Can Electronic Medical Record Systems Transform Health Care? Potential Health Benefits, Savings, And Costs

The adoption of interoperable EMR systems could produce efficiency and safety savings of \$142–\$371 billion.

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ABSTRACT: To broadly examine the potential health and financial benefits of health information technology (HIT), this paper compares health care with the use of IT in other industries. It estimates potential savings and costs of widespread adoption of electronic medical record (EMR) systems, models important health and safety benefits, and concludes that effective EMR implementation and networking could eventually save more than \$81 billion annually—by improving health care efficiency and safety—and that HIT-enabled prevention and management of chronic disease could eventually double those savings while increasing health and other social benefits. However, this is unlikely to be realized without related changes to the health care system.

The U.S. health care industry is arguably the world's largest, most inefficient information enterprise. However, although health absorbs more than \$1.7 trillion per year—twice the Organization for Economic Cooperation and Development (OECD) average—premature mortality in the United States is much higher than OECD averages.[1] Most medical records are still stored on paper, which means that they cannot be used to coordinate care, routinely measure quality, or reduce medical errors. Also, consumers generally lack the information they need about costs or quality to make informed decisions about their care.

It is widely believed that broad adoption of electronic medical record (EMR) systems will lead to major health care savings, reduce medical errors, and improve health.[2] But there has been little progress toward attaining these benefits. The United States trails a number of other countries in the use of EMR systems.[3] Only

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15–20 percent of U.S. physicians' offices and 20–25 percent of hospitals have adopted such systems.[4] Barriers to adoption include high costs, lack of certification and standardization, concerns about privacy, and a disconnect between who pays for EMR systems and who profits from them.

In 2003 the RAND Health Information Technology (HIT) Project team began a study to (1) better understand the role and importance of EMRs in improving health care and (2) inform government actions that could maximize the benefits of EMRs and increase their use. This paper summarizes that study's results about benefits and costs. A companion paper by Roger Taylor and colleagues in this volume describes the policy implications of our findings.[5]

Study Data And Methods

Here we summarize the methodologies we used to estimate the current adoption of EMR systems and the potential savings, costs, and health and safety benefits. We use the word *potential* to mean "assuming that interconnected and interoperable EMR systems are adopted widely and used effectively." Thus, our estimates of potential savings are not predictions of what will happen but of what could happen with HIT and appropriate changes in health care. We also provide a more thorough explanation of our data and methods in an online supplement.[6]

■ **Estimation of current HIT adoption and related factors.** Our primary data source was the Healthcare Information and Management Systems Society (HIMSS)–Dorenfest survey, which represents a broad canvassing of acute care hospitals, chronic care facilities, and ambulatory practices on their adoption and plans to adopt various HIT components.[7] We included in the adoption category the provider organizations that had contracted for but not yet installed an EMR system. To examine the factors related to differences in adoption, we merged additional data about the providers and then performed probit regression analysis. Our lower-bound estimate of HIT adoption assumed an integrated system that had an EMR, clinical decision support, and a central data repository—from the same vendor to ensure interoperability. We adjusted the estimates according to the known underrepresentation of smaller providers in this survey.

■ **Estimation of potential HIT efficiency savings.** We conducted a broad literature survey to capture evidence of HIT effects. The survey was primarily from peer-reviewed literature, but it included some information from non-peer-reviewed literature. Expert opinion was used to validate some of this evidence. In some cases, such as savings from transcription, reported results covered a broad range, and we used these ranges to estimate a possible distribution of savings. For effects supported by only a few useful articles, we superimposed the same degree of dispersion.[8]

In general, the currently useful evidence is not robust enough to make strong predictions, and we describe our results only as "potential." However, we do not believe that they represent the "best-case scenario," for three reasons: (1) We have not included many other effects (such as transaction savings, reductions in malpractice costs, and research and public health savings), and there may be more sizable savings from HIT-motivated health care changes that we are not able to predict: Modern EMR systems may be more effective than the legacy systems reporting evidence; (2) we have not included certain domains such as long-term care; and (3) we do not report possible values above the mean.

The results are not worst-case, either. We chose to interpret reported evidence of negative or no effect of HIT as likely being attributable to ineffective or not-yet-effective implementation. Characteristics of the provider organizations that reported the savings were used to scale the results for cases of broader EMR adoption. Assuming ten- and fifteen-year HIT adoption periods, we used Monte Carlo simulation to generate the range of savings that might be achieved at different points in the future, assuming that at least part of the reported benefit could be achieved by each newly adopting provider organization. We generally report the mean value of the potential savings.

■ **Estimating the costs of adoption.** For hospital adoption, we built a model of EMR system costs based on the literature and on information supplied directly to us from hospitals. We included one-time implementation costs, such as provider downtime and hardware costs, and ongoing maintenance costs. Our data allowed us to relate hospital adoption costs to size and operating expenses of hospitals and generally represented the adoption of newer, more complete EMR systems, including clinical decision support and computerized physician order entry (CPOE).

For the acquisition and setup costs of ambulatory systems, we used a publicly available database of commercial systems and excluded products that did not have most of the desirable features of an ambulatory EMR system.[9] To these costs, we added a productivity loss of 15 percent for three months, $3,000 per physician for additional hardware costs, and yearly maintenance costs equal to 20 percent of the one-time cost. Starting with current adoption rates of EMR systems, we simulated ten- and fifteen-year adoption periods, in which physicians' choices were approximated by random selections from the ambulatory EMR list, and hospitals adopted systems and paid costs consistent with our data related to size and operating expenses. From these simulations, we report the mean and show sensitivity to assumptions about the initial adoption rate and assumed adoption period.

■ **Estimating potential safety benefits.** Using medication error and adverse drug event rates from the literature, as well as limited evidence of CPOE's reduction of medication error rates, we extrapolated these potential safety benefits to a future with broad national adoption of CPOE.[10] Several databases—the Medical Expenditure Panel Survey (MEPS) 1999 Inpatient File (which tracks a large number of patients and their interaction with health care), the American Hospital Association (AHA) 2000 Hospital Survey, and the Healthcare Cost and Utilization Project (HCUP) 2000 National Inpatient Sample—were used to distribute the errors across hospitals and patients.[11] A spreadsheet model was then used to calculate the potential adverse drug events and costs avoided as a function of hospital size and patient age. For ambulatory care, our model used error and adverse drug event reductions reported in the literature for ambulatory CPOE. Using the 2000 National Ambulatory Medical Care Survey (NAMCS) database on office visits, we extrapolated the effects to full national adoption and show the likely distribution of possible savings and adverse drug events avoided as a function of practice characteristics and size.[12]

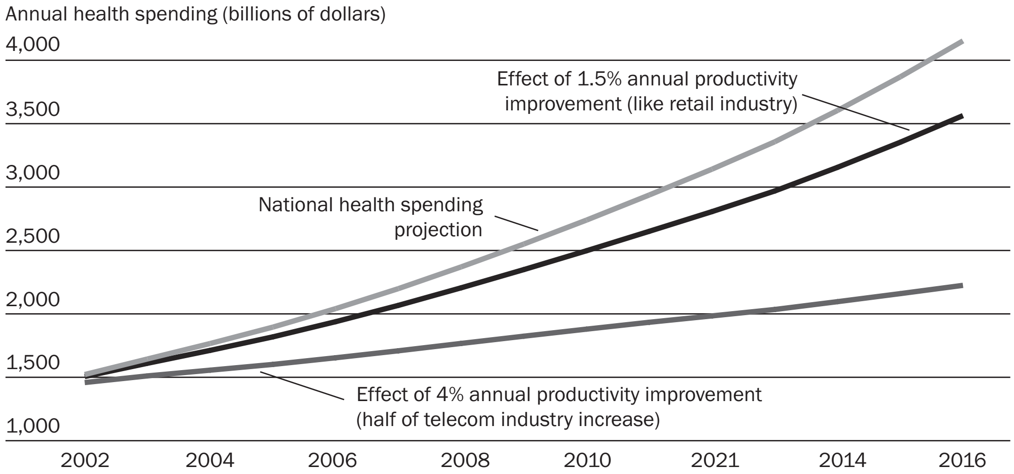
■ **Estimating other potential health benefits.** We considered two kinds of interventions—disease prevention and chronic disease management—that would exploit key features of HIT. To estimate the potential effects enabled by EMR systems, we used several years of the MEPS data to develop a representative national patient sample, with its associated information on health care use, diagnosis, and self-reported health status. We applied recommended disease management and prevention interventions to appropriate members of that population. Then, given the literature and clinicians' opinions regarding the effect of the interventions, we calculated the differences in cost, use, health status, and other outcomes measured in MEPS, such as sick days in bed and workdays lost. We evaluated a representative sample of near-term (some effects within one or two years of intervention) prevention, near-term disease management, and long-term (most effects five or more years into the future) chronic disease management and prevention interventions. We report the health benefits and savings associated with various degrees of patient participation in these programs, as might be obtained with HIT support.

What Can We Learn From Other Industries?

We examined a range of industries to understand IT's effects on productivity and related enabling factors. During the 1990s, many industries—most notably, telecommunications, securities trading, and retail and general merchandising—invested heavily in IT.[13] Consumers saw the fruits of this investment in bar-coded retail checkouts, automated teller machines, consumer reservation systems, and online shopping and brokerages. During the late 1990s and continuing into this century, these industries recorded 6–8 percent annual productivity growth, of which at least one-third to one-fourth annually can be attributed to IT. But dramatic productivity improvements did not follow automatically from IT investments. For example, the hotel industry, which underused its IT investment in the late 1990s, did not see sizable productivity increases.

What if health care could produce productivity gains similar to those in telecommunications, retail, or wholesale? Exhibit 1 superimposes a range of productivity improvements on a plot of estimated growth in national health care spending from 2002 to 2016. The smaller improvement (1.5 percent per year) is similar to the productivity gains in retail/wholesale attributed to IT; the upper end (4 percent per year) is half the IT-enabled gains in telecommunications. Either level of productivity improvement could greatly reduce national health care spending. The lower improvement implies an average annual spending decrease of $346 billion, and the upper end, $813 billion.

EXHIBIT 1
Possible Improved Productivity Effects Of Health Information Technology (IT) On Future National Health Spending, 2002–2016



SOURCE: Authors' analysis based on data from Centers for Medicare and Medicaid Services, "National Health Accounts," 17 March 2005, www.cms.hhs.gov/statistics/nhe (26 May 2005).

However, we believe that when thought leaders discuss transforming health care with HIT, they are talking about the kinds of benefits seen in the telecom and securities industries: gains of 8 percent or more per year, year after year. These sectors illustrate that it can be done. But our analysis found that the ingredients needed to achieve this growth (strong competition on quality and cost, substantial investments in EMR systems, an enhanced infrastructure that can accommodate increased future demand or reduce costs without increasing labor, a strong champion firm or institution that drives change, and integrated systems) are mostly absent in today's health care industry. Achieving savings at the upper end of the range will be limited by the degree of transformation that accompanies HIT.

What Are The Potential Efficiency Savings From HIT?

There are few comprehensive estimates of savings from HIT at the national level.[14] Using a simulation model of HIT adoption and scaling literature-based HIT effects, we built a national estimate.[15]

At 90 percent adoption, we estimate that the potential HIT-enabled efficiency savings for both inpatient and outpatient care could average more than $77 billion per year (an average annual savings of $42 billion during the adoption period). Exhibit 2 shows the most important sources of the savings we estimated: The largest come from reducing hospital lengths-of-stay, nurses' administrative time, drug usage in hospitals, and drug and radiology usage in the outpatient setting.[16]

These potential savings, while quite large, are considerably lower than the annual IT-enabled productivity gains just described in other industries. Although achieving these more limited savings would not require radical changes in the

EXHIBIT 2
Potential Efficiency Savings With Adoption Of Electronic Medical Record (EMR) Systems

Savings category	Mean yearly savings ($ billions)	Cumulative savings by year 15 ($ billions)	Annual savings ($ billions)		
			Year 5	Year 10	Year 15 (90% adoption)[a]
Outpatient					
Transcription	0.9	13.4	0.4	1.2	1.7
Chart pulls	0.8	11.9	0.4	1.1	1.5
Lab test	1.1	15.9	0.5	1.5	2.0
Drug usage	6.2	92.3	3.0	8.6	11.0
Radiology	1.7	25.6	0.8	2.4	3.3
Total outpatient savings	10.6	159.0	5.2	14.8	20.4
Inpatient					
Nursing time	7.1	106.4	3.4	10.0	13.7
Lab test	1.6	23.4	0.8	2.2	2.6
Drug usage	2.0	29.3	1.0	2.8	3.5
Length-of-stay	19.3	289.6	10.1	27.6	34.7
Medical records	1.3	19.9	0.7	1.9	2.4
Total inpatient savings	31.2	468.5	16.1	44.5	57.1
Total	41.8	627.5	21.3	59.2	77.4

SOURCE: F. Girosi et al., *Extrapolating Evidence of Health Information Technology Savings and Costs,* Pub. no. MG-410 (Santa Monica, Calif.: RAND, 2005), sec. 4.2.6.

NOTE: These savings have not been discounted, nor do they take into account inflation in health care expenditures.

[a] The potential savings at 100 percent adoption would obviously be larger, but the uncertainty about when and whether that level can be reached is very high. We have assumed a fifteen-year adoption period, based on A. Bower, *The Diffusion and Value of Healthcare Information Technology,* Pub. no. MG-272-HLTH (Santa Monica, Calif.: RAND, 2005).

health care delivery system, it would require process changes and, in some cases, resource reduction. Also, the potential savings would not be realized immediately. They would require widespread adoption of HIT by providers, and most of the savings would start only after a successful implementation period and associated process changes or resource reductions had taken place. Also, the efficiencies could be used to improve health care quality rather than to reduce costs.

Although the savings would accrue to different stakeholders, in the long run they should accrue to payers. If we allocate the savings using the current level of spending from the National Health Accounts (kept by the Centers for Medicare and Medicaid Services), Medicare would receive about $23 billion of the potential savings per year, and private payers would receive $31 billion per year. Thus, both have a strong incentive to encourage the adoption of EMR systems. Providers face limited incentives to purchase EMRs because their investment typically translates into revenue losses for them and health care spending savings for payers.

What Are The Potential Safety Benefits Of EMR Systems?

Studies showing improved patient safety from EMR use in hospital and ambulatory care largely focus on alerts, reminders, and other components of CPOE.[17] CPOE makes information available to physicians at the time they enter an order—for example, warning about potential interactions with a patient's other drugs.

Once the order has been entered, the system can track the steps involved in executing the order, providing an additional mechanism for identifying and eliminating errors. In the longer term, CPOE provides the information needed to redesign the order-execution process so that errors become even harder to make. To provide these benefits, CPOE must be an integrated component of a more comprehensive health care information system that is designed and used well.[18] We addressed the safety benefits of CPOE by using models to extrapolate existing evidence to the national level and estimated separately the potential to reduce adverse drug events in inpatient and outpatient settings.

■ **Reducing adverse drug events in the inpatient setting.** The measures—adverse drug events avoided, and bed days and dollars saved—all follow the same pattern, which suggests that CPOE could eliminate 200,000 adverse drug events and save about $1 billion per year if installed in all hospitals. But the bulk of the savings could be realized by installation in hospitals with more than 100 beds. About two-thirds of the CPOE benefits are attributable to adverse drug events avoided for patients age sixty-five and older. Although this group comprises only 13 percent of the population, it accounts for a much larger fraction of hospital bed days, and its members are more susceptible than others to adverse drug events.

■ **Reducing adverse drug events in the ambulatory setting.** Medication errors and adverse drug events in ambulatory settings have been studied much less than in hospitals. The available data suggest that roughly eight million outpatient events occur each year, of which one-third to one-half are preventable. About two-thirds of preventable adverse drug events might be avoided through widespread use of ambulatory CPOE. Each avoided event saves $1,000–$2,000 because of avoided office visits, hospitalizations, and other care.[19] Scaling these numbers to the national level, we estimate that two million such events could be avoided, generating annual savings of $3.5 billion.[20] Avoided adverse drug events in patients age sixty-five and older account for 40 percent of the savings.

Our models also show that to obtain the benefits of ambulatory CPOE, one cannot ignore small providers. About 37 percent of the potential savings and error avoidance would come from solo practitioners. Recent estimates suggest that CPOE systems can be cost-effective even for small offices.[21]

What Are The Potential Health Benefits Of EMR Systems?

Beyond safety, the literature provides little evidence about EMR systems' effects on health. We must, therefore, hypothesize about both mechanisms and magnitudes of effects. We considered two kinds of interventions intended to keep people healthy (or healthier): disease prevention measures and chronic disease management.

These interventions are key to understanding HIT's potential. First, they would exploit important features and capabilities of EMR systems: communication, coordination, measurement, and decision support. Second, they are potentially high-leverage areas for improving health care. Physicians deliver recommended care only about half of the time, and care for patients with chronic illnesses absorbs more than 75 percent of the nation's health care dollars.[22] Third, evidence from regional health information network (RHIN) demonstrations suggests that these are key applications of HIT.[23]

■ **Using HIT for short-term preventive care.** EMR systems can integrate evidence-based recommendations for preventive services (such as screening exams) with patient data (such as age, sex, and family history) to identify patients needing specific services. The system can remind providers to offer the service during routine visits and remind patients to schedule care. Reminders to patients generated by EMR systems have been shown to increase patients' compliance with preventive care recommendations when the reminders are merely interjected into traditional outpatient workflows.[24] More systemic adaptation—for example, by Kaiser Permanente and Group Health Cooperative—appears to achieve greater compliance.[25]

We estimated the effects of influenza and pneumococcal vaccination and screening for breast cancer, cervical cancer, and colorectal cancer, using data about the current compliance rate, the recommended population, and the costs.[26] We assumed that the services are rendered to 100 percent of people not currently complying with the U.S. Preventive Services Task Force recommendation.[27] We also applied the health benefit estimates from the literature to this population (Exhibit 3). We conclude that all of these measures, except for pneumococcal vaccination, will increase health care use and spending modestly. But the costs are not large, and the health benefits are significant: for example, 13,000 life-years gained from cervical cancer screening at a cost of $0.1–$0.4 billion.

■ **Using HIT for near-term chronic disease management.** The U.S. burden of chronic disease is extremely high and growing. In one study, fifteen chronic conditions accounted for more than half of the growth in health care spending between 1987 and 2000, and just five diseases accounted for 31 percent of the increase.[28] Disease management programs identify people with a potential or active chronic disease; target services to them based on their level of risk (sicker patients need more-tailored, more-intensive interventions, including case management); monitor their condition; attempt to modify their behavior; and adjust their therapy to prolong life, minimize complications, and reduce the need for costly acute care interventions.

EMR systems can be instrumental throughout the disease management process. Predictive-modeling algorithms can identify patients in need of services. EMR systems can track the frequency of preventive services and remind physicians to offer needed tests during patients' visits. Condition-specific encounter templates implemented in an EMR system can ensure consistent recording of disease-specific clinical results, leading to better clinical decisions and outcomes. Connection to national disease registries allows practices to compare their performance with that of others. Electronic messaging offers a low-cost, efficient means of distributing reminders to patients and responding to patients' inquiries. Web-based

EXHIBIT 3
Summary Of Estimated Results For Increasing Five Preventive Services

Program description	Influenza vaccination	Pneumococcal vaccination	Screening for breast cancer	Screening for cervical cancer	Screening for colorectal cancer
Target population (age)	65 and older	65 and older	Women 40 and older	Women 18–64	50 and older
Frequency	1 per year	1 per lifetime	0.5–1 per year	0.33–1 per year	0.1–0.2. per year
Population not currently compliant	13.2 million	17.4 million backlog; 2.1 million new per year	18.9 million	13.0 million	52.0 million
Financial impacts					
Program cost (with 100% compliance)	\$134–\$327 million per year	\$90 million per year	\$1–\$3 billion per year	\$152–\$456 million per year	\$1.7–\$7.2 billion per year
Financial benefits	\$32–\$72 million per year	\$500–\$1,000 million per year	\$0–\$643 million per year	\$52–\$160 million per year	\$1.16–\$1.77 billion per year
Health benefits					
Reduced workdays missed	180,000–325,000 per year	100,000–200,000 per year	–[a]	–[a]	–[a]
Reduced bed days	1.0–1.8 million per year	1.5–3.0 million per year	–[a]	–[a]	–[a]
Deaths avoided	5,200–11,700 per year	15,000–27,000 per year	2,200–6,600 per year	533 per year	17,000–38,000 per year
Life-years gained	–[a]	–[a]	–[a]	13,000 per year	138,000 per year

SOURCE: J. Bigelow et al., *Analysis of Healthcare Interventions That Change Patient Trajectories* (Santa Monica, Calif.: RAND, 2005), 74, Table 5.1.
NOTE: Assumes 100 percent participation.
[a] Not applicable.

patient education can increase the patient's knowledge of a disease and compliance with protocols.

For higher-risk patients, case management systems help coordinate workflows, including communication between multiple specialists and patients. In what may prove to be a transformative innovation, remote monitoring systems can transmit patients' vital signs and other biodata directly from their homes to their providers, allowing nurse case managers to respond quickly to incipient problems. Health information exchange via RHINs or personal health records promises great benefits for patients with multiple chronic illnesses, who receive care from multiple providers in many settings.

We examined disease management programs for four conditions: asthma, congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD), and diabetes (Exhibit 4) and estimated the effects of 100 percent participation of people eligible for each program.[29] By controlling acute care episodes, these programs greatly reduce hospital use at the cost of increased physician office visits and use

EXHIBIT 4
Potential Annual Effects Of Near-Term Disease Management Programs For Four Diseases: Asthma, Congestive Heart Failure (CHF), Chronic Obstructive Pulmonary Disease (COPD), And Diabetes

Effect	Change
Use (millions)	
Inpatient stays	−4
Hospital outpatient visits	−5
Physician office visits	33
Spending (billions)	
Hospital	−$30.1
Physician	−$0.0
Rx drugs	$1.9
Total	−$28.5
Outcomes (millions)	
Workdays lost	−28
School days lost	−13
Bed days	−245

SOURCE: J. Bigelow et al., *Analysis of Healthcare Interventions That Change Patient Trajectories* (Santa Monica, Calif.: RAND, 2005), 137, Table 6.17.
NOTE: Assumes 100 percent participation.

of prescription drugs. As shown, the programs could generate potential annual savings of tens of billions of dollars. Keeping people out of the hospital is, of course, a health benefit, but we can also expect important outcomes such as reductions in days lost from school and work and in days spent sick in bed.

Exhibit 4 also highlights an important disincentive for health care providers to offer these kinds of services or to invest in HIT to effectively perform them: The savings come out of provider receipts, as patients spend less time in acute care. This key misalignment of incentives is an important barrier to EMR adoption and, more generally, to health care transformation.

■ **Using HIT for long-term chronic disease prevention and management.** A program of EMR-enhanced prevention and disease management should change the incidence of chronic conditions and their complications. We considered cardiovascular diseases (hypertension, hyperlipidemia, coronary artery disease/acute myocardial infarction, CHF, cerebrovascular disease/stroke, and other heart diseases), diabetes and its complications (retinopathy, neuropathy, lower extremity/foot ulcers and amputations, kidney diseases, and heart diseases), COPD (emphysema and chronic bronchitis), and the cancers most strongly associated with smoking (cancers of the bronchus and lung, head and neck, and esophagus, and other respiratory and intrathoracic cancers). Using our MEPS-based model, we estimated how combinations of lifestyle changes and medications that reduced the incidence of these conditions would affect health care use, spending, and outcomes (Exhibit 5).

Savings are evenly divided between the populations under age sixty-five and those age sixty-five and older, despite the fact that the older population consti-

EXHIBIT 5
Estimated Long-Term Effects Of Prevention And Management Of Selected Chronic Conditions, By Age Group

	Under age 65	Age 65 and older	Total
Population (millions)	244.8	37.3	282.1
Utilization (millions)			
Inpatient stays	−3.2	−3.9	−7.1
Inpatient nights	−18.6	−30.6	−49.2
Hospital outpatient and ER visits	−8.8	−3.7	−12.5
Office visits	−63.2	−54.8	−118.0
Expenditures (billions)			
Hospital	−$31.8	−$39.9	−$71.7
Physician	−$11.7	−$11.4	−$23.1
Rx drugs	−$16.2	−$13.4	−$29.6
Other	−$4.4	−$9.9	−$14.3
Total change	−$64.1	−$74.6	−$138.7
Outcomes (millions)			
School days lost	−1.6	0.0	−1.6
Workdays lost	−39.4	−2.5	−41.9
Total bed days	−132.1	−125.1	−257.3
Deaths (thousands)	−119.4	−280.4	−399.8

SOURCE: J. Bigelow et al., *Analysis of Healthcare Interventions That Change Patient Trajectories* (Santa Monica, Calif.: RAND, 2005), 160, Table 7.6.
NOTE: Assumes 100 percent participation. ER is emergency room.

tutes only 13 percent of the total. Since chronic diseases are, by and large, diseases of the elderly, a large fraction of the long-term savings attributable to prevention and disease management would accrue to Medicare. Yet, to realize these benefits, people would have to begin participating in these programs as relatively young adults.

We combined the effects of the reduced incidence attributable to long-term prevention and management and reduced acute care due to disease management. We estimated the potential combined savings, again assuming 100 percent participation, to be $147 billion per year.[30]

■ **Realizing the potential of these interventions.** Realizing the benefits of prevention and disease management requires that a substantial portion of providers and consumers participate. Since, on average, patients comply with medication regimens about half the time, it is plausible to assume that about half of the chronically ill would participate in disease management programs and, therefore, the health care system would reap about half of the estimated short-term benefits, assuming that EMR systems and community-based connectivity were operational.[31]

Patients comply with their physician's lifestyle recommendations only about 10 percent of the time.[32] We assumed that in a future with EMR-based reminders and decision support and patient-physician messaging, we could realize at least 20 percent of the long-term benefits shown in Exhibit 5. Under these assumptions, the net savings would be on the order of $40 billion per year. We varied the participation in disease management and prevention activities parametrically to show the potential beyond these estimates.[33]

What Will It Cost To Implement EMR Systems?

There are a few published estimates of the costs of widespread implementation of EMR systems in the United States. Samuel Wang and colleagues have provided a model for estimating the cost and return on investment for a physician office practice.[34] Jan Walker and colleagues have estimated the costs ($28 billion per year during a ten-year deployment, $16 billion per year thereafter) and net savings ($21.6–$77.8 billion per year, depending on the level of standardization) of a broadly adopted, interoperable EMR system.[35] The Patient Safety Institute estimated the initial cost of widespread connectivity of EMR systems (not of the EMR system itself) to be $2.5 billion.[36]

■ **Adoption costs for hospitals.** From cost data obtained from the literature, as well as from direct discussions with providers, we used simulation to estimate that the cumulative cost for 90 percent of hospitals to adopt an EMR system is $98 billion if 20 percent of hospitals now have such a system. Average yearly costs for the fifteen-year adoption period are $6.5 billion—about one-fifth of our earlier-described estimate of potential efficiency savings in hospitals.[37]

■ **Adoption costs for physicians.** Our models for adoption by physicians show that the cumulative costs to reach 90 percent adoption are $17.2 billion, almost equally split between one-time costs and maintenance costs. The average yearly cost during the adoption period is about $1.1 billion. In comparison, we estimated the potential annual average efficiency and safety benefits from ambulatory EMR systems during the same period to be $11 billion.

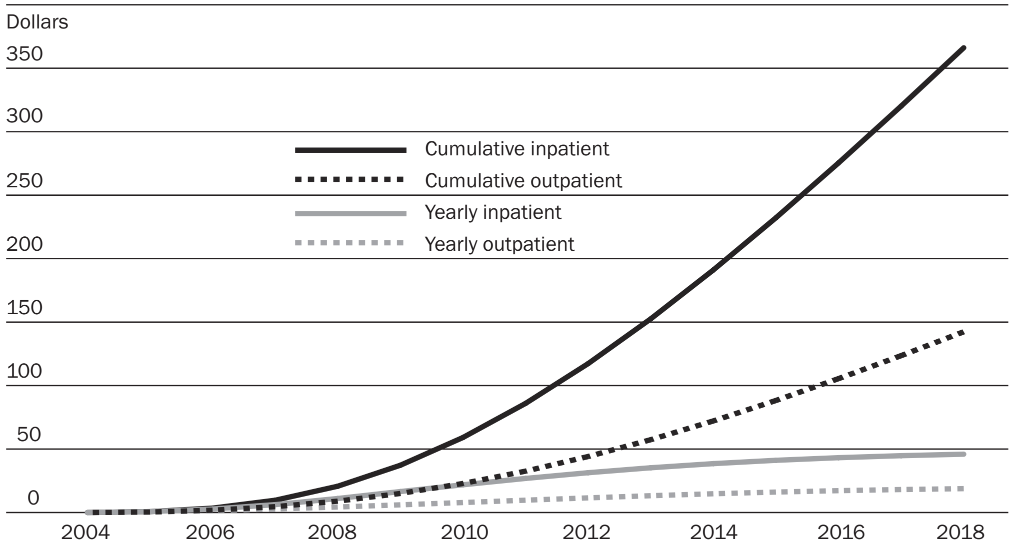
What Are The Potential Net Savings From EMR Systems?

Exhibit 6 plots the net cumulative and yearly potential savings (benefits over costs) from EMR systems in hospital and outpatient settings over time. Because we do not take credit for savings from providers already in the adoption process and because process changes and related benefits take time to develop, net savings are initially low and then rise steeply. Over fifteen years, the cumulative potential net efficiency and safety savings from hospital systems could be nearly $371 billion; potential cumulative savings from physician practice EMR systems could be $142 billion. This potential net financial benefit could double if the health savings produced by chronic disease prevention and management were included.

Barriers To Realizing The Health Benefits And Savings

Our analysis shows that moving the U.S. health care system quickly to broad adoption of standards-based EMR systems could dramatically reduce national health care spending at a cost far below the savings. Further, these potential savings would outweigh the costs relatively quickly during the adoption cycle. But

EXHIBIT 6
Net Potential Savings (Efficiency Benefits Over Adoption Costs) For Hospital And Physician Electronic Medical Record (EMR) Systems Adoption During A Fifteen-Year Adoption Period (2004–2018)



SOURCE: F. Girosi et al., *Extrapolating Evidence of Health Information Technology Savings and Costs* (Santa Monica, Calif.: RAND, 2005), sec. 4.2.3.

key barriers in the HIT market directly impede adoption and effective application of EMR systems; these include acquisition and implementation costs, slow and uncertain financial payoffs, and disruptive effects on practices.[38] In addition, providers must absorb the costs of EMR systems, but consumers and payers are the most likely to reap the savings. Also, even if EMR systems were widely adopted, the market might fail to develop interoperability and robust information exchange networks.

Given our analysis, we believe that there is substantial rationale for government policy to facilitate widespread diffusion of interoperable HIT. Actions now, in the early stages of adoption, would provide the most leverage. Taylor and colleagues discuss several alternatives for government action to remove barriers, correct market failures, and speed the realization of EMR system benefits.[39]

We have shown some of the potential benefits of HIT in the current health care system. However, broad adoption of EMR systems and connectivity are necessary but not sufficient steps toward real health care transformation. For example, adoption of EMR systems and valid comparative performance reporting would enable the development of value-based competition and quality improvement to drive transformation. HIT also should facilitate system integration for broader optimization, and comparative benchmarking should encourage development of market-leading examples of ways to better organize, pay for, and deliver care.

It is not known what changes should or will take place after widespread EMR system adoption—for example, increased consumer-directed care, new methods of organizing care delivery, and new approaches to financing. But it is increasingly clear that a lengthy, uneven adoption of nonstandardized, noninteroperable EMR systems will only delay the chance to move closer to a transformed health care system. The government and other payers have an important stake in not letting this happen. The time to act is now.

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NOTES

1. Organization for Economic Cooperation and Development, "Health at a Glance—OECD Indicators 2003," 17 September 2003, www.oecd.org/document/11/0,2340,en_2649_201185_16502667_1_1_1_1,00.html (20 July 2005).
2. The term *EMR systems* as used here includes the electronic medical record (EMR), containing current and historical patient information; clinical decision support (CDS), which provides reminders and best-practice guidance for treatment; and a central data repository (CDR), for the information. It also includes IT-enabled functions, such as computerized physician order entry (CPOE). We use the terms *health information technology* (HIT) and *EMR systems* interchangeably.
3. H. Taylor and R. Leitman, "European Physicians, Especially in Sweden, Netherlands, and Denmark, Lead U.S. in Use of Electronic Medical Records," *Harris Interactive* 2, no. 16 (8 August 2002), www.harris interactive.com/news/newsletters_healthcare.asp (20 July 2005).
4. K. Fonkych and R. Taylor, *The State and Pattern of Health Information Technology Adoption* (Santa Monica, Calif.: RAND, 2005).
5. R. Taylor et al., "Promoting Health Information Technology: Is There a Case for More-Aggressive Government Action?" *Health Affairs* 24, no. 5 (2005): 1234–1245.
6. The online supplement is available at content.healthaffairs.org/cgi/content/full/24/5/1103/DC1. The RAND Web site provides a comprehensive description of our methods, data, and models. See www.rand.org/publications/MG/MG408; MG409; and MG410.
7. HIMSS AnalyticsSM Database (formerly the Dorenfest IHDS+TM Database), second release, 2004.
8. See J.H. Bigelow, K. Fonkych, and F. Girosi, Technical Executive Summary in Support of "Can Electronic Medical Record Systems Transform Healthcare?" This online summary of our methods includes a table listing the most important literature findings and some measures of their quality; see Note 6.
9. See K.C. Voelker, "Electronic Medical Record (EMR) Comparisons by Physicians for Physicians," www.elmr-electronic-medical-records-emr.com (26 May 2005).
10. In R. Koppel et al., "Role of Computerized Physician Order Entry Systems in Facilitating Medication Errors," *Journal of the American Medical Association* 293, no. 10 (2005): 1197–1203, it was reported that the medication error rate actually increased because of computer- and interface-induced errors. We have assumed that this is not the case for a carefully redesigned medication process supported by modern CPOE.
11. See Agency for Healthcare Research and Quality (AHRQ), Medical Expenditure Panel Survey (MEPS) (multiple years of data and documentation), at www.meps.ahrq.gov (24 February 2005); American Hospital Association, AHA Annual Survey Database (a survey conducted since 1946; data must be purchased); and AHRQ, Nationwide Inpatient Sample (NIS), part of the Healthcare Cost and Utilization Project (HCUP), at www.hcup-us.ahrq.gov/nisoverview.jsp (24 February 2005).
12. National Center for Health Statistics, National Ambulatory Medical Care Survey (NAMCS)—multiple years of data and documentation available at www.cdc.gov/nchs/about/major/ahcd/ahcd1.htm (24 February 2005).
13. A. Bower, *The Diffusion and Value of Healthcare Information Technology,* Pub. no. MG-272-HLTH (Santa Monica, Calif.: RAND, 2005).
14. Recently, Jan Walker and colleagues quantified the value of full adoption of interoperable EMR systems. J. Walker et al., "The Value of Health Care Information Exchange and Interoperability," *Health Affairs,* 19 Janu-

ary 2005, content.healthaffairs.org/cgi/content/abstract/hlthaff.w5.10 (2 May 2005). Laurence Baker argued that these savings were overestimated. L.C. Baker, "Benefits of Interoperability: A Closer Look at the Estimates," *Health Affairs*, 19 January 2005, content.healthaffairs.org.cgi/content/abstract/hlthaff.w5.22 (26 May 2005).

15. F. Girosi et al., *Extrapolating Evidence of Health Information Technology Savings and Costs*, Pub. no. MG-410 (Santa Monica, Calif.: RAND, 2005).
16. Other factors and savings, mentioned in the Study Data and Methods section, could increase this total potential.
17. D.W. Bates et al., "Effect of Computerized Physician Order Entry and a Team Intervention on Prevention of Serious Medication Errors," *Journal of the American Medical Association* 280, no. 15 (1999): 1311–1316.
18. Koppel et al., "Role of Computerized Physician Order Entry Systems."
19. D. Johnston et al., *Patient Safety in the Physician's Office: Assessing the Value of Ambulatory CPOE*, April 2004, www.chcf.org/topics/view.cfm?itemID=101965 (26 May 2005).
20. J.H. Bigelow et al., *Analysis of Healthcare Interventions That Change Patient Trajectories* (Santa Monica, Calif.: RAND, 2005).
21. S.J. Wang et al., "A Cost-Benefit Analysis of Electronic Medical Records in Primary Care," *American Journal of Medicine* 114, no. 5 (2003): 397–403.
22. E.A. McGlynn et al., "The Quality of Health Care Delivered to Adults in the United States," *New England Journal of Medicine* 348, no. 26 (2003): 2635–2645; and Centers for Disease Control and Prevention, "Chronic Disease Overview," 15 October 2004, www.cdc.gov/nccdphp/overview.htm (26 May 2005).
23. See, for example, Institute for Healthcare Improvement, "My Shared Care Plan," www.ihi.org/IHI/topics/chronicconditions/diabetes/tools/my+shared+care+plan.htm (26 May 2005).
24. R.C. Burack and P.A. Gimotty, "Promoting Screening Mammography in Inner-City Settings: The Sustained Effectiveness of Computerized Reminders in a Randomized Controlled Trial," *Medical Care* 35, no. 9 (1997): 921–931.
25. B. Kaplan, "Evaluating Informatics Applications—Clinic Decision Support Systems Literature Review," *International Journal of Medical Informatics* 64, no. 1 (2001): 15–37.
26. Bigelow et al., *Analysis of Healthcare Interventions.*
27. We make the 100 percent assumption to provide an upper bound on the net costs and the health effects of their service. We do not suggest that 100 percent participation can be realized in practice.
28. K.E. Thorpe, C.S. Florence, and P. Joski, "Which Medical Conditions Account for the Rise in Health Care Spending?" *Health Affairs*, 25 August 2004, content.healthaffairs.org/cgi/content/abstract/hlthaff.w4.437 (26 May 2005).
29. Bigelow et al., *Analysis of Healthcare Interventions.*
30. This is less than the direct sum, because reduced incidence implies a lesser requirement for disease management.
31. R.B. Haynes, H.P. McDonald, and A.X. Garg, "Helping Patients Follow Prescribed Treatment: Clinical Applications," *Journal of the American Medical Association* 288, no. 22 (2002): 2880–2883.
32. D.L. Roter et al., "Effectiveness of Interventions to Improve Patient Compliance: A Meta-Analysis," *Medical Care* 36, no. 8 (1998): 1138–1161.
33. Bigelow et al., *Analysis of Healthcare Interventions.*
34. Wang et al., "A Cost-Benefit Analysis."
35. Walker et al., "The Value of Health Care Information Exchange."
36. Because there is not much experience with regional connectivity, cost estimates fall within a wide range. Our own scaling of data provided by the Santa Barbara Care Data Exchange indicates $2.4 billion for a non–standards-based system.
37. Girosi et al., *Extrapolating Evidence.*
38. R. Miller and I. Sim, "Physicians' Use of Electronic Medical Records: Barriers and Solutions," *Health Affairs* 23, no. 2 (2004): 116–126; and D.W. Bates et al., "A Proposal for Electronic Medical Records in U.S. Primary Care," *Journal of the American Medical Informatics Association* 10, no. 1 (2003): 1–10.
39. Taylor et al., "Promoting Health Information Technology."