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# Future Delivery of Health Care: Cybercare

## *A Distributed Network-Based Health-Care System*

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*There is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things.*

—Niccolò Machiavelli

**H**ealth-care system reforms can change the structure of the current U.S. health-care system, from centralized large hospitals to a distributed, networked health-care system. In our model, medical care is delivered locally in neighborhoods and individual homes, using computer technologies like telemedicine, to link patients and primary care providers to tertiary medical providers. This decentralization could reduce costs enough to provide all citizens with medical insurance coverage; it would benefit patients and providers; and as a dual-use system, it would better protect the country's resources and citizens in an event of biological terror or natural disasters.

### Health-Care Delivery: Current Problems

The American health-care system has many ironies. We continue to have arguably the best health care in the world, but it is not equally available to all citizens. There are now more than 47 million uninsured Americans, "those not old enough for Medicare or poor enough for Medicaid" [1] and also many who are uninsurable, patients so ill that insurance companies reject them outright or charge unaffordable high premiums. Even with insurance, some working people pay hundreds of dollars each month, in addition to their premiums, for medications, copayments, deductibles, and out-of-network costs, which results in a crippling expenditure for working- or middle-class families or the elderly on fixed incomes. The current health-care system will suffer in the long term from the lack of adequate preventive care. Although founded as a caring, altruistic field, the medical profession has increasingly become a for-profit entrepreneurial venture, in which MDs have been replaced by MBAs and large companies profit from people's illness, which creates a strong ethical dilemma and results in a contradiction to the doctors' Hippocratic Oath. The American health-care problems will reach a tipping

point [2] when the uninsured will not tolerate it any longer; they may rebel and demand quality medical care and insurance coverage.

### **Transforming Delivery of Care Through Technology: Cybercare**

As an affluent country with vast resources, and as a world leader, the United States is in a unique position to set an example by providing all its citizens with access to good health care. After all, "a society that spends millions on lawn care can find the resources to provide life-giving necessary care to its poorest members" [1]. The medical, social, and financial problems facing this dilemma are solvable if the right resources are applied. Our top priority must be to deliver the best health care in the world, accessible to anyone regardless of money or connections, in a financially responsible manner.

Is a better health-care system possible? We believe so. We believe that the current health-care dilemmas can be solved by a new system that moves medical care away from the hospital and into the community clinic. Patients and their primary care providers will then use telemedicine over a distributed network to link to tertiary medical providers and systems worldwide. Medical care will become Cybercare, a name that means health care delivered via cyberspace. This distributed system will help reduce costs, improve quality of care, and potentially make insurance and medical care affordable to all citizens. The system will include incentives for prevention and education, which will further increase efficiency and access [3].

Technology will transform our medical system, just as computers and the Internet have transformed our personal and work lives, by bringing technology directly into the home. As one example of how technology impacted life, people can now work from home via telecommuting, whereas just 30 years ago, the technology to network homes to offices was not widely available. Consider how bank ATMs, online bill payments, online travel reservation systems, e-mail, and Web shopping have helped busy people. Similarly, in the medical arena, we can now link from the home to the provider or hospital via telemedicine and related technologies to access specialists worldwide; this system will not only improve everyday patient care but will also facilitate our country's response to natural or man-made medical disasters [4], [5].

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## How Did We Get Here? Medical Care Delivery Models, Past and Present

Current U.S. health care is centralized. Patients may be transported up to two hours to a centralized medical center with specialized equipment and services. This system is expensive and inconvenient for patients because it was chosen to primarily suit doctors.

Before the 20th century, medical care was given at home, with visits from mobile family physicians who packed the necessary medical technology into a doctor's bag. Rare and expensive resources, such as heavy technology and specialist providers, had to be centralized in hospitals to make utilization effective. Today, patients often choose hospitals, and especially emergency rooms (ERs), because they provide immediate care with diagnosis and treatment from all needed specialists.

Hospital care is very expensive as is nursing home or agency care. Primary care in the ER is also very expensive. The ER is filled with people who should not be there. In a culture characterized by fast food and Wal-Mart convenience, many people come to the ER for minor problems because they can get their labs, X-rays, and specialist consults in a matter of hours, whereas as an outpatient, it would take months because each step would require an appointment, then a decision, then another appointment, etc.

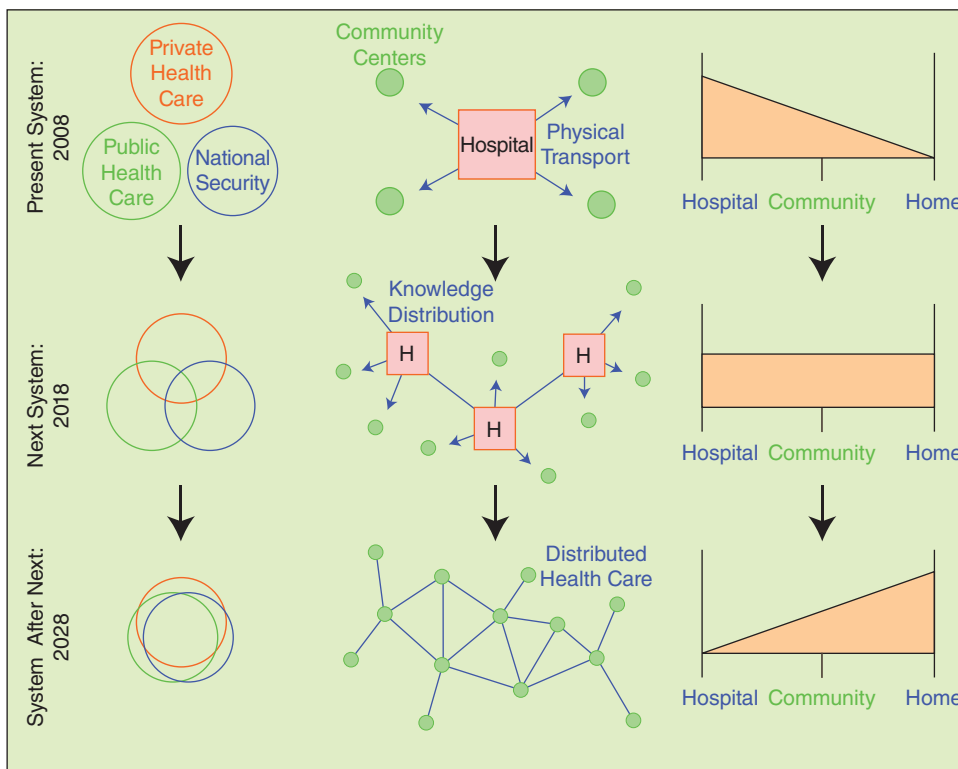
Our proposed Cybercare system would combine what is best from the old medical system and the new: the family doctor and the central hospital. The family doctor in a local clinic would be empowered with technology that allows him or her to provide an ER-like immediate coordination of care by linking across the network to any specialist and by substituting some in-person visits

with on-camera visits [6], [7]. We would still need central hospitals for specialized services like trauma care, transplantation, oncology, and positron emission tomography scanning. Figure 1 shows how the balance of care will shift from hospital to home over 20 years.

### The Impact of Prevention on Cost Efficiency and Quality of Care

A Cybercare medical system will employ preventive strategies to ultimately transform health care. We need to shift our focus from treatment (after the disease) to prevention (before the disease). We spend more money on ambulances (to treat the accident damage) than we spend on safety features such as global positioning system (GPS) alerts, which might prevent the accident or reduce its impact. Table 1 shows how prevention could impact the timeline of both a disease and a traumatic incident, using military terminology (i.e., references to events that happen left of the blast, or prior to an explosion, and events right of the blast, i.e., after the damage is done). If we can prevent a catastrophe, to the left of the blast, either in medicine or the military, we save money and lives.

In terms of cost, a little prevention goes a long way: dollars spent on airbags or GPS alerts could offset the much larger financial, emotional, and societal costs later on. However, to be frank, the current health-care system survives, and is a big



**Fig. 1.** Present health-care system and its proposed change to a netcentric health-care system. Cybercare would combine private health care, public health care, and national security. Second, health-care capabilities would be more evenly distributed throughout the system using telecommunications and telemedicine. Along those same lines, the majority of health-care delivery should be moved out of the hospital and into the community and the home. (Figure taken, with permission, from [37].)

**Table 1.** Timeline of a disease and the impact of prevention (two examples).

Before Disease: Prevention Strategies (Left of the Blast)	Medical Condition and Impact	After Disease: Treatments (Right of the Blast)
Control weight, exercise, life-style factors	Diabetes type 2	Insulin treatment
Wearing helmets, airbags and seat belts, driving speed limit, safer cars, violence prevention, early recognition of an impact/GPS alerts	Trauma	Treatment in ambulance, OR, hospital, surgery, ICU, recovery and rehab, etc.

business, because it profits more from treatment than it does from prevention. Cybercare would save money by reducing the hospital bureaucracy that now profits from expensive procedures once a patient has become ill or injured and replacing it with prevention incentives.

Doctors and patients do not always agree on health and prevention. Patients want fast service, low cost, and relief of pain. Doctors want to prevent problems and reduce morbidity and mortality. Most patients do not notice if they do not feel ill or hurt. This is why primary care is so hard. The reason people do not stop smoking or overeating is because they cannot appreciate the intangible benefits of long-term prevention.

Yet, we could borrow simple ideas from other countries: in Mexico, for example, families where obese children or adults lose 50 or 100 pounds receive money to pay for the cost of the children's school. We could also employ simulation to visually demonstrate to an overweight man or woman what may happen to him or her in 20 years if he or she stays overweight (diabetes, amputation, heart disease, cancers, etc.). Patients with existing illness (diabetes, heart disease, etc.) could be monitored with sensors to detect changes and prevent, for example, diabetic comas and heart attacks. We could provide patients with Wii games that guide them through exercise programs and provide feedback to their providers or even health-care insurers. Hospitals could be rewarded for having healthy patients rather than for treating them expensively. Preventive approaches will improve the overall health of the society and save costs enormously, perhaps enough to fund the technology needed for Cybercare and to provide insurance for all citizens.

### Technologies for Cybercare

The core of Cybercare will be high technology and networks that link health-care resources anywhere in the world. Given the unlimited capacity of the human mind to invent and create, and the vast resources within industry, research, and the military now developing medical technologies, we expect that the list of technologies presented in the following sections (a mix of current and future technologies that we would employ in Cybercare) is only a starting point (Table 2).

#### Telepresence

In today's business world, we routinely make conference calls, and, soon, we will employ high-definition, two-way videoconferencing to see those remote colleagues we are now speaking to in life-size and full color. Phones will include cameras and videos so that the people conversing can see each other in real time. In the

medical setting, telepresence allows a physician and a patient to communicate remotely (and even view medical data or computer simulations) as if they were together. The Visicu system [8] remotely oversees remote intensive care units (ICUs); for example, the ICU at Tripler Army Medical Center in Hawaii supervises the ICU at the U.S. Naval Base in Guam.

#### Telemedicine

Telemedicine, which combines telecommunications and medicine, can connect rural health-care providers to urban specialists to provide diagnostic decision support for any type of medical care.

On the most remote human outpost in the world, Tristan da Cunha (population 269), located in the South Atlantic Ocean between Africa and South America, there is no air landing strip and thus no way to evacuate people in a medical emergency. The island's only doctor, Carel Van der Merwe, says, "The only physical contact with the outside world is a six- to seven-day ocean voyage...so whatever needs to be done, needs to be done here" [9]. The island has a satellite-Internet link to America for 24-h emergency medical care and consultations with specialists in lung and heart function, radiology, and surgery. It is as if the island were virtually connected to the best medical care available in the world.

Some entrepreneurial private medical practices, such as WorldClinic of New London, New Hampshire [10], provide medical concierge care (in person or via telemedicine) to traveling executives, their families, staff, etc., at any hour and at any location in the world. This includes people traveling by yacht, who are far from ERs, etc. Commercial airlines also

Table 2. Health-care technologies and purposes.

Technology	Goals and Purpose
Telepresence	Video presence of a provider with two-way communication and viewing.
Telemedicine	Medicine provided to a remote area by experts in another area or region. This includes remote and mobile ultrasound or other expanded scope of practice.
Home telehealth and remote monitoring	Patients at home have medical equipment, monitors, etc., which relay information to providers at the hospital.
Telesurgery	Surgery done by robots under remote control by a human operator.
Electronic medical records	Medical records stored on a computer or computer network, possibly linking different providers and one individual's records over a lifetime.
Electronic continuum (military)	Integration of care for injured soldiers into an electronic continuum from first response to rehabilitation, such that at each subsequent step, all the previous steps have been recorded and filed to inform later decisions.
Modeling and simulation	Modeling: Creation of a computer (often 3-D) model of a human body that clinicians can use for simulation. Simulation: practicing a medical procedure on a model or simulator, as a surrogate for the person, for education and training purposes.
Robotics	Use of robots to replace humans for telesurgery, telecare, military, or biohazard duties.

have links to the ground system to provide in-flight medical assistance when caring for a disabled passenger [11].

Telemedicine- and electronic medical record (EMR)-linked technologies were used in a prototype program in Vietnam [12] to enhance the computerization for communication, medical data exchange, and patient data access. It allowed for the virtual presence of someone remote to consult, supervise a surgical procedure, or interpret images. Smart phones were also used in Vietnam to link medical data from one location to another. A Web-based telemedicine system provided patient data that could be used for research, including data forms and clinicians' written notes [13]. A pilot software-based diagnostic decision support tool for infectious diseases was used to help diagnose infectious respiratory conditions like severe acute respiratory syndrome or avian flu, providing both a differential diagnosis and the confidence level of any specific diagnosis based on the quality and specificity of input data [13].

Currently, the fastest growth in U.S. telemedicine is in home care for longitudinal management of chronic disease, which is described later.

### **Home Telehealth and Remote Monitoring**

Telemonitoring is the remote monitoring of people with known medical conditions, in which patients are outfitted with wearable or implanted sensors and other equipment to conduct lab tests and transmit results to clinicians. Germany-based Body-Tel has developed sensors that allow patients to measure their own glucose levels, blood pressure, and weight and upload results to their doctors via a wireless connection to a secure Web server. Another Honeywell system allows patients with lung disease and congestive heart failure to take their own electrocardiograms and monitor their peak lung flow, oxygen saturation, and blood pressure. Doctors monitor the remote data and can respond to any problems. Patients are happy to stay independent at home, and their treatment costs are lower [9].

The Veterans Healthcare Administration (VA) hospitals have a robust home telehealth network, where nurse practitioners monitor patients with congestive heart failure, diabetes mellitus, hypertension, etc., at home through the use of a home telehealth buddy. Notes from nurses and data are input into VA's EMR that can be accessed from any VA provider for any VA patient around the United States. This network is based on open-source software [14]. Other commercial systems are now available for remote patient monitoring [15].

The firefighting industry actively uses telemonitoring to track physiological data on firefighters in a burning building. The same systems are used for police and the military. The National Aeronautics and Space Administration (NASA) has had astronauts wear sensors that record very sophisticated physiological data that can be integrated into a coherent electronic record and interpreted on site with alarms for local response as well as being transmitted for distant management and response. The highly detailed events of an open, as well as laparoscopic, surgical procedure can be captured in multimedia using small cameras and voice recognition transcription to allow subsequent review of a procedure for safety or medical record purposes.

### **EMRs**

An EMR, also called an electronic health record or computerized patient record, is an individual patient's medical or health record in a digital format, often shared or accessible via a network. Such systems can reduce medical errors and speed

communication of results among providers but are not yet standardized, widely implemented, or integrated with each other. Kun et al. analyzed the interoperability of EMRs as a way to reduce the medical errors that can occur from a lack of coordination between people, processes, and technology [16]. Google Health allows people to integrate health-care data, some automatically collected and some patient-entered, to make information known across health-care systems and avoid errors such as medication errors [17]. Other vendors including Microsoft and Intel have similar systems. The Health Records Banking Association is an authority in this arena [18].

Mental health records, vaccine registries, and dental records are examples of islands of information that are today kept out of the electronic health record produced by hospitals and others. We propose a change of focus to a patient health record, which a patient might bring with him or her to these disparate and (currently) unlinked providers, increasing coordination and reducing error. The president has committed to implementing EMR by 2014, and a bill currently in Congress, the Patient-Controlled Health IT Act, would allow patients to obtain their medical history electronically if their health-care providers use EMRs [19]. The military plans to implement patient-controlled personal health records in 2008 [20].

A current study by Joseph Rosen [21] will employ just-in-time training to predict and prevent medical errors, such as wrong-site errors or giving a diabetic the wrong insulin dose. This employs technology similar to military systems, e.g., Blue Force Tracker, that show alarms if a soldier was accidentally about to shoot one of his own troops in a friendly fire accident. We could also extend such technology to examine databases to determine trends that cause medical errors in both individuals and populations.

### **Electronic Continuum**

There is an ample technology, much developed by the Department of Defense, that could fully integrate the care of injured soldiers into an electronic continuum from point of injury to rehabilitation, such that at each subsequent step, all the previous steps have been recorded and filed to inform later decisions. The continuum begins with the capture of the first encounter events with video, digital images, voice text, physiologic data, and diagnostic images. The event file can be captured with compact and effective sensors that feed into a recording device like a personal digital assistant (PDA). The data can be transmitted back and forth to the military field hospital and reviewed even further along for input. If connectivity is needed, wireless communication can be employed even in chaotic circumstances. The record captured can be printed onto an electronic chip and sent with the patient as hard electronic copy, with the redundancy of transmission electronically to the next and even subsequent sites of care by wireless means. Event recognition, capture, transmission, and integration via an electronic continuum are described in [22]–[25].

### **Modeling and Simulation**

A human body in the real world can be scanned and displayed as a three-dimensional (3-D) human body model on a computer. The result is an anatomical information model that clinicians use, as a surrogate for the person, to simulate procedures, predict outcomes, and make mistakes upon the model, before providing medical diagnosis or treatment on the real person.

An advanced human model could include individual cells, tissues and organs, vital signs, mechanics, physiology, individual and group behavior traits or genome, and the epidemiology of



human groups and large populations. Such a comprehensive model could truly predict and possibly prevent injury [36]. Behavioral models could predict which people are likely to indulge in more risk-taking behaviors that adversely impact their health and which people are cautious and conservative. Finally, by including a person's individual genome or a constellation of biomarkers in the model, we can possibly ascertain an individual's susceptibility to various injuries or disease and perhaps mitigate those susceptibilities. No model encompassing the physical body, behavior, and biomarkers yet exists, but it is being developed now. In the future, simulation will be combined with very advanced human body models to simulate clinical trials of drugs or medical treatments on humans so that the current evidence-based medicine would be replaced and human clinical trials would still be done, but only on simulated humans, and the results would be used to predict outcomes.

In the future health-care system, everyone is likely to carry a computer ID card with a 3-D model of his or her own body stored inside, just as some people wear medical ID bracelets today. When a person becomes sick, there will be an available dataset (image) of his or her normal healthy body for comparison, detection of change, and diagnosis. It could help plastic surgeons to rebuild the person accurately if reconstructive surgery were needed.

Just as industrial engineers test their models of automobile engines or airplanes via numerous simulations, virtual prototyping, and testing, to ensure that only the most robust products will be produced, doctors of the future will increasingly use human modeling and simulation to practice surgery and improve outcomes. Modeling and simulation have dramatically reduced costs, time, and errors in developing a new product or testing a new method or procedure [26]. Medical root-cause analysis can be combined with simulation to help detect and prevent future medical errors, especially when electronic capture of the event allows a subsequent review to identify problems and give guidance to future prevention. Simulation can also be used therapeutically, e.g., the Army is studying the use of virtual reality to help soldiers recover from or mitigate the development of posttraumatic stress disorder [27].

### ***Robotics for Telesurgery, Telemedicine, and Biohazard Activities***

In telesurgery, also called remote surgery, a surgeon at a site away from the patient remotely controls a robotic system that performs the actual surgical tasks. Robotic surgery will ultimately allow a patient in one area of the world to choose a top surgeon on another continent without having to travel to that surgeon. It will allow surgeons to operate on remote patients such as soldiers on a battlefield or astronauts in space. Telesurgery was pioneered successfully in 2001, when two surgeons in New York removed the gallbladder of a woman in France without complications, using a remotely controlled robot, Zeus [28].

The RP-6 mobile telemedicine robot is a robotic platform with a flat-panel monitor supported by a telemedicine connection. The nurse can take this robot on rounds, and the patient can see and converse with the doctor over the telemedicine link. There has been a surprisingly good acceptance of this technology, especially in nursing homes where physicians do not have much time for rounds.

A remotely operated robot called Hazbot is able to open doors and navigate into an elevator using the call button and appropriate movements and, in the future, will be programmed to navigate an entire building or area for bioevent disaster

response and to possibly deliver medicine to isolated patients, assess such patients, or help a downed firefighter [29].

### ***Military Health Care: From Echelons of Care to Robotic Care on the Battlefield***

In the Iraq conflict, critical injuries sustained by soldiers have led to revisions in engineering designs for prosthetic limbs and eyes. Ten years from now, telerobots such as the da Vinci Intuitive Robot may perform surgery in combat zones with a surgeon controlling it from afar [14], [30]. Twenty years from now, robots will retrieve an injured person on the battleground and immediately (without any human intervention) scan the patient, diagnose injury from the scan, and do surgical repairs [31]. The robot will then place the soldier into an unmanned helicopter using a life support for trauma and transport (LSTAT), a bed for transporting sick patients with a fully functional ICU onboard to care for the wounded patient during transport to a hospital. In a pandemic, we could also deliver LSTATs with a power supply and instructions for laypersons to operate, just as laypeople can operate automatic external defibrillators (AEDs) today.

### ***The Contemporary Military Operating Environment and Ad Hoc Medical Evacuation Networks***

In the current military, as in the civilian world, the availability of information technology and telecommunications technology (landline, FM, cell phone, satellite communications, and e-mail) changes everything. Computer or Internet networks have a physical layer and a software layer and so does a network of combat casualty care. The physical layer, in this case, is composed of medical evacuation and medical treatment units. The software layer should be a seamless information grid that links information about the soldier's injury, his or her treatment during active duty, and his or her medical records after discharge from active military service.

The ultimate goal of the U.S. military evacuation system for the severely wounded in improvised explosive device (IED) strikes, common in Iraq and Afghanistan, is to expeditiously return the wounded soldier to a point of definitive care, alive and with no decrement in the patient's condition or the least amount of ultimate injury possible. U.S. military trauma surgeons must actually suppress their desire to perform definitive therapy in the war zone if they hope to have the best possible outcomes because their patients often have multiple severe injuries, the combat environment is chaotic, and continental U.S. hospitals are large fixed facilities with obvious safety and technological advantages. These factors make optimization toward expeditious patient evacuation the most prudent goal of the successful combat surgeon.

### ***Education: Training Clinicians About New Technologies Using New Technologies***

The future netcentric health-care system and its underlying technology will change the practice of medicine for patients and therefore necessarily the training of their providers. The new tools and methodology used for patient care should be taught to the health-care providers of the future and also used to teach them. We must expand and enhance curricula to include 1) evidence-based medicine, which teaches students to maintain best practice through objective standards; 2) telemedicine and EMRs, which help students learn to maximize efficiency of care; and 3) epidemiology, which helps providers to integrate private medicine with public health. In turn, health-care providers can also be taught using instruments that

will enable more efficient and effective learning, such as distance education tools and simulation.

The increased access to a more robust database will allow students to conduct real-time data mining and interpretation, which leads to a continuous quality improvement.

Medical modeling and simulation will play a central role in the future of health-care education because they maximize resources while maintaining patient safety. Many U.S. simulation centers, including that at Dartmouth-Hitchcock Medical Center, use systems including the SimMan [32], a portable and advanced patient simulator for team training. Sophisticated surgical simulation systems, such as the Red Dragon and Blue Dragon, provide accurate measurements of hand motions, forces, and direction, which enable computational evaluation of performance. In another capacity, computer-based modeling and simulation programs teaching anatomy, or surgical procedures from a cognitive standpoint, for instance, provide an interactive 3-D medium for residents to learn.

To maximize its impact, the education system must teach providers continuously, rather than episodically. In the aforementioned example, the anatomy simulation program could be available via a PDA, where a resident could access it during any limited period of time. Teaching health-care providers in this manner will serve to support the information infrastructure of the greater system. The utilization of technology for a networked training system, coupled with an investment in an effective networked health-care system, will ultimately facilitate improved care for all patients.

### **Health Care Future Scenario: Integrating All the Technologies into a Cybercare System**

In the next 25 years, the American health-care system will transition from the current paradigm where health care is done mostly in hospitals to a system in which health care is done mainly at home or in local clinics via telemedicine.

Suppose, for example, that you have recently noticed a skin lesion on your face. You will visit your primary care provider in your home or neighborhood; she will examine your lesion and then bring up a link via telemedicine (videoconferencing) to tertiary providers, dermatologists, and surgeons at a central location. You and your doctors will view a large video screen that contains your individual 3-D body model as part of your electronic record to compare how your skin looked five years ago to the lesion that is there now. If the doctors decide that the lesion should be removed, the primary care doctor can practice surgical simulation, to feel comfortable removing the lesion in her local office, with assistance from the dermatologist and surgeon if needed [33].

In the future, each of us will carry our medical records with us on a computer chip like a credit card. If you have a known disease, like diabetes, you may wear sensors and other monitoring equipment that send your lab values back to a computer that can alert nurses if a problem is flagged. These data will be available 24/7/365 and will transmit and be managed through health records data banks [18]. Therefore, if a person were to have an accident, the information would be immediately available to clinicians in the ER. Doctors will use simulations and models to calculate what time of the day the therapy or medications should be given to maximize positive outcomes, given our condition, age, gender, or genome. Eventually, robots will have the capacity to assist people in performing medical procedures and even telesurgery at home.

Does this sound far fetched? We already have residential robots that vacuum and mow lawns, medical robots that perform surgery, and military robots that conduct surveillance of buildings and explode bombs safely. Computers and the Internet have transformed the everyday world of people in their homes and offices. Those of us born before 1980 may recall that in the 25-year period between 1983 and 2008, Americans went from a time when nobody had home computers, to a time when some people bought personal computers, to the present time when many homes have multiple networked personal computers, wireless Internet, iPods, video cell phones, and PDAs. The generation now in college has been raised on computers and the Internet. People are uploading their videos to YouTube, posting their profiles on MySpace.com, and extensively using virtual communities and social networks to interact. The American medical system, too, will be transformed via networked technology.

### **A Road Map for Cybercare**

Cybercare would be implemented using the steps described in the following sections, and perhaps including others.

#### **Network Infrastructure**

The first step is to install clinics in every neighborhood, linked via telemedicine. This would include three substeps: physically build more clinics, install the network to link them, and install the telemedical equipment and needed software to run over the network. Engineers would install, test, and troubleshoot equipment and maintain it on an ongoing basis. We would need maintenance staff and funding for every clinic. All medical equipment and processes would need to follow Food and Drug Administration (FDA) Good Manufacturing Practices (GMPs) guidelines for medical devices, etc.

#### **Training for Medical Providers**

The second step is to recruit and train new doctors, nurses, and aides at the local (or remote) clinics, as well as tertiary providers at central hospitals, in how to use telemedicine, EMR, and other computer information systems. Initially, it is unlikely we will have enough doctors and nurses to staff clinics in every neighborhood; if so, we may need to train the general public on how to perform some basic medical care at home. The system will also need to train staff to accommodate billing or coding for remote consultation, credentialing consultants who may be across state or national boundaries, etc.

#### **Public Education**

The third step is to educate the public to convince them to use local clinics instead of the ER for one-stop shopping. We should include incentives and describe how the Cybercare system specifically benefits patients, doctors, and the payers, and include more discussion of how each technology benefits all of these. For example, for patients, the new system would greatly save time and transportation costs.

#### **Insurance (Universal or Not)**

We believe that the money saved by telemedicine will fund insurance for all, so we need to demonstrate that. How long will it take to have cost savings, especially given the possibly large start-up costs for installing network infrastructure and conducting training for medical providers? Can we realize savings in time to insure more people to use the system?

## **Review and Oversight**

Some sort of review board will need to oversee the process, evaluate how it is going, administer the funding, conduct quality improvement processes, and iterate the aforementioned steps until we get it all running seamlessly. This might involve the Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) or other governmental bodies.

## **Technological Challenges**

There will be various technical issues for engineers to deal with in combining and decentralizing medical technology. These are discussed in the following sections.

### **Ensuring Quality of Information**

Medical information published on the Internet is not guaranteed to be accurate, correct, or statistically significant. So, as we move to a distributed medical information network, we need to focus on the goals of quality, privacy, and ethics.

### **Information Overflow and Knowledge Management**

The average person has too much e-mail, paperwork, and information to cope with in daily life. With so much information being produced in the medical field, how will medical providers and IT engineers find, filter, and fuse this information and make timely sense of it for both themselves and patients?

### **Privacy Concerns**

The public has legitimate fears about breaches of privacy, which can occur both from the use of EMRs and from the fact that medical organizations often have decentralized operations (i.e., procedures kept under separate chains of command: for instance, IT and medical departments), which increases the chance for medical errors. Until we can resolve such privacy issues, it may be difficult to shift our medical care system into a preventive mode, for example, to take advantage of genetic information. However, the banking and airline industries have mostly overcome privacy issues when implementing ATMs and online banking and reservations systems.

### **Interoperability of Medical Record Data**

Patient medical records are often not cohesive; a patient's dental, medical, and psychological records may be stored on different systems, and their medical records from various life stages (childhood, college, career, and retirement) are often separate. A unique, interoperable personal health record that follows someone through his or her lifetime could potentially save lives (by having the proper data at the critical time), improve quality of life, and reduce the potential for medication or allergy errors. The record could provide insight into the short- and long-term effects of lifestyle factors (including environment, diet, exercise, vaccines) or treatments. Combining these factors with genetic information may allow our system to achieve true disease prevention. So, interoperability can positively impact the quality of health care while reducing expenses [16].

### **Social Challenges**

Engineers are well versed in overcoming technological challenges by connecting disparate technologies into a seamless, cohesive network where all pieces work together. If humans could imitate technology, people with disparate views could also connect and work together seamlessly! To implement Cybercare, people will need to come together in a nonpartisan way and

decide how to overcome social barriers, some of which will not be settled in the arena of medicine and health but rather in the arenas of money, politics, and law. Doctors, nurses, engineers or IT staff, and health-care administrators will need to engage in cohesive dialog with insurance representatives, governmental legislators and executives, military leadership, lawyers, and ethicists. If we were to keep in mind the thought that health care should be the same for every citizen as it is for every senator and congressman, we would find that there are multiple barriers to reform: cultural, geographic, economic, and ethical.

### **Resistance to Change**

No matter what we predict and how much we would like to see Cybercare happen, because we have the tools to make it work, Mr. & Mrs. America still want Marcus Welby, M.D. (the kindly family physician) to take care of the ordinary things, but they also want Massachusetts General Hospital, the Mayo Clinic, and the University of California, in case there is a time when medicine has to go all out to save a patient's life or make his or her quality of life more tolerable. So, the first tension arises between a system such as Cybercare and one the public favors, a continuation of Marcus Welby and the closest university hospital.

### **Medical Elitism**

There is a self-generated elitist movement among affluent people not to be treated like everyone else. It is almost a reverse herd instinct. Said another way, the affluent will prefer a system that suits people such as themselves, and universal acceptance of a mini clinic in a shopping mall is not to their liking.

### **Poverty**

If one measures health care in America based solely on outcomes for the middle and upper classes, we come out looking good. However, there are ghettos within one mile of the best hospitals where people's health-care statistics are comparable to third-world countries, in terms of life expectancy or child morbidity and mortality. We need to address the health care of the poorest members of society who are least able to lobby for themselves. We need to ask ourselves why we spend more money on health care than other countries with better hard outcomes like mortality or longevity?

### **Means Testing**

Even our most affluent citizens are eager to accept any largess from the government, such as Social Security and Medicare. Some think this is a misguided sense of fairness. But, nevertheless, it is seldom even mentioned in discussion by health-care planners.

### **Salaried Physicians**

To mention the idea of salaries for physicians, which would be a great means of leveling the playing field of medical economics, is a sacred cow. Any discussion of physicians being on set salary, rather than earning as much as they can, arouses union-like behavior on the part of physicians. It would change the entrepreneurial attraction of medicine for a large number of people; yet, the National Health Service of the United Kingdom could not run without it. We certainly could learn from examining the positive and negative aspects of other countries' experiences with health care.

### **Flexible Schedules for Health-Care Workers**

Families in which both mother and father work full-time will need benefits such as maternal and paternal leave, affordable

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childcare, and part-time or flexible work schedules. Also, physicians nearing retirement may wish to transition to part-time work. The answer may be in supplementing work by having larger mobile, available pools of clinicians and support staff willing to do temporary work, something that might eventually become a national locum tenens resource, or group practices implementing flexible scheduling, without coverage of patient needs being slighted or falling victim to underprovision. It is very likely that we would also employ providers with locations in various states, time zones, or countries; for example, some practices already hire providers in India to read X-rays at night.

Medicine does not speak with one voice when it comes to economic, gender, cultural, geographical, and ethical diversities. Each of the challenges, technological and social, may impact the transition to Cybercare. Cybercare's implementation might best be envisioned as an evolutionary series of small accomplishments, rather than a revolutionary turnover of a time-honored system, in which changes affect too many people. When considering the social challenges, we cannot neglect the tremendous political clout of special interests, their advocacy groups, and their paid lobbyists in resisting any change or lobbying for their own interests to prevail when and if such changes are made. We also need to engage in ethical discussions; for example, would we insure, hire, or employ workers with at-risk diseases, behaviors, or genomes, and would we promote people or even make their health insurance contingent on their weight loss compliance?

### **Conclusions: Combining Information Technology, Social Collaboration, and a Political Mandate to Make the Future Scenario Work**

There is no right to health care written into, or even implied in, the Declaration of Independence and the Constitution of the United States. Yet, polls suggest that public sentiment, increasing year by year, is that everyone is entitled or has the right to health care such as would be available to a millionaire.

We have proposed that the best health-care system would be Cybercare: moving from a centralized system to a decentralized one, moving care from hospitals toward clinics, and empowering primary care providers with technology and connections to tertiary-care specialists. The cost savings realized from decentralizing health care and eliminating large hospitals might allow for more patients who are now uninsured to be insured and for a better distribution of the wealth of this system to every citizen, not just the medical insiders or the affluent. Decentralization would benefit patients and save money on a daily basis, especially in the rural environment, where access to the hospital-centric system is challenged by geography, weather, cost of gas, etc. It would also better protect the country's health-care system in the event of bioterror; removing a central point to target makes us inherently safer.

Cybercare will, thus, be a dual-use medical network system, one that will employ technology to enhance health in daily life and protect us in the event of bioterror or natural disasters.

Cybercare will optimize the full value of our present resources. It will shift the health-care system to one that is truly patient centric. A health-care network could be envisioned as analogous to the travel networks we have in place now. If one wants to travel from point A to B, he or she uses the network to plan the best route. When a patient wants to go from sick to well, he or she can use the Cybercare network to select routes that will best move him or her from point A to point B. There will be various resources—costs, time, space, and expertise—that need to be balanced on the network to ultimately provide just-in-time care. Cybercare will minimize costs and provide the best return on investment: for a given dollar spent on health care, you get back more if the money is spent on prevention as opposed to treatment.

### **Technology, People, and Processes**

Even the best technology will fail if processes and people are not taken into account within any organization. Both the engineer and the policy maker need to understand these three forces and how they interact. In one example, in October 2001, the president of the American Public Health Association [34] told Congress that 300 to 450 out of 3,000 local health departments did not have electronic mail. Congress immediately sent computers, which sat in the hallways because staff was not trained in how to operate them. Cybercare will require cross-platform training in telecom technology, databases, EMR; the executives in information, technology, and finance will all need to be involved.

### **A Political Mandate**

In addition to the technological and social issues to be considered during any health-care transformation, it may take a national or executive mandate to really put a Cybercare system in place. In the 1950s, President Eisenhower decided that the U.S. highway transportation needed a vast overhaul from secondary roadways to the major highway system we now know. Through a huge executive initiative, he sponsored the creation of a high-speed highway network that linked all cities in the United States with superhighways. A similar situation and similar need exist today: we have pockets of electronically linked medical facilities, but our capacity is analogous to the old slow secondary roadways. Pandemic illnesses, whether naturally occurring or man made, have the potential to take thousands, if not millions, of lives. The Cybercare system will require a transformation that is equally ambitious (in effort, cost and final bandwidth, or capacity) as putting in the U.S.-wide highway network in the 1950s–1960s. The concept of Cybercare as a dual-use network also parallels the U.S. interstate highway system; each highway can also be used (along straight sections) as a runway for military aircraft in the event of a war on U.S. soil or to move populations in the event of a disaster.



The highway transformation allowed the United States to vastly improve transportation to the benefit of businesses, individuals, and the government. Our current U.S. industry simply would not exist without our major interstate highway system, which supports the movement of goods and services that drives our economy. Similarly, the health-care transformation will vastly improve the delivery of medical care, which, in turn, will benefit individuals, providers, businesses (via new technology initiatives), and the government. In one sense, we already have the highways for cyberspace. We now need safe vehicles to use those highways (i.e., medical technology), as well as expansion of the networks, to bring health care to every home.

We need to put the Cybercare system into place because it will ultimately help us merge private health care, public health care, and national security. It must be a comprehensive integrated system, which we implement now, not later. It needs leadership, perhaps the new presidential administration taking office in January 2009. We have provided the strategy; the new government can provide resources and a mandate. The Department of Defense is in the process of moving its military medical system to one that is netcentric, and the netcentric medical model is the stated goal of the Office of the Assistant Secretary of Defense for Health Affairs. Other countries will also begin to put netcentric medical care into place with the potential for worldwide cooperation in both health and disaster situations.

### Federal Medical Board

Once the Cybercare system is in place, we will need to manage the flow of health-care resources. Management will help distribute resources to the greatest amount of people and solve, hopefully, the current problems where so many people are uninsured and underinsured. We suggest the creation of a Federal Medical Board, similar in philosophy to the Federal Reserve Board, whose stated purpose is "to provide the nation with a safe, flexible, and stable monetary and financial system" [35]. The Federal Medical Board would track the use of health care on a national level and balance the amount of resources coming in (insurance money, equipment, personnel) and the resources going out (use of medical services by patients) on a regular basis. It would titrate or triage the flow of resources in the medical care system and perhaps have a virtually identical mission statement as that of the Federal Reserve, "to provide the nation with a safe, flexible, and stable networked medical system with access to all who need it."

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