living chip' changes science of disease monitoring." University of Rochester Medical Center, Rochester, NY: September 15, 2006 (www.urmc.rochester.edu/pr/news/story.cfm?id=1226). For a useful overview of biosensors, see Turner, A.P.F. "Biosensors: past, present and future." Cranfield Biotechnology Centre: 1996 (www.cranfield.ac.uk/biotech/chinap.htm).

California
HealthCare
Foundation

1438 Webster Street, Suite 400
Oakland, CA 94612
tel: 510.238.1040
fax: 510.238.1388
www.chcf.org