A Cost-Benefit Analysis of Electronic Medical Records in Primary Care

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PURPOSE: Electronic medical record systems improve the quality of patient care and decrease medical errors, but their financial effects have not been as well documented. The purpose of this study was to estimate the net financial benefit or cost of implementing electronic medical record systems in primary care.

METHODS: We performed a cost-benefit study to analyze the financial effects of electronic medical record systems in ambulatory primary care settings from the perspective of the health care organization. Data were obtained from studies at our institution and from the published literature. The reference strategy for comparisons was the traditional paper-based medical record. The primary outcome measure was the net financial benefit or cost per primary care physician for a 5-year period.

RESULTS: The estimated net benefit from using an electronic medical record for a 5-year period was $86,400 per provider. Benefits accrue primarily from savings in drug expenditures, improved utilization of radiology tests, better capture of charges, and decreased billing errors. In one-way sensitivity analyses, the model was most sensitive to the proportion of patients whose care was capitated; the net benefit varied from a low of $8400 to a high of $140,100. A five-way sensitivity analysis with the most pessimistic and optimistic assumptions showed results ranging from a $2300 net cost to a $330,900 net benefit.

CONCLUSION: Implementation of an electronic medical record system in primary care can result in a positive financial return on investment to the health care organization. The magnitude of the return is sensitive to several key factors. **Am J Med. 2003;114:397–403.** ©2003 by Excerpta Medica Inc.

Electronic medical record systems have the potential to provide substantial benefits to physicians, clinic practices, and health care organizations. These systems can facilitate workflow and improve the quality of patient care and patient safety (1–4). Application of information technology has been identified by the Institute of Medicine as one of the principal ways to improve the quality of health care (5). Because of these benefits, the Leapfrog Group (6), a coalition of the nation's largest employers, is considering making use of outpatient electronic medical records its next standard for health care purchasing contracts.

In several other countries, use of electronic medical records ranges from 50% to 90% (7–9). In the United States, however, adoption of electronic medical records has been slow, and only about 7% of physicians use them (10). The cost of implementation is often cited as a barrier to their use. Although there are anecdotal reports suggesting that electronic medical records provide financial benefits by helping to reduce costs and improve revenues (11–26), few formal cost-benefit analyses have been done. Because their widespread adoption will depend in part on the ability to make a business case for financial benefits to the health care organization, we performed a formal cost-benefit analysis of implementing an electronic medical record system.

METHODS

Study Design

We performed a cost-benefit analysis of electronic medical record usage by primary care physicians in an ambulatory-care setting. The primary outcome measure was net financial costs or benefits per provider during a 5-year period. The model was framed from the perspective of the health care organization, and the reference strategy was the traditional paper-based medical record. All costs and benefits were converted to 2002 U.S. dollars (27).

Data on costs and benefits came from primary data collected from our electronic medical record system, from other published studies, and from expert opinion. When data were not available, expert opinion was obtained using a modified Delphi (28) technique to arrive at group consensus with a 7-member expert panel. Primary data were obtained from several internal medicine clinics using our internally developed electronic medical record

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Table 1. Costs of Electronic Medical Record System Used in the Model (Per Provider in 2002 U.S. Dollars)

	Base Case	Sensitivity Analysis (Range)	Reference
System costs			
Software (annual license)	$1600	$ 800–$3200	*
Implementation	$3400		†
Support and maintenance	$1500	$ 750–$3000	*
Hardware (3 computers + network)	$6600	$3300–$9900	*
Induced costs			
Temporary productivity loss	$11,200	$5500–$16,500	*

* Data from Partners HealthCare System, Boston, Massachusetts.
† B. Middleton, MD, MPH, MSc, MedicaLogic, written communication, 1998.

system (29) at Partners HealthCare System, an integrated delivery network formed in 1994 by the Brigham and Women's Hospital and the Massachusetts General Hospital.

We constructed a hypothetical primary care provider patient panel using average statistics from our institution. This panel included 2500 patients, 75% of whom were under 65 years of age; 17% of patients under 65 years old belonged to capitated plans. In sensitivity analyses, panel size was varied from 2000 to 3000 patients, and the proportion of patients under the age of 65 years whose cases were capitated was varied from 0% to 28.7%. According to industry estimates, health maintenance organization enrollment was 28.7% of the U.S. population in 2000 (30,31).

Costs

There are two categories of costs associated with electronic medical record implementation: system costs and induced costs (Table 1). System costs include the cost of the software and hardware, training, implementation, and ongoing maintenance and support. Induced costs are those involved in the transition from a paper to electronic system, such as the temporary decrease in provider productivity after implementation.

The software costs of $1600 per provider per year were based on the costs for our electronic medical record system at Partners HealthCare on an annual per-provider basis (as an "application service provider" model); this figure includes the costs of the design and development of the system, interfaces to other systems (e.g., registration, scheduling, laboratory), periodic upgrades, and costs of user accounts for support staff. Although these software costs were based on our internally developed system, they are consistent with license fees for commercially available systems, which have been estimated at between $2500 and $3500 per provider for the initial software purchase, plus annual maintenance and support fees of 12% to 18% (K. MacDonald, First Consulting Group, Lexington, Massachusetts, written communication, 1999). In sensitivity analyses, software costs were varied from 50% to 200% of the base value.

Implementation costs, estimated at $3400 per provider in the first year, included workflow process redesign, training, and historical paper chart abstracting. Ongoing annual maintenance and support costs were estimated to be $1500 per provider per year and included the costs of additional technical support staff and system/network administration.

Hardware costs were calculated to be $6600 per provider for three desktop computers, a printer, and network installation. We assumed that hardware would be replaced every 3 years.

Based on our experience, we modeled the induced costs of temporary loss of productivity using a decreasing stepwise approach, assuming an initial productivity loss of 20% in the first month, 10% in the second month, and 5% in the third month, with a subsequent return to baseline productivity levels. Using the average annual provider revenues for our model patient panel, this amounted to a revenue loss of $11,200 in the first year.

Benefits

Financial benefits included averted costs and increased revenues. We obtained figures for average annual expenditures for a primary care provider at our institution before the implementation of an electronic medical record, and applied to this the estimated percentage cost savings after implementation (Table 2). For each item, the estimated savings was varied across the indicated range of values in the sensitivity analysis. Benefits were divided into three categories: payer-independent benefits, benefits under capitated reimbursement, and benefits under fee-for-service reimbursement (32–40).

Payer-independent benefits, which apply to both capitated and fee-for-service patients, come from reductions in paper chart pulls and transcription. The average cost of a chart pull at our institution is approximately $5, accounting for the time and cost of medical records personnel to retrieve and then re-file a paper chart. After con-

Table 2. Annual Expenditures Per Provider (in 2002 U.S. Dollars) before Electronic Medical Record System Implementation and Expected Savings after Implementation

	Annual Expenditures before Implementation		Expected Savings after Implementation		
	Amount	Reference	Base Case Estimated Savings	Sensitivity Analysis (Range)	Reference
Payer independent					
Chart pulls	$5 (per chart)	*	600 charts	300–1200	*
Transcription	$9600	*	28%	20%–100%	*,32
Capitated patients					
Adverse drug events	$6500	33–36	34%	10%–70%	‡
Drug utilization	$109,000	†	15%	5%–25%	‡
Laboratory utilization	$27,600	†	8.8%	0–13%	37–39
Radiology utilization	$59,100	†	14%	5%–20%	‡
Fee-for-service patients					
Charge capture	$383,100	†	2% (increase)	1.5%–5%	25,40
Billing errors	$9700	†	78%	35%–95%	‡

* Primary data from the Partners HealthCare Electronic Medical Record System, Boston, Massachusetts.
† From the Department of Finance, Brigham and Women's Hospital, Partners HealthCare System.
‡ Expert panel consensus.

version to the electronic medical record system, chart pulls can be reduced by 600 charts (range, 300 to 1200) per year, based on the experience at one Partners HealthCare clinic. Transcription costs were reduced by 28% from partial elimination of dictation. In the sensitivity analysis, we varied the savings from 20% to 100% based on the experiences from other implementations (32).

Benefits under capitated reimbursement accrue to the practice and health care organization primarily from averted costs as a result of decreased utilization. Clinical decision support alerts and reminders can decrease utilization by reducing adverse drug events, offering alternatives to expensive medications, and reducing the use of laboratory and radiology tests (37–39,41–44). The expert panel consensus was that adverse drug events would be reduced by approximately 34% (range, 10% to 70%) as a result of basic medication decision support. We used standard financial benchmarks (33–35) to assign baseline costs for adverse drug events, which took into account additional outpatient visits, prescriptions, and admissions due to adverse drug events (36).

The expert panel estimated that alternative drug suggestion reminders would save 15% (range, 5% to 25%) of total drug costs per year, and this was applied to the baseline annual drug expenditures for the capitated patients in the panel. We estimated that laboratory charges could be reduced by 8.8% (range, 0 to 13%) using decision support (37–39). Based on information from other studies, the expert panel estimated that decision support for radiology ordering would achieve average savings of 14% (range, 5% to 20%).

Benefits under fee-for-service reimbursement included increased revenue and reduced losses. Computerizing the encounter form process can improve the capture of in-office procedures that were performed but not documented. Based on other studies (25,40), we projected a 2% improvement in billing capture (range, 1.5% to 5%). By using an electronic medical record system that either supplies or prompts for certain required fields, billing error losses can be reduced. The expert panel estimated that computerizing the encounter form could decrease these errors by 78% (range, 35% to 95%).

Statistical Analysis

We assumed that initial costs would be paid at the beginning of year 1 and that benefits would accrue at the end of each year (Table 3). We assumed a phased implementation, in which only basic electronic medical record features were available in the first years (e.g., medication-related decision support), and more advanced features were added in subsequent years (e.g., laboratory, radiology, and billing benefits). The primary outcome measure was net benefit or cost per primary care provider. A discount rate of 5% was used in the base case and varied from 0% to 10% in the sensitivity analysis.

One-way and two-way sensitivity analyses were performed using the ranges shown in Tables 1 and 2. Two-way sensitivity analyses were performed using all combinations of the five most important variables identified in the one-way sensitivity analysis, and with pairwise combinations of one benefit variable with each of the three primary cost variables (software, hardware, and support). A five-way sensitivity analysis was performed using the most and least favorable conditions for the five variables. The time horizon was also varied from 2 to 10 years.

Table 3. 5-Year Return on Investment Per Provider for Electronic Medical Record Implementation

	Initial Cost	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Costs							
Software license (annual)	$1600	$1600	$1600	$1600	$1600	$1600	
Implementation	$3400						
Support	$1500	$1500	$1500	$1500	$1500	$1500	
Hardware (refresh every 3 years)	$6600			$6600			
Productivity loss		$11,200					
Annual costs	$13,100	$14,300	$3100	$9700	$3100	$3100	$46,400
Present value of annual costs*	$13,100	$13,619	$2812	$8379	$2550	$2429	$42,900
Benefits							
Chart pull savings		$3000	$3000	$3000	$3000	$3000	
Transcription savings		$2700	$2700	$2700	$2700	$2700	
Prevention of adverse drug events			$2200	$2200	$2200	$2200	
Drug savings			$16,400	$16,400	$16,400	$16,400	
Laboratory savings					$2400	$2400	
Radiology savings					$8300	$8300	
Charge capture improvement					$7700	$7700	
Billing error decrease					$7600	$7600	
Annual benefits		$5700	$24,300	$24,300	$50,300	$50,300	$154,900
Present value of annual benefits*		$5429	$22,041	$20,991	$41,382	$39,411	$129,300
Net benefit (cost)	$(13,100)	$(8600)	$21,200	$14,600	$47,200	$47,200	$108,500
Present value of net benefit (cost)*	$(13,100)	$(8190)	$19,229	$12,612	$38,832	$36,982	$86,400

* Assumes a 5% discount rate.

To account for variations in functionality among different systems, we constructed two additional models in which only subsets of the full functionality were included (Table 4). The "light" electronic medical record system included savings from chart pulls and transcriptions only, whereas the "medium" system also included benefits from electronic prescribing (adverse drug event prevention and drug expenditure savings).

RESULTS

In the 5-year cost-benefit model (Table 3), the net benefit of implementing a full electronic medical record system was $86,400 per provider. Of this amount, savings in drug expenditures made up the largest proportion of the benefits (33% of the total). Of the remaining categories, almost half of the total savings came from decreased radiology utilization (17%), decreased billing errors (15%), and improvements in charge capture (15%).

Sensitivity Analyses

The model was most sensitive to variations in the proportion of patients in capitated health plans; the net benefit varied from $8400 to $140,100 (Figure). The model was least sensitive to variations in laboratory savings, in which the net benefit ranged from $82,500 to $88,300.

In two-way sensitivity analyses, the pair of input variables that yielded the least favorable outcome was a low proportion of capitated patients and a high discount rate;

Table 4. Effect of Electronic Medical Record Feature Set Variations on Net Benefits

Feature	Benefit	Light EMR	Medium EMR	Full EMR
Online patient charts	Chart pull savings	+	+	+
	Transcription savings	+	+	+
Electronic prescribing	Adverse drug event prevention		+	+
	Alternative drug suggestions		+	+
Laboratory order entry	Appropriate testing guidance			+
Radiology order entry	Appropriate testing guidance			+
Electronic charge capture	Increased billing capture			+
	Decreased billing errors			+
Net benefits (costs):		($18,200)	$44,600	$86,400

EMR = Electronic Medical Record.

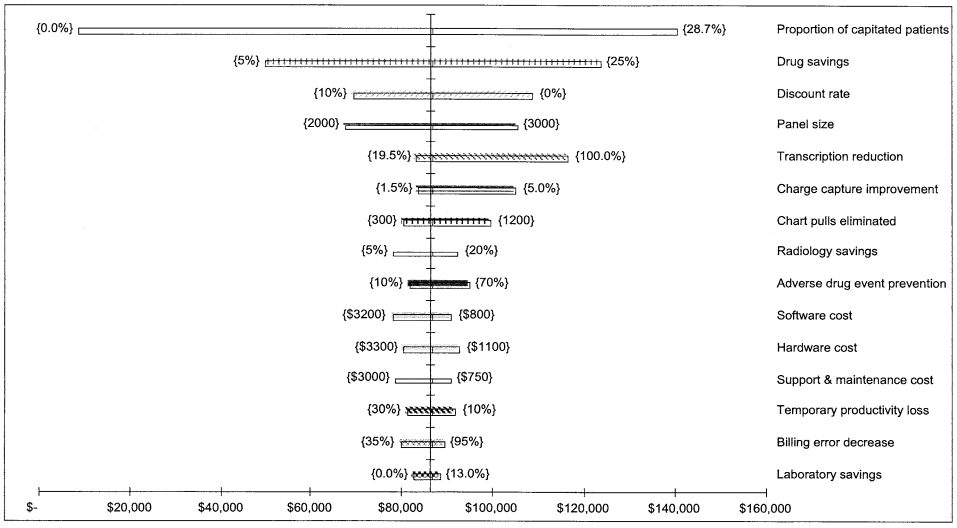

Figure. Tornado diagram showing the one-way sensitivity analysis of net 5-year benefits per provider. Each bar depicts the overall effect on net benefits as that input is varied across the indicated range of values, while other input variables are held constant. The vertical line indicates the base case.

the net benefit range was as low as $3000 per provider. The pair that had the most favorable outcome was a high proportion of capitated patients and greater savings from drug suggestions; the net benefit was as high as $202,200 per provider. For the two-way sensitivity analyses performed with the three primary cost variables, the pair of variables that yielded the least favorable outcome was a low proportion of capitated patients and a high annual software license (net cost of $200 per provider), and the pair with the most favorable outcome was a high proportion of capitated patients and a low hardware cost (net benefit of $146,200 per provider).

In the five-way sensitivity analyses, when the most pessimistic assumptions were made, the model showed a net cost of $2300 per provider. When the most optimistic assumptions were used, this analysis yielded a net benefit of $330,900 per provider.

When the time horizon was reduced to 2 years instead of 5 years, the net cost was $2100 per provider, and when the time horizon was lengthened to 10 years, the net benefit was $237,300 per provider.

For the "light" electronic medical record, in which the system is used only to reduce paper chart pulls and transcription costs, the net cost was $18,200 per provider (Table 4). For the "medium" electronic medical record, in which benefits from electronic prescribing are added, the net benefit was $44,600 per provider.

DISCUSSION

Our analysis indicates that the net financial return to a health care organization from using an ambulatory electronic medical record system is positive across a wide range of assumptions. The primary areas of benefit are from reductions in drug expenditures, improved utilization of radiology tests, improvements in charge capture, and decreased billing errors. Benefits increase as more features are used and as the time horizon is lengthened. In sensitivity analyses, the net return was positive except when the most pessimistic assumptions were used.

Savings to the health care organization are obtained under both capitated and fee-for-service reimbursement, but these savings depend on the reimbursement mix: the greater the proportion of capitated patients, the greater the total return. Among fee-for-service patients, a large portion of the savings from improved utilization may accrue to the payer instead of the provider organization. As a result, payers may be motivated to offer incentives to providers to use an electronic medical record to help control costs. In addition, although full capitation appears to be less prevalent now than several years ago, with the continued rise in health care expenditures, other types of risk-sharing arrangements are likely to become more common in the future (45), such as partial capitation, risk pools, and pharmacy withholds.

We used conservative estimates of cost savings from an electronic medical record. For example, one clinic was able to reduce chart pulls by 60% to 70% and its medical records staff by 50%, for an annual savings of about $4000 per provider (15). Others have identified even larger savings from the use of drug suggestions for certain classes of medications (46). In one outpatient clinic, display of formulary information at the time of ordering lowered drug costs by up to 26% (M. Overhage, MD, Regenstrief Institute, Indianapolis, Indiana, written communication, 2001). Savings due to prevention of adverse drug events

in the model did not include costs of malpractice settlements, injury to patients, or decreased quality of life for patients, so the actual savings may be higher. We may have also underestimated future cost savings because the model did not account for the annual growth rate of expenditures, which may outpace inflation in some categories, such as in drug and radiology costs.

Other potential areas of savings were not included in the model because adequate data were not available. These include savings in malpractice premium costs (40), storage and supply costs (47), generic drug substitutions (48), increased provider productivity (19,23,24), decreased staffing requirements (23,24,49), increased reimbursement from more accurate evaluation and management coding, and decreased claims denials from inadequate medical necessity documentation.

Although we accounted for a temporary (3-month) loss of productivity in our model, some providers may have a longer period of reduced productivity. To measure this effect, we performed a sensitivity analysis that included a prolonged 10% productivity loss for 12 months and found that there was still a 5-year net benefit of $57,500 per provider.

This study has several limitations. The cost-benefit model was based on primary data from our institution, estimates from published literature, and expert opinion. The effectiveness of some of these interventions has been demonstrated in the inpatient setting, but outpatient effectiveness is less certain. There may be other costs associated with implementation of an electronic medical record. For example, system integration costs may be greater at other institutions, depending on the number and complexity of system interfaces that are required. However, the majority of benefits in this model can be obtained even with a minimal number of interfaces (i.e., registration, scheduling, and transcription). In addition, there may be other unforeseen expenses associated with clinic workflow process redesign, reassignment of clinic staff, or productivity loss during unscheduled computer system or network outages.

In most cases, clinical decision support features will decrease utilization by suggesting more appropriate testing. This leads to cost savings among capitated patients, but it could also have an adverse effect on revenues from fee-for-service patients that may offset billing improvements. The overall net effect would depend on the mix of capitated versus fee-for-service patients.

Our cost-benefit model was geared toward primary care providers. Diagnostic test utilization may be higher for specialists, so there may be more opportunities for cost-saving interventions. On the other hand, specialists may be less likely to comply with computer reminders recommending alternative medications or tests.

This study was framed from the perspective of the health care organization to aid in making decisions about implementation of an electronic medical record. It may also be worthwhile to take the societal perspective, which would include benefits to payers and patients. For example, despite the trend away from global risk capitation, payers are moving toward patient cost-sharing approaches, such as differential co-payments, high deductible options, and health savings accounts. With these types of arrangements, patients may prefer to seek care with providers who use electronic medical records to control costs and improve quality of care.

Not all benefits of an electronic medical record are measurable in financial terms; other benefits include improved quality of care, reduced medical errors, and better access to information (2,3,50–54). A cost-benefit analysis is only one part of a complete analysis of the effects of implementing an electronic medical record system. At our institution, the electronic medical record is a key component of a strategic goal of clinical system integration to allow providers to move between sites in the network to deliver seamless care at the most appropriate primary, secondary, or tertiary care location.

Based on a combination of savings data from our institution and projections from other published studies, we conclude that implementing an ambulatory electronic medical record system can yield a positive return on investment to health care organizations. The magnitude and timing of this financial return varies, but is positive in the long run across a wide range of assumptions. Because of their quality and cost benefits, electronic medical records should be used in primary care, and incentives to accelerate their adoption should be considered at the national level.

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