Innovative, “disruptive” changes in the way health care is organized, paid for, and delivered may lead to a transformation of the overall health care system.

Disruptive Innovation in Health Care: Challenges for Engineering

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Seven years after the publication of two seminal reports by the Institute of Medicine, *To Err Is Human* (IOM, 2000) and *Crossing the Quality Chasm* (IOM, 2001), which documented uneven quality, dangers, and inconsistencies in health care delivery, a majority of the nation’s health care providers are still struggling with those same challenges. Simultaneously, a backlash against the managed-care systems of the 1980s and 1990s has led to very rapid increases in health care expenditures and consequent rapid increases in the number of uninsured and underinsured people, both of which continue unabated. Today, there is a growing consensus that the twentieth-century model of health care is no longer sustainable.

After nearly a decade of subcritical attempts in the public and private sectors to improve the quality of health care and bring costs under control, a buyers’ revolt, led by businesses and insurers, combined with advances in medical and information and communication technologies (ICT), has begun to open the closed market for health care services to new business models, as well as to new models of care delivery.

Innovative, “disruptive” models of care delivery are opening the way to a new division of labor among health care providers and changes in the structure and location of care delivery. Eventually, they could catalyze a wholesale transformation of the overall health care system by accelerating the development and application of ICT tools and techniques that would...
make possible the design, analysis, and governance of new processes and systems throughout the health care system. Engineering will play a major part in supporting this disruptive dynamic and realizing its promise.

Understanding the Logjam

More than 98,000 Americans die and more than one million patients are injured each year as a result of broken health care processes and system failures (IOM, 2000; Starfield, 2000). In addition, the gulf between the rapidly advancing medical knowledge base and the application of that knowledge to patient care continues to widen. In fact, barely 50 percent of patients in the United States receive known “best practice” treatment for their illnesses (Mangione-Smith et al., 2007; McGlynn et al., 2003). According to one survey, 75 percent of patients consider the health care system to be fragmented and fractured, a “nightmare” to navigate, and plagued by duplications of effort, poor communication, conflicting advice, and tenuous links to the evolving medical evidence base (Picker Institute, 2000).

Poor quality is not only dangerous but also costly. David Lawrence, retired chairman and chief executive officer of the Kaiser Foundation Health Plan (2005), estimates that 30 to 40 cents of every dollar spent on health care, more than a half-trillion dollars per year, is spent on costs associated with “overuse, underuse, misuse, duplication, system failures, unnecessary repetition, poor communication, and inefficiency.”

Since the late 1990s, annual health care costs have risen by double digits—roughly three times the rate of inflation—claiming an increasingly large share of every American’s income, inflicting economic hardships on many, and limiting access to care. By 2006, the nation’s uninsured population had risen to nearly 47 million, about 16 percent of people under the age of 65 (DeNavas-Walt et al., 2007), and it has continued to increase since then.

The immediate causes of this “perfect storm” of quality and cost crises in health care are well understood. U.S. health care is a highly complex enterprise with a “cottage-industry” structure (i.e., many small-scale, interdependent service providers that act independently creating “silos” of function and expertise). This siloed system is sorely mismatched to the nation’s overriding health challenge, namely, providing coordinated, integrated, continuous care to more than 125 million Americans who suffer from chronic disease. Seventy-five percent of U.S. health care dollars is spent on patients with one or more chronic conditions (Partnership for Solutions, 2002).

This fragmented care system has been sustained by an outdated fee-for-service reimbursement model and regulatory framework that has rewarded health care providers as well as drug, device, and equipment manufacturers for providing high-priced services based on new medical technologies and procedures. While this framework has supported rapid advances in medical science and the development of increasingly precise diagnostic tools and therapeutic interventions, it has been indifferent to, if not discouraging to, innovation directed at harnessing advances in medical knowledge and precision diagnostics to improve the quality and efficiency of health care.

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Largely because of its cottage-industry structure and dysfunctional reimbursement and regulatory framework, the health care sector has woefully underinvested in ICT—the nervous system of all information-intensive industries—to support core clinical and administrative/business operations. Health care is also underinvested in mathematical/conceptual tools and techniques for designing, analyzing, and controlling a myriad of complex processes and systems. Without these tools and technologies, most health care providers lack the capacity to translate the rapidly expanding stream of diagnostic and therapeutic advances in medical science into high quality, affordable health care for all.

To be sure, there are isolated pockets of progress. Large integrated salaried group practices with managerial hierarchies, such as Mayo Clinic, Kaiser Permanente, Intermountain Healthcare, Veterans Administration (VA), and the Military Health System, are committed to the cost-effective use of precision diagnostics and therapeutics and the consistent practice of evidence-based medicine. These groups have also invested in ICT to support quality care and have even begun to use systems engineering tools and techniques to improve clinical operations.
However, the vast majority of groups and institutions in the health care delivery system have made little progress. The hodgepodge of individual providers, small group practices, clinics, academic medical centers, community hospitals, and others continues to lag far behind in the efficient use of precision diagnostics and therapies, the practice of evidence-based medicine, and the use of ICT systems and tools. For example, it is estimated that only 25 percent of physicians currently use some form of electronic health record and that less than 10 percent of doctors use a “fully operational” system. In the meantime, costs continue to rise, and the quality battle is, at best, at a standstill.

The struggle to improve the quality of care is, at best, at a standstill.

Breaking the Logjam

Private-sector purchasers, especially large self-insured organizations, convinced that the current system is broken and unlikely to be transformed by government action, have begun to purchase health care services for their employees directly (i.e., not through insurers) from existing or new high-value service providers, especially for wellness and preventive care, primary care, and chronic disease management. Many large employers offer fully integrated health care services for their employees from existing large multispecialty salaried group practice providers, such as Kaiser Permanente, Intermountain Healthcare, and others. At the same time, many start-up companies, backed by venture capital, are offering high-quality, low-cost wellness care, primary care, and chronic-care services that can be delivered via the World Wide Web or low-cost intermediaries.

Pressure on regulators to increase transparency in health-care markets and lower entry barriers to new types of service providers is beginning to have an impact, especially at the state level. The primary force behind these changes is “disruptive innovation,” a combination of technological advances and new business models that has the potential to transform the structure, organization, and performance of the health-care system as a whole.

Disruptive Innovation

Clay Christensen, professor of business administration at Harvard, introduced the theory of disruptive innovation in his book, The Innovator’s Dilemma, in 1997. He postulated that consumers will seek out those who can do the jobs they want done and evaluate them by three simple measures: level of transparency, convenience of delivery, and cost that represents value. In the industries Christensen studied, consumers brought about wholesale transformations of the prevailing business models by purchasing new products and services that were much more affordable and accessible than those that had been traditionally offered.

Christensen argues that two conditions are necessary for disruptive innovation to increase to scale: (1) technological enablers (i.e., technologies that provide routine solutions to problems that previously required trial and experimentation); and (2) a disruptive business model that can profitably deliver these routine solutions to customers in affordable and convenient ways.

The personal computer is an instructive example of a disruptive innovation. Prior to the 1970s, only a small number of engineers worldwide had the expertise to design mainframes or minicomputers, which were, therefore, expensive to make and market; in fact, they required gross profit margins of 45 to 60 percent just to cover overhead costs. In addition, users also needed expertise to operate them. The personal computer disrupted this model by making computing affordable and accessible to hundreds of millions of people. The technological enabler of this disruption was the microprocessor, which radically simplified computer design and assembly (Christensen, 1997).

Technological Enablers for Disruptive Innovation in Health Care

Precision Diagnostics and Therapies

Technological enablers of disruptive innovation in health care are: (1) advances in medical knowledge and

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1 The 2006 report of the Robert Wood Johnson Foundation, Health Information Technology in the United States: The Information Base for Progress, provides a definition of a fully operational electronic health record: “An electronic approach to collecting, storing and manipulating patient data must be able to accomplish at least four tasks: collection of patient health information and data, results management, order entry management, and decision support.”

more precise medical diagnostics and therapies (including drugs, devices, equipment, and procedures); and (2) advances in ICT, including Web 2.0 applications, broadband communications, and wireless integrated microsystems (WIMS).

Over the past half century, advances in medical knowledge and diagnostic technologies have greatly increased the accuracy of diagnoses and treatments of disease. If precision diagnosis is not available, treatment is determined by "intuitive medicine" (i.e., therapeutic problems solved by highly trained, expensive professionals through intuitive experimentation and pattern recognition). Intuitive medicine gives way to evidence-based medicine when a patient's treatment is guided by data showing which therapeutic interventions are, on average, most effective.

If precision diagnosis is available, treatment becomes "precision medicine"—targeted therapies, including drugs, devices, procedures, and so on, that can be developed and routinized to address the causes rather than the symptoms of an illness. Precision medical care can be delivered by less highly trained, less expensive care providers. So called "minute clinics," for example, staffed by nurse practitioners using rules-based care, offer a limited range of services in shopping malls and drugstores (Scott, 2006). In another case, at Intermountain Healthcare, four specialist physicians supervise the care of nearly 20,000 diabetics, mostly by family physicians, helped by nurse practitioners, specially trained technicians, and volunteers.

Diagnostic technologies have already changed the treatment of most infectious diseases from intuitive to precision medicine. In recent years, the emergence of molecular diagnostics and imaging diagnostics has made medical diagnosis and treatment even more precise. Advances in genomics and proteomics promise even greater precision, as well as personalization, of clinical diagnoses and treatments.

Advances in Information/Communications Technologies

The second technological enabler, advances in ICT, not only supports precision medicine by enabling the development of increasingly precise techniques and devices and the capture and integration of clinical data for research purposes. They also facilitate the codification, continuous updating, and diffusion of precision therapies or best-practice care protocols based on advancing medical knowledge.

ICT can make feasible the integration of a patient's health care data with a continuously advancing medical evidence base to provide real-time medical decision support to professional care providers, as well as to patients and their families. ICT also enables the collection, integration, and analysis of data on the performance of the overall system and supports the use of many advanced systems design, analysis, and governance tools and methods to improve system performance.

Since 1960, efforts have been made to encourage the use of electronic records, but implementation has been limited mostly to integrated multispecialty group practices. One of the most promising disruptive information technologies, the personal health record (PHR), has advanced efforts to put electronic medical records in place throughout the health care system. Omid Moghadam, director of PHR programs at Intel, describes a PHR as a record "owned and controlled by the patient that incorporates data the patient enters, but also includes authenticated information . . . from all of the places the patient is involved with—insurance company, hospital, doctors' offices, labs, and so forth" (Harvard Medical School, 2006).

The personal health record is one of the most promising disruptive information technologies.

Some companies have already adopted PHRs for their employees, and some insurers are using them to try to retain customers. Even Microsoft and Google are competing for PHR business. The hope is that by bringing together an individual's medical information from all relevant sources, that individual will be in a better position to manage and control his or her medical care. Widespread use of PHRs could create an

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3 Personal communication, Brent James, MD, vice president for medical research at Intermountain Healthcare.

4 A good analogy is Intuit's Quicken software, which brings together financial information from many sources so an individual can manage and control his or her own assets. See http://quicken.intuit.com.
informed consumer base that can begin to buy health services directly, rather than through third parties. PHRs are diffusing very rapidly from academic environments to academic-corporate-consortium partnerships, and recently to the commercial world (e.g., Microsoft HealthVault).\(^5\)

WIMS is another emerging disruptive ICT. These combinations of sensors based on microelectromechanical systems, microelectronics, and wireless interfaces may provide remote, real-time monitoring, diagnosis, and therapeutic intervention in health care (NAE, 2005).

As the information infrastructure to support advancing precision diagnosis and therapy improves, more kinds of precision, routinized diagnostics and therapies can be moved to locations that are convenient for patients (e.g., from outpatient facilities to in-office or even in-home care) staffed by less highly trained, less expensive health care providers—again providing better value.

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**Precision medicine has been grafted onto the existing organizational framework.**

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**Disruptive Business Models for Health Care**

At present, the sustaining business model in health care is the 60-year-old Medicare “fee-for-service” model, which is controlled by special interests with political control over the regulatory and reimbursement system. Most private insurers mimic Medicare, and each state imposes further regulations. This is an inflationary, distorted, “third-party” model.

The two prevailing institutional modes of care delivery in the United States, general hospitals and physician practices, developed more than a century ago when the practice of medicine was focused predominantly on the diagnosis and solution of unstructured problems by highly trained clinicians. As some areas of medicine, especially some aspects of primary and chronic care, moved toward more precise, routinized diagnostics and therapies, the value of care became increasingly determined by the precision, consistency, and efficiency of care delivery.

Rather than change the overall system, precision medicine was grafted onto the existing organizational framework. However, because of their high overhead costs, general hospitals and physician practices have not been able to translate precision medical services to higher value (i.e., low-cost, high-quality, accessible care) for patients. Meanwhile, the development of new business models capable of harnessing the potential of precision medicine to yield value have been stymied by the entrenched fee-for-service model and regulatory framework that protect the intuitive-medicine model of care from disruptive competitors.

Nevertheless, new forces in health-care markets have begun to open the way to disruptive business models in both purchasing and the delivery of care. Large corporations and consortia of organizations are reconfiguring their conceptions of employee health care benefits. One emerging model is “direct-value purchasing” by self-insured enterprises (e.g., large employers, multi-employer union trusts [such as voluntary employee benefit associations]) from entrepreneurial, venture-backed health-service delivery companies. In this model, employers contract directly with providers to deliver high-value health care that matches the needs of employees and their families. The most likely companies to be self-insured have 1,000 or more employees, and estimates are that they now represent more than 100 million employees/consumers. Self-insured companies pay insurance companies an administrative fee to process claims but bear the full cost of medical care.

In response to these disruptive models, new care-delivery models are emerging, such as Carena, a venture-backed enterprise that provides primary care.\(^6\) Microsoft has contracted directly with Carena to make home visits by family practitioners to Microsoft employees and arrange for follow-up (e.g., prescriptions, tests, specialists), as needed. Microsoft has found that, even at a very high hourly rate, employee satisfaction and increased productivity more than cover the costs of the service. In addition, costs for Microsoft families are comparably low. Carena’s latest contract is with the state of Kentucky, another self-insured entity, in partnership with Humana.

Other examples of “disruptive care” are delivered

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\(^5\) For additional information on Microsoft HealthVault record, see http://www.healthvault.com.

\(^6\) For additional information on Carena, see the company’s website at: http://www.carenamd.com.
by Renaissance Health, a private contractor hired by a union to deliver primary care, including simple blood tests and x-rays, and over-the-counter and generic prescription drugs for $30/month for janitors in the Houston area who are uninsured. Boeing has also contracted with Renaissance Health to care for chronically ill patients. These cases are handled by small care-teams located in the general clinics used by Boeing. 

If present trends continue, disruptive business models and advances in precision care and diagnostics are likely to spread to encompass a significant segment of the market, especially for providing primary care and chronic care. As high-quality, reliable, safe, health care services delivered effectively by less highly trained staff are documented by careful, authoritative research, the spread of disruptive service enterprises should accelerate, pulled along by the diffusion of disruptive business models by self-insured private, and eventually, public (state-level) organizations determined to ensure high-value health care.

Implications for Engineering

The dynamics of disruptive innovation in health care present general as well as specific challenges for engineers. On a general level, disruptive innovation will require combining the technologies, tools, and techniques of systems engineering with a deep understanding of business processes and organization in the health care and services industries. As health care markets open up to new business models, engineers can pursue fruitful research on tools, techniques, and engineered technologies to support the design, analysis, and governance of new delivery modes and networks.

On a more specific level, engineers can develop, adapt, and help implement the technological enablers of continuing disruptive innovations in health care. These will include WIMS to support the remote delivery of high-value care (e.g., monitoring, diagnosis, and therapy); the development of decision support tools for professional providers, health care purchasers, and equally important, patients and their families; the application of bioengineering and systems engineering to accelerate the spread of personalized, precision medicine; and the application of systems engineering tools and techniques for managing and improving the performance of complex, interdependent processes and subsystems, guiding investment in ICT infrastructure, and managing policy, reimbursement, and regulatory systems to support the transformed health care system.

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References