Saving Lives, Saving Money:

The Imperative for Computerized Physician Order Entry in Massachusetts Hospitals

MASSACHUSETTS TECHNOLOGY COLLABORATIVE

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The Clinical Baseline and Financial Impact Study

February 2008

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Clinical Baseline and Financial Impact Study Partnership

The Massachusetts Technology Collaborative

The Massachusetts Technology Collaborative is the state's development agency for the innovation economy and clean energy. It works to stimulate economic activity by bringing together leaders from industry, academia, and government to advance technology-based solutions that lead to economic growth, improved care and reduced costs in the health care system, and a cleaner environment. *www.masstech.org*

The New England Healthcare Institute

The New England Healthcare Institute is an independent, not-for-profit organization dedicated to transforming health care for the benefit of patients and their families. In partnership with members from all across the health care system, NEHI conducts evidence-based research and stimulates policy change to improve the quality and the value of health care. Together with this unparalleled network of committed health care leaders, NEHI brings an objective, collaborative and fresh voice to health policy. *www.nehi.net*

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Table of Contents

Executive Summary

Clinical Baseline and Financial Impact Study

Medical innovations often bear the burden of a mixed reputation: on the one hand, they can be costly to acquire and implement; on the other hand they may save lives and save money over the long run. Assessing this double-edged duality—cost versus effectiveness—is critical to determining a medical technology's value and ultimately its adoption by the health care system.

That is exactly what the **Massachusetts Hospital CPOE Initiative** set out to do with the technology known as Computerized Physician Order Entry (CPOE), a computer application used by physicians to enter diagnostic and therapeutic orders for hospitalized patients. Coordinated by the Massachusetts Technology Collaborative (MTC) and the New England Healthcare Institute (NEHI), and in partnership with the Massachusetts Hospital Association, the Massachusetts Council of Community Hospitals and a broad spectrum of key stakeholders in the health care system, the Massachusetts Hospital CPOE Initiative was organized to speed the adoption of CPOE systems, which have been shown to improve the quality of care and to reduce costs.

Adverse drug events, or ADEs, have long been a significant cause of injury and death among hospital patients. Conservative estimates show that nationwide, adverse drug events result in more than 770,000 hospital injuries and deaths each year and cost up to $5.6 million per hospital, according to a report published in 2001 by the Agency for Healthcare Research and Quality (AHRQ)[1]. Just as distressing: many of those injuries and costs are *preventable*—yet they still occur at alarming rates. "Anywhere from 28 percent to 95 percent of ADEs can be prevented by reducing medication errors through computerized monitoring systems," the AHRQ report said.

Implementing CPOE is a daunting task because there are significant barriers impeding adoption, in particular the high capital costs involved and

the fact that adoption requires major, disruptive changes in the workflow of a hospital. While there have been studies in academic medical centers showing that CPOE can reduce costs and improve quality, there are no studies that indicate where and to what extent the quality improvements and savings would occur in the community hospital setting. For this reason, any Massachusetts hospital contemplating the considerable effort necessary to implement CPOE would face a high degree of uncertainty in terms of the quality and cost benefits it could reasonably expect, especially in regard to the financial impact of this substantial investment.

One in every ten patients admitted to these Massachusetts community hospitals suffered a preventable adverse drug event.

The Clinical Baseline and Financial Impact Study was conducted to address these uncertainties. MTC and NEHI were joined by a team headed by Dr. David Bates, Chief of the Division of General Medicine at the Brigham and Women's Hospital, PricewaterhouseCoopers, and other experts in the field in conducting an in depth analysis of six Massachusetts community hospitals. The study teams reviewed 4,200 charts to determine the baseline level of preventable adverse drug events, and the unnecessary use of expensive drug and laboratory tests, that could be improved by implementing CPOE.

The results are stunning.

The average baseline rate of preventable adverse drug events was 10.4 percent. ***This means that one in every ten patients admitted to these community hospitals suffered a preventable adverse drug event.*** **If CPOE with robust clinical decision support were implemented, these levels could be substantially reduced. Adding in the cost reductions from unnecessary drug and laboratory test use, the annual savings to each hospital could be $2.7 million. The onetime average total cost of a CPOE system is $2.1 million with an annual increment in operating costs of $435,000. The savings from a CPOE system could provide full payback to the average hospital in about 26 months.**

In addition to the financial impact on the hospitals, the annual benefit to payers, on average, could amount to $900,000 for each of the hospitals.

Based on the findings in these six representative hospitals, it is estimated that if all Massachusetts hospitals that don't have CPOE adopt it, the annual savings for the hospitals and payers could be approximately $170 million and 55,000 adverse drug events could be prevented every year.

The study recommends that all Massachusetts hospitals complete implementation of CPOE systems with clinical decision support by 2011; that the Hospital CPOE Initiative, working in collaboration with all stakeholders, develop performance metrics to assure that CPOE systems are being operated effectively, and that payers adopt robust incentives to facilitate attainment of this goal. In addition, the state should continue to support the search for and evaluation of valuable new technologies that both save lives and save money.

Taken together, the clinical and financial benefits of a fully implemented CPOE system offer a win-win opportunity for patients, hospitals, and payers across the Commonwealth of Massachusetts. Eliminating preventable adverse drug events, improving patient care and reducing medical costs are fundamental tenets of sound health care policy. CPOE now has a strong reputation based on evidence, and the Commonwealth must seize this chance to save lives and save money and to become a national leader in patient safety along the way.

Chapter One

Introduction to the Clinical Baseline and Financial Impact Study

"There are advanced technologies that can dramatically lower health care costs and improve quality. The technologies are proven. The associated benefits are known. But there are barriers in the system which impede their implementation. We can change that."

Mitchell Adams, Massachusetts Technology Collaborative, and
Wendy Everett, New England Healthcare Institute

The Value of Innovative Technologies

The Fast Adoption of Significant Technologies (*FAST*) Initiative is a program dedicated to the process of speeding the adoption of innovative health care technologies that improve the quality of care and reduce its costs at the same time. Pioneered jointly in 2003 by the Massachusetts Technology Collaborative and the New England Healthcare Institute, the Initiative, working in collaboration with all key stakeholders in the health care system, identifies technologies that:

- Are shown to be effective in improving quality and reducing cost.
- Will have a high impact on the health care system.
- Have a low level of adoption.
- Have barriers that can be addressed effectively.

Each year, *FAST* identifies a slate of promising technologies, analyzes their value, and then develops a collaborative action plan to speed their adoption. This process began five years ago with a report published by MTC and NEHI titled *Advanced Technologies to Lower Health Care Costs and Improve Quality*. This seminal report identified seven technologies that, if adopted state-wide, could dramatically lower health care costs and improve the quality of patient care in the Commonwealth. The technologies included: inpatient Computerized Physician Order Entry (CPOE); electronic health records in regional, coordinated systems; remote monitoring in Intensive Care Units (Tele-ICUs); disease management applications; e-prescribing; and others.

The first innovative technology to go through the *FAST* process was inpatient CPOE, a program that has matured into the Massachusetts Hospital CPOE Initiative. The CPOE Initiative has developed to the point where all key stakeholders

are involved and hope to achieve a goal of full implementation of CPOE in 100 percent of Massachusetts hospitals by 2011. *FAST* initiated two additional projects in 2006 and 2007, one on Tele-ICUs in Massachusetts and another on Remote Physiologic Monitoring (RPM) for heart failure patients. Each of these technologies offers the potential of substantially improving patient safety and significantly reducing costs in the health care system.

FAST's efforts to make the state's health care system more efficient are critically important to the Commonwealth, whose health care industry employed 462,000 people and generated more than $44 billion in expenditures in 2004. The *FAST* Initiative's support of processes that identify and speed the adoption of high value, innovative technologies that save lives and save money makes the state's health care system more efficient and improves our patient care.

The Massachusetts Hospital CPOE Initiative

The 1999 Institute of Medicine report, *To Err is Human*, estimated that there are between 50,000 and 100,000 deaths in the U.S. each year due to preventable medical errors—many of which could be averted if a computer system were in place to provide information and guidance.[1] There are 215,000 patients who are harmed each year by avoidable medication errors—7,000 of whom die unnecessarily. It is widely understood that computer systems can save these lives and reduce the estimated $2 billion in national costs that are associated with these medication mistakes.

CPOE is a computer application used by physicians to enter patient care orders; the system assures accuracy and delivers clinical decision support so that the most common errors are avoided. Clinical decision support provides physicians with knowledge of potential medication errors and recent test results, and prompts for standard screening tests. Implementation of these systems has demonstrated significant cost savings and improved quality in health care. However, to date only a small percentage of hospitals across the country have implemented it.

The Massachusetts Hospital CPOE Initiative (the Initiative) is a ground-breaking and dynamic undertaking that was created to both improve care and reduce the costs of hospitalizations for all patients throughout the Commonwealth. When the Initiative began in 2004, very few of the 73 Massachusetts hospitals had effective, computerized clinical decision support systems that would help physicians and nurses avoid costly medical errors when ordering medications and clinical diagnostic tests.

Coordinated by MTC and NEHI, the Massachusetts Hospital CPOE Initiative brought critical decision-makers together to accelerate the adoption of this innovative technology. The Massachusetts Hospital Association and the Massachusetts Council of Community Hospitals, senior hospital executives, and the leadership of health plans, public payers, health care quality organizations and the business community have worked together to give the Initiative real momentum. Collaboration has been critical to the success of this statewide effort to ***save lives and save money***.

Background

As described above, the benefits of CPOE for Massachusetts first were published in 2003 in *Advanced Technologies to Lower Health Care Costs and Improve Quality*. Of the seven technologies that were featured, inpatient CPOE demonstrated the greatest potential for improvement in patient care and financial benefit. A second report published in 2004 by MTC and NEHI, *Treatment Plan: High Tech Transfusion*, demonstrated that substantial savings to the health care system in Massachusetts could be achieved by the widespread adoption of robust inpatient CPOE systems. Published research studies have demonstrated that CPOE systems save lives by reducing adverse drug events.

This technology can also save hospital costs by improving resource utilization and lowering the length of hospital stays.

However, hospitals have been slow to adopt this innovation in spite of the documented benefits of CPOE and the imperative to improve patient safety. The primary barriers are the perception that the overall costs of the system (capital, installation, training, and on-going operating costs) are high and that it is difficult to implement a technology that changes physician and staff workflow in such a significant way. Other barriers include the lack of minimum standards for CPOE applications or for interoperability with other systems and the paucity of measures to quantify the effective use and operation of CPOE systems.

The Massachusetts Hospital CPOE Initiative Process

The goal of the Initiative is to complete implementation of CPOE systems with sophisticated clinical decision support programs in all Massachusetts acute care hospitals within four years. For the Initiative to go forward there are several key things that need to be accomplished: an assessment of the "readiness" of all hospitals in Massachusetts to adopt CPOE; the development of CPOE standards to ensure that the computer systems contain the necessary capabilities; and a fair estimate of what it would cost individual hospitals to adopt CPOE. The Initiative engaged the First Consulting Group (FCG) to conduct this initial work.

Readiness Assessment: FCG designed an online survey to send to all hospitals in Massachusetts without CPOE systems. Of the 73 hospitals in Massachusetts, thirteen had CPOE systems in 2005, leaving 60 hospitals to be surveyed. The survey was endorsed by the Massachusetts Hospital Association and the Massachusetts Council of Community Hospitals and covered the general state of information technology (IT) management and infrastructure in the hospital, the clinical IT experience of the physicians and nurses, and the organizational structure, processes, and leadership abilities of each institution. With this "readiness" assessment, the Initiative was able to determine which hospitals were ready to implement CPOE and should be the first to be invited to join the Initiative.

Standards for CPOE: The second key element to the Initiative was the development of CPOE standards. A group of expert advisors that included Chief Information Officers, Chief Medical Information Officers and physicians who had implemented CPOE systems developed a set of standards that focused on the system requirements for physician acceptance, ease of implementation and determination of value. The advisors adapted standards that had been developed by the Health and Human Services staff for the Health Insurance Portability and Accountability Act (HIPAA) and the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) to create a set of final CPOE standards to guide hospitals in their selection of CPOE technology vendors. These standards identified the features of a CPOE system that are necessary to meet the order entry, data management, and HIPAA or JCAHO regulatory requirements for any hospital in Massachusetts.

Of the 73 hospitals in Massachusetts, only 13 had CPOE systems in 2005, leaving 60 hospitals without this valuable technology.

Cost Analyses: FCG developed a cost model to assist Massachusetts hospitals in projecting their CPOE acquisition and implementation costs. The hospitals used this model to categorize their budget projections into capital, one-time operating and ongoing operating expenses. The budgets that were subsequently developed also enabled FCG to identify capital and operating line item costs that were common across all sites.

Funding of the Initiative: Seed funding for the Initiative was essential to conduct a readiness assessment of Massachusetts hospitals; set standards for CPOE systems to ensure that the available systems had the necessary capabilities to realize the potential of CPOE; estimate an individual hospital's cost of implementing CPOE; and conduct the baseline study of current clinical and financial performance in a sample of Massachusetts' community hospitals.

State appropriations, supplemented by funding from MTC and NEHI, have supported the cost of these activities during the past three years. The Initiative has been successful because it has had adequate personnel to support the collaboration and to manage the project on a day-to-day basis.

The Need for Baseline Clinical and Financial Data

Because CPOE adoption requires system-wide change in the way that work is done in the hospital, implementation can be very disruptive. In order to be confident that the clinical and financial improvements that come from implementing CPOE warrant the level of effort necessary for success, the Initiative commissioned two efforts:

- A baseline study of the level of medication errors and the expenses associated with the use of unnecessary medications and laboratory tests in six Massachusetts community hospitals, and
- Financial analyses of the impact of CPOE implementation on the hospitals and their payers.

This was important because most of the prior benefit work had been done in academic medical centers, while the majority of the hospitals in the state are community hospitals.

The results of these studies are detailed in Chapters Two and Three of this report and confirm the critical importance of the Massachusetts Hospital CPOE Initiative to saving lives and saving money in the Commonwealth.

Chapter Two

Preventable Medical Errors: The Clinical Baseline Study

On average, a total of 10.4 out of every 100 patients admitted to the six Massachusetts hospital study sites suffered from a *preventable* adverse drug event.

Introduction

Before advocating for universal and timely adoption of CPOE in all Massachusetts hospitals, it was critical to determine the current level of medical errors and the use of expensive drugs and tests that could be *prevented* or reduced by the effective implementation of a CPOE system. In partnership with the Massachusetts Technology Collaborative and the New England Healthcare Institute, Dr. David Bates led a team of researchers from the Brigham and Women's Hospital in conducting our CPOE Clinical Baseline Study. Collected data covered events that occurred in the study hospitals from January 2005 to August 2006.

The specific goal of the Clinical Baseline Study was to assess the improvement in the quality of patient care and in the efficiency of operations that could be achieved by implementing CPOE systems with clinical decision support in Massachusetts hospitals. The study was designed to examine five areas of significant improvement that directly resulted from implementing CPOE at the Brigham and Women's Hospital: the prevention of adverse drug events; the inappropriate utilization of expensive medications; the prevention of medication errors in renal dosing; the timely substitution of oral for intravenous medications; and the reduction in redundant ordering of laboratory tests.[1]

Baseline Study Design

There were five specific aims of the CPOE Clinical Baseline Study that paralleled the seminal Brigham and Women's Hospital study:

Aim 1. To determine the baseline rate of adverse drug events (ADEs).

Aim 2. To determine the baseline rate of the inappropriate use of specific expensive drugs.

Aim 3. To determine the baseline rate of renal dosing errors (nephrotoxic and renally excreted drugs used in patients with renal insufficiency).

Aim 4. To identify the use of intravenous (I.V.) medications when oral medications are indicated.

Aim 5. To identify the frequency of redundant laboratory tests.

Six community hospitals were selected as pre-implementation study sites to determine their baseline rates in each of these five areas. These hospitals were chosen from a group of twenty Massachusetts institutions that were at various stages (from early planning to partial implementation) of CPOE implementation. They are representative of the larger Massachusetts hospital community.

Once the baseline rates were established, the results then could be extrapolated to all Massachusetts hospitals so that there could be an estimate of the magnitude of improvement if CPOE were implemented throughout the Commonwealth.

Meetings were conducted at each hospital with senior executives and clinical staff to describe the planned study and to clarify roles and responsibilities for research personnel and hospital staff. The research study design was approved by the Institutional Review Board at each institution. A total of 4,200 patient medical records were reviewed by research nurses from the Brigham and Women's Hospital to analyze the first three Aims (adverse drug events, expensive drug ordering, and renal dosing errors). The nurses' results were reviewed by physicians from the Brigham and Women's Hospital research team and then verified by physicians from the respective study institutions.

The analyses of Aims 4 and 5 (the use of more expensive intravenous drugs instead of oral medications, and redundant lab orders) were based on data collected from each hospital's clinical information technology system. Summary results for all five Aims were then reviewed by management and clinical staff at each institution and presented to senior management at the end of the study period.

Baseline Study Results

Aim 1: Adverse Drug Events

Adverse drug events are injuries that are caused by drugs, such as severe allergic reactions or interactions among medications. *Preventable* ADEs are injuries that are caused by human error, such as prescribing or administering the wrong dose of a drug. The research team reviewed a statistically significant random sample of 200 charts at each hospital, analyzing data about the incidence and type of preventable adverse drug events for patients who were hospitalized between January 1, 2005 and August 31, 2006. They used an adaptation of the Health Evaluation through Logical Processing (HELP) model that was developed at LDS Hospital in Salt Lake City and later used at Brigham and Women's Hospital. These "trigger" events identified patients with adverse drug reactions, ranging from a change in respiratory rate to a fever or a seizure to anaphylactic shock. The rates of preventable adverse drug events that were found in our study are displayed for each of the six community hospital sites in Table 2.1.

The research team found that on average, 8.8 out of every 100 patients admitted to these hospitals had a *preventable* adverse drug event, with the rates ranging from a low of 7.0 to a high of 11.5 percent. See Appendix 1 for a more detailed presentation of these rates.

TABLE 2.1: PREVENTABLE ADVERSE DRUG EVENTS							
Study site	1	2	3	4	5	6	Average
Preventable ADEs/100 admissions	11.5%	7.0%	8.5%	10.0%	8.0%	7.5%	8.8%

Aim 2: Inappropriate Use of Specific Expensive Drugs

The appropriateness with which medications are used has substantial influence on the total cost of health care[2]. Intelligent and appropriate use of prescription drugs can be a very cost-effective use of technology in health care; the massive costs of some illnesses that are averted by intelligent prescribing can dwarf the relatively modest cost required for purchase of the drugs themselves. In addition to the rational use of medications, there are times when less expensive drugs can be substituted for more costly drugs, with a savings to society as a whole and no threat to patient outcomes. These drug substitution protocols exist at most hospitals to guide the prescribing practices of physicians but are not always used effectively.

Our research team was interested in determining whether or not less expensive drugs were being used in hospitals where prescribing guidelines existed, and whether the appropriate guidelines were being followed. Patients for whom an expensive drug had been prescribed were identified by the hospital's pharmacy system and a random sample of these charts was reviewed. At each study site, the research team reviewed approximately 280 hospital charts of patients who were prescribed expensive drugs during the time period January 1 to August 31, 2006. The potential savings associated with reducing the use of these expensive medications are shown in Table 2.2 below. On average, hospitals could save approximately $154,000 per year by substituting generic drugs for more expensive medications. However, there was high variability and a very broad range among five of the hospitals, from a low of $8,800 to a high of $155,500, with a sixth hospital as an outlier at almost $490,000.

Aim 3: Renal Dosing Errors

Renal dosing errors are adverse events that are caused by giving a nephrotoxic drug to patients with compromised kidney function. Prescribing a drug or a dose of a drug that can't be metabolized by the patient is a frequent cause of these generally severe and expensive adverse drug events. Using computerized clinical decision support systems to suggest medications and their appropriate dose levels for patients with decreased kidney function have been shown to reduce both adverse drug events and length of stay in hospitalized patients.

The research team reviewed a statistically significant random sample of 150 medical records of patients with reduced kidney function (signified by a baseline creatinine level of 1.5 mg/dL) at each hospital. On average, patients with renal insufficiency comprised approximately 18 percent of all patient admissions at the six sites. Table 2.3 shows that the average rate of *preventable* renal dosing errors across all study hospitals was 9.1 percent, with a range of 3.3 to 13.3 percent. See Appendix 2 for a detailed presentation of these rates.

TABLE 2.2: INAPPROPRIATE USE OF EXPENSIVE DRUGS								
Study site	1	2	3	4	5	6	Total	Avg. Per Hospital
Total Annual Savings	$98,500	$155,500	$489,800	$98,200	$8,800	$78,000	$928,800	$154,800

TABLE 2.3: PREVENTABLE RENAL DOSING ERRORS							
Study Site	1	2	3	4	5	6	Average
Renal Dosing Errors	10.7%	9.3%	12.0%	13.3%	3.3%	6.0%	9.1%

Aim 1 and Aim 3 Combined: Total Preventable Adverse Drug Events

Adverse drug events and renal dosing errors together fall under the broader category of adverse drug events and constitute significant areas where medication errors could be prevented. In Aim 1, we demonstrated that there was an average rate of preventable adverse drug events of **8.8 percent** of total hospital admissions across all six hospitals. In Aim 3, we showed that there was an average rate of preventable adverse drug events of **9.1 percent** of patients with reduced kidney function (creatinine level of 1.5 mg/dl). Since the patients in this latter category amount to an average of 18.0 percent of total hospital admissions for all six hospitals, the rate of preventable adverse drug events due to renal dosing errors as a portion of total hospital admissions is 1.6 percent (.091 x 18.0 percent = 1.6 percent). **Therefore the total rate of preventable adverse drug events is 10.4 percent (8.8 + 1.6 = 10.4 percent)**.

These are serious medical errors causing harm to patients and resulting in many extended hospital stays with substantially increased costs.

Aim 4: Use of I.V. Medications When Oral Medications Are Indicated

Many drugs can be given either intravenously or by mouth, but are less expensive and just as well tolerated if given orally rather than by I.V. Computerized decision support prompts that remind the physician that the patient is able to eat (after surgery, for example) can improve the chance that the physician will switch to the oral form of the medication.

The research team assessed the frequency with which patients were receiving a number of medications that could be given orally but were instead given intravenously. Individual pharmacy data were analyzed, and if the route could not be determined from pharmacy data, then chart reviews were conducted. While the medication list varied based on the specific hospital, target medications reviewed included fluconazole, levofloxzcin, metronidazole, amiodarone, and ranitidine. The number of doses of more expensive I.V. medications that were administered when an oral substitute could have been given was multiplied by the cost differential between the I.V. and the oral drug. The savings for each hospital are listed in Table 2.4 and average just under $48,000, with a range from a low of $16,400 to a high of $102,300.

TABLE 2.4: SAVINGS FROM SUBSTITUTION OF ORAL FOR I.V. DRUGS								
Study site	1	2	3	4	5	6	Total	Average Per Hospital
Total Annual Savings	$26,800	$44,100	$102,300	$75,200	$16,400	$23,000	$287,800	$47,900

TABLE 2.5: LABORATORY TESTS AND RECOMMENDED TEST INTERVALS	
Laboratory Test	Redundant Time Interval
Creatinine	<12 hours
Theophylline Level	<16 hours
AST	<20 hours
Tobramycin Level	<20 hours
Vancomycin Level	<20 hours
Gentamicin Level	<20 hours
Amikacin Level	<20 hours
Manual White Blood Cell Count	<36 hours
Routine Urinalysis	<36 hours

Aim 5: Redundant Laboratory Tests

A certain percentage of laboratory tests done on hospitalized patients are repeated earlier than necessary and may be redundant[3]. The published literature suggests that approximately 10-20 percent of tests are redundant and could be safely eliminated. Computerized notices to physicians that another test (of the same type) has been completed can decrease the chance that a redundant test will be ordered.

The research team reviewed the use of high volume or high marginal cost laboratory tests to determine if tests were being ordered more frequently than recommended by standard clinical guidelines (see Table 2.5). Each hospital had electronic laboratory test data available for the research team to analyze. With the exception of one site, the data were collected from January 1, 2005 to August 31, 2005. For the one remaining site, data were available for January 1, 2006 to August 31, 2006. All hospital admissions were identified using each institution's administrative database, and all laboratory tests that were performed during that time were reviewed and evaluated. Any laboratory test in the same hospitalization with a prior result less than the time interval allowed was considered redundant unless the prior result was abnormal. The marginal cost of each of these tests was then multiplied by the number of redundant tests done at each site to reach a total financial cost per hospital. These results are displayed in Table 2.6 below.

We then projected the potential annual savings associated with eliminating redundant laboratory tests. Contrary to what has been found in academic medical centers, the number of redundant laboratory test orders in these community hospitals was small, with the exception of manual white blood counts (WBC) with a mean redundancy rate of 24 percent. However, the marginal cost of a WBC is so low that the financial savings are negligible.

Improvements Achievable with CPOE Implementation

CPOE with clinical decision support can result in significant improvements in all of the areas identified in the CPOE Clinical Baseline Study. The most significant potential for improvement revealed in this study is in the area of preventable adverse drug events. Table 2.7 shows the categories and distribution of ADEs in Aim 1 found in our analyses. Only 19 percent would not be preventable by the adoption of a robust CPOE program. Clinical decision support applications in CPOE systems can effectively address potential errors in all of the categories that are listed.

Our team of physician experts believe that CPOE with clinical decision support can be

TABLE 2.6: REDUNDANT LABORATORY TESTS								
Study site	1	2	3	4	5	6	Total	Average Per Hospital
Total Annual Savings	$6,300	$6,400	$3,200	$45,500	$3,700	$5,900	$71,000	$11,800

TABLE 2.7: DISTRIBUTION OF ADEs IN AIM 1	
Prevention Strategy: Aim 1	All Sites
Duplicate med check	1%
Drug dose suggestion	9%
Drug-allergy	4%
Drug-drug	2%
Drug-lab check	27%
Drug frequency	3%
Renal check	19%
Drug-age	9%
Patient characteristic	1%
Drug-specific guidelines	7%
Sub-total	**81%**
Not preventable by CPOE	19%
Total	100%

expected to achieve substantial and increasing rates of improvement in each of the five critical areas during the first three years of CPOE implementation (see Table 2.8 below). Published studies support these estimates. The Agency for Healthcare Research and Quality reports that "anywhere from 28 to 95 percent of ADEs can be prevented by reducing medication errors through computerized monitoring systems" and that "CPOE has the potential to prevent an estimated 84 percent of dose, frequency and route errors."[4]

The clinical data that resulted from the CPOE Clinical Baseline Study formed the basis for an in-depth analysis of the capital and operating expenses associated with the adoption of CPOE. A team from PricewaterhouseCoopers conducted a review of the expenses associated with implementing CPOE in the six Massachusetts study hospitals. This included a determination of the revenue and expense implications of controlling the medication errors and drug and laboratory use associated with the five Aims that were highlighted in the Clinical Baseline Study. These results, along with a refined estimate of the payback period for hospitals and the financial benefit to the payers, are presented in Chapter Three. The data demonstrate that there can be a rapid payback to the hospitals for their investment, and ongoing financial benefits to both the providers and the payers. Together, the dramatic improvements in patient care and the potential financial returns reinforce the need for the Massachusetts Hospital CPOE Initiative.

TABLE 2.8: MINIMAL EXPECTED RATES OF IMPROVEMENT WITH CPOE			
Aims	Year 1	Year 2	Year 3
1. ADEs	15%	50%	70%
2. Expensive Drugs	20%	60%	80%
3. Renal Dosing	15%	60%	93%
4. I.V. to Oral	50%	75%	82%
5. Redundant Labs	50%	75%	85%

Chapter 3

Costs and Payback: The Financial Impact on Hospitals and Payers

The average hospital could achieve an annual reduction in operating costs of $2.7 million. Full payback of the funds invested could be achieved in 26 months.

In addition, the benefit to payers would average $900,000 annually for each of the hospitals.

Introduction

The Clinical Baseline Study discussed in Chapter Two demonstrated that there is significant potential for both clinical and financial improvement in the six study hospitals and that CPOE systems can achieve a very large portion of this potential benefit. In order to understand fully the economic results of achieving these improvements in patient care, the Massachusetts Hospital CPOE Initiative commissioned PricewaterhouseCoopers (PwC) to assess the financial impacts associated with the clinical outcomes in the CPOE Clinical Baseline Study. The analysis includes an assessment of financial challenges which might be barriers to some hospitals in adopting CPOE.

In this chapter, we estimate the financial impact of CPOE implementation on the six community hospitals and their payers; we estimate the capital, one-time operating, and on-going operating costs of CPOE implementation for each site, and we estimate a payback period as a way of determining the hospitals' recoupment of their investment.

The Financial Impact Analysis

Members of the PwC team met with financial executives at each of the six hospital sites. Information was supplied by each hospital to the PwC team so that they could compute the financial effects of the changes that could result from CPOE implementation. Each clinical improvement that CPOE could accomplish in the five Aims discussed in Chapter Two has a financial impact for either hospitals or payers and in many cases, for both. The benefits are different for each Aim, and have been calculated to show the specific results of improving the clinical outcomes for that event (adverse drug events, reducing the use of expensive drugs, and decreasing redundant laboratory tests).

In general, the majority of the savings from implementing a CPOE system derive from avoiding adverse drugs events. The consequence of each preventable adverse drug event is based

on an additional 4.6 days of hospitalization[1]. This increase in the length of stay is very costly, and if the adverse event can be prevented, the hospital and/or the payer save a significant amount. With patients whose care is paid for on a prospective (fixed) payment basis, those daily variable costs that are avoided accrue directly to the hospital. With patients whose care is paid for on a Fee-for-Service (FFS) basis, the public and private payers experience a reduction in cost, but the hospital revenues are then decreased by an equal amount. The PwC team calculated these amounts for each study site according to the individual hospital's payer mix and the results are shown in Tables 3.2 through 3.4.

Hospital Costs: Hospital costs for fiscal year 2006 were provided to PwC by each site. Cost elements included variable costs per patient day (labor and other costs, some of which require management action), variable costs per lab test, the costs of certain expensive drugs, and the hospital-specific costs of certain intravenous and oral medications.

Reimbursement Information: The impact of a reduction in patient days and costs affect hospitals differently depending on their payer mix and reimbursement arrangements. For this study, the hospitals provided information about their payer mix and general payment agreements with the health plans.

Baseline Clinical Data: The results of the baseline clinical data assessments conducted by Dr. Bates' team at each site were incorporated into the model. They included the baseline rates of adverse drug events, the costs of inappropriate use of specific expensive drugs, the rates of renal dosing errors, the costs of unnecessary use of I.V. medications when oral medications are indicated, and the costs of the number of redundant laboratory tests. These results are discussed at length and are listed in Chapter Two in Tables 2.1 through 2.4, and 2.6.

Effectiveness Rates: The expected effectiveness of a robust clinical decision support system ranges from 15 to 93 percent and increases over time as physicians' skill and system capability improve with practice and use. A complete list of the expected CPOE effectiveness rates is included in Chapter Two in Table 2.8.

Information Technology (IT) Costs: Capital and one-time operating costs for fiscal year 2006 associated with implementation, as well as ongoing incremental operating costs related to maintaining CPOE systems, were provided to the PwC team by each site[2]. They included hardware and software expenses, implementation costs, staff training expenses, and costs associated with hiring additional personnel. The average costs across all sites were computed, as well as the average costs per bed.

A summary of the IT costs is shown in Table 3.1 below. For a more complete discussion of the IT cost items and the drivers of these costs, see Appendix 3.

See Appendix 4 for a breakdown of the components of capital, one-time operating, and ongoing operating costs.

Computation of Financial Benefits for Hospitals and Payers

As noted above, estimates of the financial benefits for each hospital and for payers were made using

TABLE 3.1: AVERAGE TOTAL AND PER-BED COST TO PURCHASE, IMPLEMENT AND MAINTAIN A CPOE SYSTEM IN SIX STUDY HOSPITALS

	Total Cost	Range Among Hospital Sites	Cost Per Bed	Range Among Hospital Sites
Capital and One-Time Operating Costs	$2,078,000	$1,063,079 - $3,733,587	$10,057	$7,933 - $13,448
Ongoing Operating Costs	$435,914	$276,074 - $523,976	$2,141	$1,878 - $2,586

the results of the Clinical Baseline Study, the financial data submitted to PwC by the hospitals, and the estimates of CPOE effectiveness in Chapter Two. (See Appendix 4 for a listing of assumptions.)

Specific costs that could be avoided with the support of a CPOE system were calculated in the following manner:

Determine the Current Costs of Preventable Events and Unnecessary Expenses

Adverse Drug Events (Including Renal Dosing Errors): The annual number of discharges was multiplied by the rate of adverse drug events at each study site to determine the number of patients expected to experience an adverse drug event. This number was then multiplied by the cost of each of these events. The cost of adverse drug events (Aims 1 and 3) was determined by taking the variable cost per day multiplied by 4.6 days.

Inappropriate Use of Specific Expensive Drugs (Including the Use of I.V. Medications When Oral Medications Are Indicated): During the chart review process at each hospital site, the research team identified patients who were receiving drugs that were expensive and where an alternate, less expensive medication was available. In addition, on a per patient basis the researchers identified the overuse of intravenous drugs when oral medications were indicated. Dr. Bates' team determined the hospital-specific costs for this excessive drug use and annualized the potential savings at each study site. The opportunity cost of not converting from expensive drugs to less costly medications in a timely way was determined by multiplying the cost of the expensive medication minus the cost of the less costly form of the drug multiplied by the number of times the expensive drug was used.

Redundant Laboratory Tests: The cost of redundant laboratory tests was calculated using the variable cost of laboratory tests and multiplying that number at each site by the number of laboratory tests that were repeated earlier than necessary.

Determine the Estimated Net Savings of CPOE to Hospitals and to Payers

The costs of preventable adverse drug events and unnecessary expenses are estimated to be reduced by CPOE over the first three years of implementation, according to the increasing effectiveness rates presented in Table 2.8 of Chapter Two. Financial benefits, therefore, increase in each of the first three years, as presented in Tables 3.2 through 3.4.

Hospitals: As discussed above, under a DRG or per-discharge-based reimbursement arrangement, the hospital experiences no change in payments from payers while potentially experiencing a reduction in variable operating costs. Under a FFS or per diem reimbursement arrangement, the hospital experiences a decrease in payments from payers while also experiencing a reduction in variable operating costs. The benefit to the hospital under these arrangements is the net effect of the two—in our analysis a negative impact (see per diem and FFS in Tables 3.2 through 3.4). Payer mix, payment rate and reimbursement type were used to compute the net benefit to the hospital and to the payer for each preventable event type for each of the first three years of CPOE implementation.

Payers: For health plans and public entities that are providing FFS and per diem reimbursement for patient care, a reduction in adverse drug events with the consequent decrease in patient days equals a direct savings for care that did not need to be provided to the patient. These savings were determined by analyzing the payer mix and payment rates for each payer at each hospital site for each of the three years of CPOE implementation.

The estimated savings and reduction in both costs and revenues for both hospitals and payers are shown on Tables 3.2 through 3.4.

TABLE 3.2: YEAR 1 - AVERAGE EXPECTED HOSPITAL AND PAYER SAVINGS

	#Admits[1]		Rate of Prevent-able ADEs	# of Patients	Patient Days (x4.6)	Hospital Variable Cost/Day	Payer Variable Cost/Day	Year 1 Effective-ness Rate	Total Hospital Expenses	Revenue Loss to Hospital	Net Hospital Benefit	Net Payer Benefit
AIM 1	Total	**11,055**										
	DRG	9,345	0.088	818	3,762	$912		15%	$514,389		$514,389	
	Per Diem	1,078	0.088	94	434	$912	$1,764	15%	$59,341	$114,842	$(55,500)	$114,842
	Fee-For-Service	312	0.088	27	126	$912	$2,083	15%	$17,178	$39,243	$(22,065)	$39,243
	Free Care	225	0.088	20	91	$912		15%	$12,394		$12,394	
	Self-Pay	95	0.088	8	38	$912		15%	$5,215		$5,215	
									---	---	---	---
									$608,517	$154,085	**$454,433**	**$154,085**
AIM 2								20%			**$30,963** [2]	

	#Admits[1]		Rate of Prevent-able ADEs	# of Patients	Patient Days (x4.6)	Hospital Variable Cost/Day	Payer Variable Cost/Day	Year 1 Effective-ness Rate	Total Hospital Expenses	Revenue Loss to Hospital	Net Hospital Benefit	Net Payer Benefit
AIM 3	Total	**1,994**										
	DRG	1,686	0.091	154	707	$734		15%	$77,836		$77,836	
	Per Diem	194	0.091	18	82	$734	$1,764	15%	$8,979	$21,573	($12,593)	$21,573
	Fee-For-Service	56	0.091	5	24	$734	$2,083	15%	$2,599	$7,372	($4,772)	$7,372
	Free Care	41	0.091	4	17	$734		15%	$1,875		$1,875	
	Self-Pay	17	0.091	2	7	$734		15%	$789		$789	
									---	---	---	---
									$92,078	$28,945	**$63,135**	**$28,945**
AIM 4								50%			**$23,983** [3]	
AIM 5								50%			**$5,920** [4]	
TOTAL											**$578,434**	**$183,030**

1. Number of admissions based upon the time frame 10/1/05 through 9/30/06
2. Net hospital benefit for AIM 2 is calculated by multiplying the average total annual benefit by the year 1 effectiveness rate (20% x $154,814)
3. Net hospital benefit for AIM 4 is calculated by multiplying the average total annual benefit by the year 1 effectiveness rate (50% x $47,966)
4. Net hospital benefit for AIM 5 is calculated by multiplying the average total annual benefit by the year 1 effectiveness rate (50% x $11,841)

TABLE 3.3: YEAR 2 - AVERAGE EXPECTED HOSPITAL AND PAYER SAVINGS

	#Admits[1]		Rate of Prevent-able ADEs	# of Patients	Patient Days (x4.6)	Hospital Variable Cost/Day	Payer Variable Cost/ Day	Year 2 Effective-ness Rate	Total Hospital Expenses	Revenue Loss to Hospital	Net Hospital Benefit	Net Payer Benefit
AIM 1	Total	**11,055**										
	DRG	9,345	0.088	818	3,762	$912		50%	$1,714,629		$1,714,629	
	Per Diem	1,078	0.088	94	434	$912	$1,764	50%	$197,804	$382,806	($185,002)	$382,806
	Fee-For-Service	312	0.088	27	126	$912	$2,083	50%	$57,261	$130,809	($73,548)	$130,809
	Free Care	225	0.088	20	91	$912		50%	$41,314		$41,314	
	Self-Pay	95	0.088	8	38	$912		50%	$17,385		$17,385	
									----------	----------	----------	----------
									$2,028,393	$513,615	**$1,514,778**	**$513,615**
AIM 2								60%			**$92,889**[2]	

	#Admits[1]		Rate of Prevent-able ADEs	# of Patients	Patient Days (x4.6)	Hospital Variable Cost/Day	Payer Variable Cost/ Day	Year 2 Effective-ness Rate	Total Hospital Expenses	Revenue Loss to Hospital	Net Hospital Benefit	Net Payer Benefit
AIM 3	Total	**1,994**										
	DRG	1,686	0.091	154	707	$734		60%	$311,342		$311,342	
	Per Diem	194	0.091	18	82	$734	$1,764	60%	$35,917	$86,290	($50,373)	$86,290
	Fee-For-Service	56	0.091	5	24	$734	$2,083	60%	$10,397	$29,486	($19,089)	$29,486
	Free Care	41	0.091	4	17	$734		60%	$7,502		$7,502	
	Self-Pay	17	0.091	2	7	$734		60%	$3,157		$3,157	
									----------	----------	----------	----------
									$368,315	$115,776	**$252,539**	**$115,776**
AIM 4								75%			**$35,975**[3]	
AIM 5								75%			**$8,881**[4]	
TOTAL											**$1,905,060**	**$629,391**

1. Number of admissions based upon the time frame 10/1/05 through 9/30/06
2. Net hospital benefit for AIM 2 is calculated by multiplying the average total annual benefit by the year 2 effectiveness rate (60% x $154,814)
3. Net hospital benefit for AIM 4 is calculated by multiplying the average total annual benefit by the year 2 effectiveness rate (75% x $47,966)
4. Net hospital benefit for AIM 5 is calculated by multiplying the average total annual benefit by the year 2 effectiveness rate (75% x $11,841)

TABLE 3.4: YEAR 3 - AVERAGE EXPECTED HOSPITAL AND PAYER SAVINGS

	#Admits[1]		Rate of Prevent-able ADEs	# of Patients	Patient Days (x4.6)	Hospital Variable Cost/ Day	Payer Variable Cost/ Day	Year 3 Effective-ness Rate	Total Hospital Expenses	Revenue Loss to Hospital	Net Hospital Benefit	Net Payer Benefit
AIM 1	Total	**11,055**										
	DRG	9,345	0.088	818	3,762	$912		70%	$2,400,480		$2,400,480	
	Per Diem	1,078	0.088	94	434	$912	$1,764	70%	$276,926	$535,928	($259,002)	$535,928
	Fee-For-Service	312	0.088	27	126	$912	$2,083	70%	$80,165	$183,133	($102,968)	$183,133
	Free Care	225	0.088	20	91	$912		70%	$57,840		$57,840	
	Self-Pay	95	0.088	8	38	$912		70%	$24,339		$24,339	
									---	---	---	---
									$2,839,750	$719,061	**$2,120,689**	**$719,061**
AIM 2								80%			**$123,851**[2]	

	#Admits[1]		Rate of Prevent-able ADEs	# of Patients	Patient Days (x4.6)	Hospital Variable Cost/ Day	Payer Variable Cost/ Day	Year 3 Effective-ness Rate	Total Hospital Expenses	Revenue Loss to Hospital	Net Hospital Benefit	Net Payer Benefit
AIM 3	Total	**1,994**										
	DRG	1,686	0.091	154	707	$734		93%	$482,580		$482,580	
	Per Diem	194	0.091	18	82	$734	$1,764	93%	$55,672	$133,750	($78,079)	$133,750
	Fee-For-Service	56	0.091	5	24	$734	$2,083	93%	$16,116	$45,704	($29,588)	$45,704
	Free Care	41	0.091	4	17	$734		93%	$11,628		$11,628	
	Self-Pay	17	0.091	2	7	$734		93%	$4,893		$4,893	
									---	---	---	---
									$570,888	$179,454	**$391,434**	**$179,454**
AIM 4								82%			**$39,333**[3]	
AIM 5								85%			**$10,065**[4]	
TOTAL											**$2,685,372**	**$898,515**

1. Number of admissions based upon the time frame 10/1/05 through 9/30/06
2. Net hospital benefit for AIM 2 is calculated by multiplying the average total annual benefit by the year 3 effectiveness rate (80% x $154,814)
3. Net hospital benefit for AIM 4 is calculated by multiplying the average total annual benefit by the year 3 effectiveness rate (82% x $47,966)
4. Net hospital benefit for AIM 5 is calculated by multiplying the average total annual benefit by the year 3 effectiveness rate (85% x $11,841)

Payback Period for a CPOE System

The payback period is determined by looking at all costs and benefits associated with implementation. Costs include capital and one-time operating costs and incremental annual operating costs over a period of five years (see Table 3.1). The cumulative costs are compared to the cumulative hospital benefits during that same time period. These data are displayed in Table 3.5.

The period of time it takes for these two trend lines to intersect is the payback period. As Table 3.5 and Figure 3.1 illustrate, the cumulative financial benefits of CPOE equal the cumulative costs at **about 26 months**.

Meeting Capital Requirements to Implement CPOE

While the substantial cost savings that can be achieved with CPOE permit a rapid payback of both the capital and operating funds expended, hospitals are required to invest significant capital up-front. For many institutions, capital requirements of this magnitude can be met through internal reserves or cash flow, or through external financing. However, since hospitals vary in their ability to access funds from these sources depending on their particular financial circumstances, it is important to determine whether there might be a set of hospitals with limited access to capital such that the cost of purchasing and implementing a CPOE system would be a significant financial barrier.

In order to explore this potential problem, in the spring of 2007 the CPOE Initiative worked with PricewaterhouseCoopers and the Massachusetts Health and Education Facilities Authority (HEFA) to assess the financing capacity of the 47 Massachusetts hospitals that had not yet even begun CPOE implementation. Detailed financial data filed with the Massachusetts Department of Public Health, Division of Healthcare Finance Policy were reviewed for the fiscal years 2004, 2005 and 2006. In order to determine the profitability, liquidity/cash flow and leverage status of the hospitals, six ratios (operating margin, days cash on hand, cushion ratio, debt service coverage, debt to capitalization and

FIGURE 3.1: ESTIMATED PAYBACK PERIOD: FIVE YEAR ESTIMATE

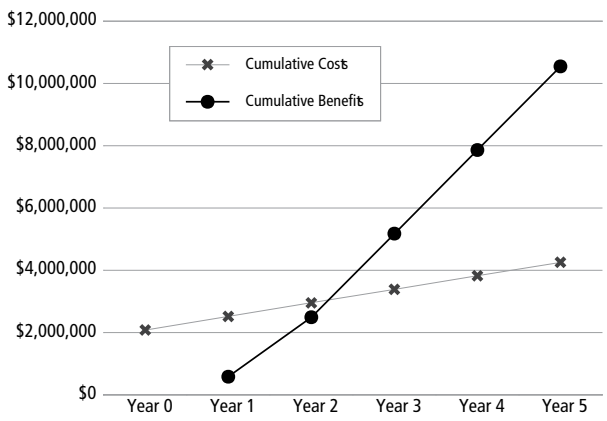


TABLE 3.5: HOSPITAL PAYBACK PERIOD FOR CPOE SYSTEM – AVERAGE OF SIX SITES

Payback Period[1]	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Capital & One-Time Costs[2]	$2,080,000					
Ongoing Costs[2]		$435,000	$435,000	$435,000	$435,000	$435,000
Cumulative Costs	$2,080,000	$2,515,000	$2,950,000	$3,385,000	$3,820,000	$4,255,000
Annual Operating Benefits[3]		$580,000	$1,910,000	$2,685,000	$2,685,000	$2,685,000
Cumulative Benefits		$580,000	$2,490,000	$5,175,000	$7,860,000	$10,545,000
Net Cumulative		($1,935,000)	($460,000)	$1,790,000	$4,040,000	$6,290,000

1. All cost and benefit figures above have been rounded to the nearest $5,000
2. Capital & one-time and ongoing costs referenced in Table 3.1
3. See total benefits for years 1–3 listed in Tables 3.2, 3.3, and 3.4

TABLE 3.6: ESTIMATED PAYER BENEFIT – AVERAGE

Payer Benefits	Year 1	Year 2	Year 3	Year 4	Year 5
Annual Operating Benefits	$185,000	$630,000	$900,000	$900,000	$900,000
Cumulative Benefits	$185,000	$815,000	$1,715,000	$2,615,000	$3,515,000

1. All cost and benefit figures above have been rounded to the nearest $5,000
2. Benefits accrue at the effectiveness rates listed in Tables 3.2, 3.3, and 3.4

unrestricted cash to debt) were calculated for each institution for each of the fiscal years. These ratios were then compared to the same ratios used by Standard & Poor's and Moody's to rate securities of all borrowing organizations with regard to their relative financial condition. About two thirds of the group had ratios above the rating agencies' standards for investment grade financing.

However, about one third (15) of the hospitals had lower ratios, suggesting that they might have difficulty generating the necessary funds. A further assessment of these institutions was made to see whether and how they had met recurring capital needs over the three years of the analysis period (2004, 2005, and 2006). This review revealed that 80 percent of them had in fact borrowed substantial amounts through HEFA during the study period. In each case the amounts borrowed were greater than the total costs of a CPOE system.

It is apparent that while hospitals vary in their capacity to generate the funds needed for capital projects, the great majority of Massachusetts hospitals appear to have sufficient access to the capital needed to implement CPOE systems.

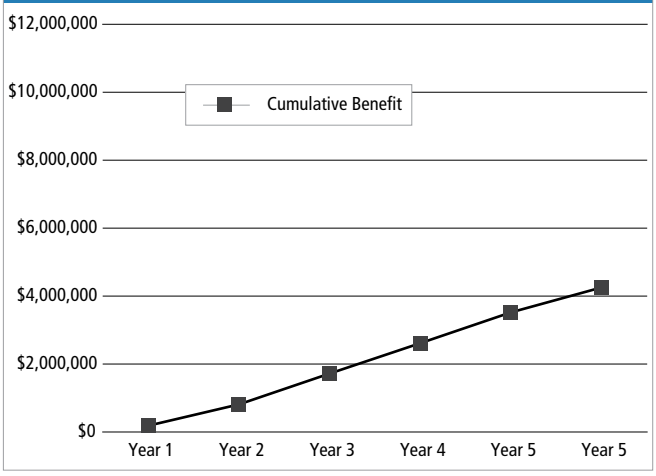
Computation of Financial Benefits for Payers

The net benefit to payers of having CPOE systems in hospitals was calculated for Aims 1 and 3. The basis for the savings for the payers is the reduction in payments to hospitals in both per diem and fee-for-service reimbursement arrangements when preventable adverse drug events are avoided and the average length of stay is shortened by 4.6 days. The cumulative payer benefits are displayed in Table 3.6 and Figure 3.2.

Significance

With a fully implemented CPOE system that has robust clinical decision support, the average community hospital in the study could achieve an annual reduction in operating costs of $2.7 million. The total capital and one-time costs of CPOE implementation average $2.1 million per hospital, and the average annual increment in on-going operating costs is approximately $435,000. On average, full payback could be achieved in about 26 months. In addition, the benefit to payers could average $900,000 annually for each of the hospitals.

FIGURE 3.2: ESTIMATED PAYER BENEFIT - FIVE YEAR ESTIMATE



Chapter Four

Conclusions and Recommendations

Conclusions

The Massachusetts Technology Collaborative, the New England Healthcare Institute, the Massachusetts Hospital Association and the Massachusetts Council of Community Hospitals worked in collaboration with many stakeholders—providers, payers, government representatives, and associations—to create the Massachusetts Hospital CPOE Initiative. Together, they worked to develop a systematic and objective assessment of how CPOE can benefit patients in Massachusetts by reducing the number of medical errors and decreasing the costs of health care. With the results of the work completed by Dr. David Bates in determining the level of preventable medical errors, and of PricewaterhouseCoopers in analyzing the costs of these errors, we can understand the substantial clinical and economic benefits of having CPOE implemented in 100 percent of hospitals in Massachusetts.

Statewide Benefits of CPOE Adoption

The goal of the Massachusetts Hospital CPOE Initiative is to have CPOE systems with sophisticated clinical decision support programs implemented in all 73 Massachusetts acute care hospitals by 2011. The adoption of CPOE by all Massachusetts hospitals will enable us to both improve care and reduce the costs of hospitalizations for all patients throughout the Commonwealth. In order to accomplish this ambitious goal, we need to work closely with the 63 hospitals that have not yet implemented CPOE with clinical decision support, beginning in 2008.

If CPOE systems were fully implemented in the 63 Massachusetts hospitals that currently have not yet done so, 55,000 dangerous adverse drug events could be prevented each year and cost savings could amount to $170 million annually.

As demonstrated in this report, the potential benefits of CPOE systems are significant. As substantial as these clinical improvements and financial savings are, they are conservative estimates of the major long-term benefits of computerizing order entry and results management. There are many reasons why these data show a conservative picture of the potential benefits of CPOE.

In the clinical area, many adverse drug events are never documented in the medical record, and "near miss" events that could have been prevented if physicians were using CPOE were not included in our calculations. In addition, our analyses did not take into consideration any of the physical and emotional costs to patients and their families who suffered from these preventable injuries. On the financial side, the calculations of financial impact were limited to documenting the direct costs associated with preventing adverse drug events and eliminating the use of expensive drugs and unnecessary laboratory tests. It also did not consider any litigation costs for malpractice suits or the economic effects of lost productivity on patients' or families' incomes.

Until recently, the majority of studies of CPOE benefits were conducted in academic medical centers or large, integrated health care delivery systems. We chose a representative sample of Massachusetts community hospitals in order to develop an accurate portrait of how CPOE could benefit patients, hospitals, and payers in 100 to 300 bed community hospitals. We initially had anticipated that the rates of adverse drug events would be lower in community hospitals as compared to academic medical centers, since community hospitals do not usually have a multitude of residents or medical students caring for patients and can potentially coordinate patient care more efficiently. To our surprise, the rates of adverse drug events in the study hospitals were higher than expected, creating a critically important opportunity for realizing the benefits of CPOE.

Our estimates of preventable adverse drug event rates of 10.4 percent and potential annual savings of $2.7 million per hospital are conservative. If CPOE systems were fully implemented in the 63 Massachusetts hospitals that currently have not completely adopted the technology, the number of adverse drug events prevented every year could be approximately 55,000 and the total cost savings could be $170 million annually.

These financial analyses demonstrate that the implementation of robust CPOE systems by all Massachusetts hospitals should be affordable. When combined with critically important improvements to patient safety afforded by the reductions in adverse drug events, they create an imperative for the Massachusetts Hospital CPOE Initiative. The Commonwealth cannot afford to lose this opportunity to save lives, save money, and to become the nation's innovative leader in patient safety.

Recommendations

The following recommendations are suggested as a framework to achieve our shared goals of improving quality and reducing costs in the Massachusetts health care system. They will be shaped and refined as all stakeholders collaborate in developing an agenda for action.

- All Massachusetts hospitals should complete full implementation of CPOE systems, including comprehensive clinical decision support, within the four year period 2008–2011.
- The Massachusetts Hospital CPOE Initiative, working in collaboration with stakeholders, should develop metrics-based performance standards that will assure effective operation of CPOE systems in all Massachusetts hospitals. Performance metrics should include a substantially reduced level of preventable adverse drug events.
- Payers and regulators should adopt robust incentives to encourage hospitals to meet the implementation goals stated here. Incentives should be tied to performance standards developed by the Massachusetts Hospital CPOE Initiative.
- The Massachusetts Hospital CPOE Initiative should continue to provide comprehensive, on-going implementation support to Massachusetts hospitals in all stages of CPOE planning, implementation and operation.
- The state of Massachusetts should continue to support the search for, and the evaluation of, innovative technologies that improve patient care and reduce health care costs.

Taken together, the clinical and financial benefits of a fully implemented CPOE system offer a win-win opportunity for patients, hospitals, and payers across the Commonwealth of Massachusetts. Eliminating adverse drug events, improving patient care and reducing medical costs are fundamental tenets of sound health care policy. CPOE now has a strong reputation based on evidence, and the Commonwealth must seize this chance to save lives and save money—and to become a national leader in patient safety along the way.

Endnotes

Executive Summary:

1. Agency for Healthcare Research and Quality. *Reducing and Preventing Adverse Drug Events To Decrease Hospital Costs*. Research in Action, Issue 1. AHRQ Publication Number 01-0020, March 2001. http://www.ahrq.gov/qual/aderia/aderia.htm

Chapter One:

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Chapter Two:

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APPENDIX 1 – Aim 1 Rates by Site

				95% Confidence Interval	
Study Site	**Aim 1 Sample Size**	**Aim 1 ADEs unique pts**	**Unique pts; rate /100 admits**	**Lower CI**	**Upper CI**
1	200	23	11.5%	7.1	15.9
2	200	14	7.0%	3.5	10.5
3	200	17	8.5%	4.6	12.4
4	200	20	10.0%	5.8	14.2
5	200	16	8.0%	4.2	11.8
6	200	15	7.5%	3.8	11.1
Total / Average	1,200	105	8.8%	4.8	12.7

APPENDIX 2 - Aim 3 Rates by Site

				95% Confidence Interval	
Study Site	**Aim 3 Sample Size**	**Aim 3 ADEs unique pts**	**Unique pts; rate /100 admits**	**Lower CI**	**Upper CI**
1	150	16	10.7%	5.8	15.6
2	150	14	9.3%	4.7	13.9
3	150	18	12.0%	6.7	17.2
4	150	20	13.3%	7.8	18.7
5	150	5	3.3%	0.4	6.1
6	150	9	6.0%	2.1	9.8
Total / Average	900	82	9.1%	4.6	13.6

APPENDIX 3: IT Infrastructure

A. IT INFRASTRUCTURE ASSUMPTIONS

Surveys show that most hospitals have already made significant investments in information technology to support basic administrative and clinical functions[1,2]. For this reason, we made assumptions that the following infrastructure was already in place when costs for deploying CPOE were assessed.

1. Technology

- Servers and operating systems to support existing administrative and clinical applications
- Interfaces to support interoperability of existing systems and applications
- Network infrastructure to support communication and flow of transactions among systems and applications [including Local Area Network (LAN), wireless connectivity, remote access via portals or Virtual Private Networks (VPN)].
- Network management and monitoring tools to support detection of intrusions, load balancing, performance monitoring, etc.
- Sufficient peripheral devices to support use of existing applications (workstations, printers, etc.)
- Business Continuity infrastructure (sufficient capacity for backup and redundancy to insure uninterrupted service)

2. Applications

- Basic administrative applications such as patient accounts, patient demographics, admissions/ discharges/ transfers (ADT)
- Basic clinical applications such as laboratory and radiology order management and results reporting, basic pharmacy system for inventory and dispensing of medications, basic nursing documentation
- Single sign-on: the ability for a clinician to log in to several applications at one time

B. IT COST ITEMS RELATED TO IMPLEMENTATION AND MAINTENANCE OF CPOE WITH DECISION SUPPORT

Group 1: Items completely assignable to CPOE - one-time and ongoing		
Item	Definition	Cost Drivers
Servers and Operating System (Initial and ongoing maintenance costs)	Upgraded or new server to host CPOE and CPOE-related clinical applications, includes additional tools to monitor usage and alert operators when there are problems with hardware or software performance Options: 1. Hosted by the site (hardware costs must be incurred); 2. Remotely hosted (license includes cost of hardware and operating system to support application)	1. Hospital bed size (used as indicator of patient population, volume of orders). These will influence the amount of server capacity required (for organizations that will host their own applications), or will influence the amount charged for monthly subscription fees for organizations that subscribe to remotely hosted applications.
CPOE Software License Cost (initial and ongoing maintenance costs)	License and ongoing maintenance fees for CPOE software	1. Complexity and sophistication of the software. Different software packages have different degrees of complexity in terms of configurability, decision support, features and functions. Lower-featured products will cost less to license and to implement. 2. Bed size (as indicator of patient population, volume of orders, number of end users)
Pharmacy System (Initial and ongoing maintenance costs)	License and ongoing maintenance fees for new or upgraded pharmacy system needed to support the CPOE implementation	1. Degree of integration with CPOE and medication administration systems will influence the ultimate cost of the CPOE system. Lack of integration means that resources must be spent on interfaces that permit bi-directional communication with the pharmacy system
Vendor Costs (Initial costs for implementation)	Clinical system vendor's fee to implement the application(s) at the hospital Note: This cost may be included in the software license costs	1. Size and complexity of the hospital environment will influence the vendor costs associated with an implementation. 2. Complexity and sophistication of the software determines the amount of resources that will be needed for implementation. The more configurable the system, the more resources are needed to implement. 3. Whether the organization uses other modules from the same vendor will also influence the costs, since integrating applications from different vendors requires much more effort. 4. Amount of in-house (or outside consulting) staff that are available also influences how much support will be required from the vendor, and thus the fees.
Consultant Costs (One-time costs for implementation)	Contracted assistance for additional implementation support for CPOE	1. Size and complexity of the hospital environment will influence the consultant costs associated with an implementation. Whether the organization uses other modules from the same vendor will also influence the costs, since integrating applications from different vendors requires much more effort. Amount of in-house staff also influences the amount of consultation resources required.
Implementation travel costs (One-time costs)	Travel expenses for vendor and outside contracted assistance as part of the CPOE implementation project	1. Cost drivers here are 1) number of consultants hired; 2) length of time required for the implementation; 3) geographic location of the consultants vis-a-vis the client
MD Resources (Initial and ongoing)	Payment to community physicians and/or hospitalists to participate in the design and implementation of CPOE	1. The size of the hospital and the number of specialties will influence how much physician time is needed. 2. The degree of sophistication and decision support capability in the system will influence how much effort will be required to develop content, order sets, rules, policies, screen flows, etc.

Group 1: Items completely assignable to CPOE - one-time and ongoing		
Item	Definition	Cost Drivers
Inhouse staff (Initial costs for implementation)	Payment to other hospital departmental staff to participate in the design and implementation of CPOE	1. The size of the hospital and the number of specialties will influence how much in-house staff time is needed. 2. The number of features and the degree of configurability in the application will influence how much effort will be required to develop content, rules, policies, screen flows, etc.
Training: Nurse Training (Initial costs for implementation)	Payment for nurses and unit coordinators for time spent in CPOE training classes (if paid in addition to salary; otherwise, cost of personnel to cover personnel while in training)	1. The number of nurses and unit coordinators to be trained 2. Whether the training is delivered during shift time (requiring backfill on the units) or off-shift time (requiring overtime) 3. Whether supplemental forms of training (like computer-based training) are used to offset in-class hours
Training: Pharmacist Training (Initial costs for implementation)	Payment for pharmacists and pharmacy techs for time spent in CPOE training classes	1. The number of pharmacists and pharmacy techs to be trained 2. Whether the training is delivered during shift time (requiring backfill on the units) or off-shift time (requiring overtime) 3. Whether supplemental forms of training (like computer-based training) are used to offset in-class hours
Construction (One-time costs)	Construction costs on the nursing units or other hospital space to provide room for additional workstations	1. Size of facility i.e. number of care units where CPOE will be implemented and where construction will be needed to accommodate hardware needs and workflow 2. Configuration of care units where CPOE will be implemented. Additional counter space and seating may be needed to accommodate workstations 3. Existing electrical infrastructure. Additional wiring and outlets may be needed to support workstations and laptops.
Ongoing costs:		
Staffing to support CPOE: Clinical Informaticists	Salary and benefits for new positions such as physician champion, nurse informaticist, pharmacist informaticist, physician integration analyst	1. Size of hospital, number of users 2. Complexity and sophistication of CPOE and medication administration products
CPOE Project Manager	Salary and benefits for new position	1. Length of implementation period. Project manager may only be needed until all units are live and well integrated 2. Size of facility. A larger hospital may require a permanent project manager position
Clinical Programmer/Screen builder/ report developer	Salary and benefits for new position	1. Amount of existing resources. It may be possible to fill this function with existing programming or other IT resources
Additional Help Desk Support	Salary and benefits for new position(s)	1. Amount of existing resources. It may be possible to fill this function with existing help desk resources 2. Degree of support on the care units. In some facilities, 24x7 availability of "super-users" lessen the need for help desk support
MDs or MD liaison	Salary and benefits for new position(s)	1. Size of facility, number of MD users 2. Sophistication of CPOE product. The more sophisticated the product, the more decisions and policies must be made and maintained
Clinical Decision Support Analysts	Salary and benefits for new position(s)	1. Sophistication of CPOE product. The more sophisticated the product, the more rules, content, decisions and policies must be made and maintained 2. Number of specialties. The greater the number of specialties, the greater the amount of content, order sets, rules and policies must be made and maintained
Compensation to non-IT resources	Compensation for ongoing nursing, unit coordinator and physician involvement with the rollout and support of CPOE application	1. Size of facility, number of clinician users 2. Implementation philosophy at facility: degree of involvement of end users. In some facilities, all staff support is done through IT-based personnel, with minimal involvement of end users. In others, end users are integrally involved in decision-making and support

Group 2: Items necessary for CPOE, but leverageable by other applications		
Item	Definition	Cost Drivers
Workstations: MD (Initial costs and maintenance/ replacement)	Additional workstations to support CPOE implementation; initial, maintenance and replacement	1. If clinical applications have already been deployed (such as Patient Demographics, Results Review, Medication Administration), there may be less need for additional workstations. Additional workstations purchased can be used for multiple purposes. 2. Size of facility, number of care units, number of end users, number of applications being used
Laptop mobile carts (Initial costs and maintenance/ replace-ment	Laptop carts to provide mobility for laptops; initial, maintenance and replacement	1. If medication administration application is also deployed or being deployed, laptop carts may support laptops being used for both applications 2. Only needed if laptops are being deployed and if mobility is desired 3. Number depends on size of facility, number and configuration of care units, and workflow that is being designed (e.g., whether orders will be written during rounds, whether medication administration will be recorded at bedside)
Business Continuity Plan/Tools (Initial costs and maintenance)	Hardware and software to support 100 percent uptime. This typically means redundant networks, application servers, and data bases Options: 1. If system is hosted by site, costs will be incurred by site; 2. If application is remotely hosted, license will likely include costs of business continuity	1. Size of the facility, number of applications, size of the database will determine amount of resources needed to support 100% uptime 2. Hardware and software costs (and maintenance) must be borne by facility if system is hosted by facility 3. If system is hosted remotely, cost of backup systems will be included in monthly subscription costs
Medication Administration Software License Cost (Initial costs and maintenance)	License and maintenance fees for medication administration software (note: NOT bar-coded medication administration).	1. Complexity and sophistication of the software. Different software packages have different degrees of complexity in terms of configurability, decision support, features and functions. Lower-featured products will cost less to license and to implement. 2. Bed size (as indicator of patient population, volume of orders, number of end users)

Group 3: Items that may be required, but these costs were not incurred by pilot sites		
Item	Definition	Cost Drivers
Training: MD Training (Initial costs for implementation)	Payment for physicians for time spent in training classes Note: In the pilot sites, training was conducted "on the job." Physicians were not paid to come to training	1. Number of MDs to be trained 2. Arrangement for training. Some sites train physicians "on demand," at the point of care. While convenient (and perhaps more effective) for physicians, this poses a demand on trainers, who have difficulty planning their time. Also, one-on-one training is inherently more expensive than group training. The alternative is to schedule group classes as part of implementation and as part of physician orientation to the facility. 3. Availability of self-administered, self-paced computer-based training (CBT) may reduce need for on-demand in-person training, though there is considerable cost in developing and maintaining CBT. The number of users to be trained, and whether MD's are frequent or only occasional users may influence whether CBT is a good alternative or supplement to traditional training methods.
Interfaces (Initial costs and maintenance)	Software license fees and implementation costs to install a new interface. For example, interfacing CPOE to another vendor's pharmacy system or medication administration system Note: In the pilot sites, CPOE was implemented within an integrated HIS system, so interfaces were not necessary	1. The number of systems to be interfaced, and whether the interface must be bi-directional or not. Possibilities include CPOE and pharmacy; CPOE and medication administration application; CPOE and administrative systems such as ADT, billing. 2. The degree to which the sending and receiving systems adhere to messaging standards such as HL7, and whether the versions used are up-to-date 3. Whether the sending and receiving systems use the same drug classification system

Group 4: Items useful for CPOE, not necessarily required by all institutions		
Item	Definition	Cost Drivers
Third party software: content for evidence-based order sets (Initial costs and maintenance)	License and maintenance fees for third party software that supports evidence-based order sets Alternative option: An organization may decide to develop its own order sets using already-developed resources and existing committees	The number of specialties for which order sets are required The vendor, and whether the vendor's software and content can easily be integrated into the CPOE product. Various vendors offer more or less compatibility with various CPOE products.
Other training costs (Initial costs and maintenance)	E.g., payment for development of custom-developed computer-based training course, payment for training in use of evidence-based content software	1. Cost for development of CBT varies widely depending on a) the developer; b) the degree of interactivity of the software; and c) the amount of reporting that must be supplied 2. The complexity of the system being taught
Handheld devices: MD/Nursing (Initial costs and maintenance/ replacement)	Additional end user devices to support CPOE implementation; initial, maintenance and replacement	1. Number of end users, ratio of devices to end users

APPENDIX 4: IT Capital and On-Going Costs

Table 1: Detail of Capital and One-Time Operating Costs, Average Per Site	
Cost Item	Average
Hardware/Software	$512,201
Implementation	$1,380,067
Training	$81,520
Construction	$57,200
TOTAL	$2,078,000
Capital and one-time cost per bed	$10,057

Table 2: Detail of Ongoing Operating Costs, Average Per Site	
Cost Item	Average
Hardware/Software	$183,339
Staffing to support CPOE	$227,253
Non-IT resources	$14,000
TOTAL	$435,914
Ongoing operating cost per bed	$2,141

APPENDIX 5:
Key Assumptions Applied for Net Benefit and Payback Period Analysis

1. Key assumptions applied to each Aim of the study

a) Aim 1 – Rate of preventable Adverse Drug Events (ADE)

- An additional 4.6 days per inpatient stay is attributed to each occurrence of a preventable ADE[3]
- Potential benefits are measured over all adult inpatient stays at each site
- The rate of preventable ADEs is a measurement of unique patient visits (Rate /100 admits)
- Only hospital variable costs are applied to these calculations
- Payers only show the potential for savings under per diem and fee-for-service reimbursement arrangements

b) Aim 2 – Expensive drug usage

- Only hospital variable costs are applied to these calculations

c) Aim 3 – Rate of preventable Adverse Drug Events (ADE) from renal dosing errors

- An additional 4.6 days per inpatient stay is attributed to each occurrence of a preventable ADE
- The rate is applied to inpatient stays for patients with renal insufficiency
- The rate of preventable ADEs is a measurement of unique patient visits (Rate /100 admits)
- Only hospital variable costs are applied to these calculations
- Payers only show the potential for savings under per diem and fee-for-service reimbursement arrangements

d) Aim 4 – Intravenous to oral failures

- Only hospital variable costs are applied to these calculations

e) Aim 5 – Redundant Lab Tests

- Only hospital variable costs are applied to these calculations

2. Key assumptions applied to payback period analysis

- Annual operational impact is measured in 2006 dollars

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