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Implementing Computerized Provider Order Entry in Acute Care Hospitals in the United States Could Generate Substantial Savings to Society

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Abstract

Background: Computerized provider order entry (CPOE) with clinical decision support is a basic criterion for hospitals' meaningful use of electronic health record systems. Yet the cost-effectiveness of CPOE has not been evaluated from the societal perspective. A study was conducted to evaluate the cost-utility of implementing CPOE in acute care hospitals in the United States.

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Methods: A decision-analytical model compared CPOE with paper ordering among patients admitted to acute care hospitals with ≥ 25 beds. Parameters included start-up and maintenance costs, as well as costs for provider time use, medication and laboratory test ordering, and preventable adverse drug events. Data sources included published literature and data, both searched in September 2013. Probabilistic analyses produced incremental costs, effectiveness, and cost-effectiveness ratios for hospitals in four bed-size categories (25–72, 72–141, 141–267, 267–2,249).

Results: Relative to paper ordering, CPOE had, on average, > 99% probability of yielding saving to society and improving health (that is, "dominates"). Per hospital in each size category, mean lifetime savings–in millions–were $11.6 (standard deviation [SD] $9.30), $34.4 ($21.2), $71.8 ($43.8), and $170 ($119) (2012 dollars), respectively, and quality-adjusted life-years (QALYs) gained were 19.9 (16.9), 53.7 (38.7), 109 (79.6), and 249 (205). Incremental effectiveness and costs were less favorable in certain circumstances, such as high implementation costs. Nationwide, anticipated increases in CPOE implementation from 2009 through 2015 could save $133 billion and 201,000 QALYs.

Conclusions: In addition to improving health, the CPOE requirement of the HITECH Act could yield substantial long-term savings to society in the United States, although results for individual hospitals are likely to vary.

The 2009 Health Information Technology for Economic and Clinical Health (HITECH) Act, part of the American Reinvestment and Recovery Act, provides approximately $30 billion in a 10-year period for the implementation and meaningful use of electronic health record systems (EHRs) by hospitals and healthcare providers.[1] One of the basic (Stage 1) criteria that hospitals must satisfy to demonstrate meaningful use is implementing computerized provider order entry (CPOE) with clinical decision support, specifically with checks for allergies and drug-drug interactions.[2] Hospitals were first eligible for HITECH subsidies beginning in 2011, and hospitals failing to attain meaningful use by 2015 may incur fines.[3] Nonetheless, a minority of hospitals have adopted EHRs with CPOE. In 2008, about 9% of general acute care hospitals had EHR systems with CPOE for medications.[4] In 2012, 44% did, including 38% of small, 47% of medium, and 62% of large hospitals.[5] By 2013, 59% had fully implemented at least a basic EHR system with CPOE for medications, and 94% of hospitals had a contractual agreement with an EHR vendor.[6]

Debate about the value of CPOE persists. About half of hospitals in one survey reported that implementing CPOE was a major barrier to attaining meaningful use.[4] On the one hand, CPOE reduces prescribing errors, the most common cause of injuries due to medication errors— preventable adverse drug events (pADEs)—among hospitalized patients.[7] An ADE adds approximately $2,400 to hospitalization costs (inflated to 2012)[8–10] and can create additional costs after discharge.[11–14] On the other hand, hospital administrators have reason to be concerned about implementation costs, and physicians, about the additional time spent entering orders via computer rather than on paper.[15]

Despite the scope and cost of the HITECH Act, no study appears to have evaluated whether implementing CPOE represents a good value to society. Previous studies have assessed the value of CPOE from the hospital perspective, which has important limitations. First, the hospital perspective underestimates CPOE's cost by omitting the value of the time that physicians and other providers spend placing orders. Second, it ignores long-term health effects and savings that may occur through reductions in pADEs. Finally, standards for conducting cost-effectiveness analysis recommend using the societal perspective, in part because it can inform public policy questions.[16]

In the study that we report in this article, our objective was to evaluate, from the societal perspective, the cost-effectiveness (specifically, cost-utility) of implementing CPOE in acute care hospitals in the United States, relative to using paper-based ordering systems. We created a probability model depicting CPOE's effects in individual, hypothetical acute care hospitals in four bed-size categories. The model considers costs incurred during the useful lifespan of a CPOE system, including costs associated with adding CPOE system to an EHR, as well as the effects of CPOE on provider time use, medication utilization, and laboratory testing. It also considers effects on medication errors and pADEs, including costs and health-related quality of life over hospitalized patients' remaining lifespans. Model parameters were based on systematic reviews of published literature and data from the American Hospital Association (AHA).

Methods

The analysis involved (1) developing the probability model; (2) deriving hospital-related parameters from AHA data; (3) conducting literature searches and developing model parameters related to CPOE and medication events; (4) estimating quality-adjusted life years (QALYs) lost to pADEs; (5) performing analyses that accounted for potential variability in CPOE implementation costs; and (6) conducting sensitivity analyses. We adhered to the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) and the Panel on Cost-effectiveness in Health and Medicine.[16,18] Further details can be found in an Appendix. All data were derived from published sources.

Probability Model

The probability (that is, decision) model (Appendix, Sections 1 and 2) compares CPOE with paper ordering systems. Model branches for both paper and computerized ordering systems include (1) whether a patient experiences a medication errors (yes, no), (2) whether the error produces a pADE (yes, no), (3) the age (years) of the patient experiencing the pADEs (18–44, 45–54, 55–64, 65–74, 75–84, 85+), and (4) the outcome of the pADE (fatal, life threatening, permanently disabling, serious, significant). To account for the effectiveness of CPOE, branch (1) also includes the relative risk of an error after CPOE implementation.

These branches depict events affecting individual patients, while the full model summarizes events across an individual, hypothetical hospital. To scale the model from the patient to hospital level, we multiplied each branch by admissions per year and embedded equations in the model that calculate certain parameters on the basis of hospital bed size.

Hospital-related Parameters

Of 6,335 hospitals in the 2009 AHA survey, we selected 4,891 general medical and surgical hospitals, excluding psychiatric, pediatric, long-term care, cancer, and rehabilitation facilities (Appendix Section 5). We used bed size to create quintiles with equal numbers of hospitals. We excluded Quintile 1 (≤ 25 beds) because cost data were limited; these hospitals serve 2% of patients nationwide.[19]

Next, we estimated regression models to predict the following size-related parameters as functions of the number of beds plus beds squared: admissions per year, inpatient days, resident physicians, licensed vocational nurses, RNs, pharmacists, hospitalists and intensivists. We used the resulting intercepts and coefficients to create the aforementioned equations embedded in the probability model that estimate parameter values based on hospital bed size.

Parameters on Computerized Provider Order Entry and Medication Events

Effectiveness of CPOE.—In an associated systematic review and meta-analysis, which included a September 2013 search of MEDLINE, the Cochrane Collabora6tion, 23 web-based databases, "grey literature," and references in selected articles, we examined changes in medication errors and ADEs following CPOE implementation in acute care hospitals (Appendix Section 3). On the basis of 16 eligible studies that compared CPOE with paper ordering systems, the mean relative risk of medication errors was 0.46 (95% CI 0.35–0.60); pADEs decreased to an almost identical degree. There was no significant difference in effectiveness between studies with and without clinical decision support (Appendix Section 4).[20]

CPOE-related Costs.—We sought studies addressing CPOE implementation costs (capital expenditures and maintenance costs), changes in provider work flow, and other potential changes in costs incurred during the useful lifespan of a CPOE system. To identify relevant literature, in September 2013, as part of our work for a previous article,[20] we searched the same databases, with the same search terms and different inclusion criteria, and then searched reference lists in some of the identified articles (Appendix Section 3). Study selection criteria consisted of originality, being based on data for multiple hospitals, including various capital and maintenance costs (for example, hardware and software, training hospital staff members, technical support, and consulting charges, among other costs), examining the cost of CPOE implementation, and having detailed descriptions of methods (Appendix Section 5).

The basic cost of CPOE implementation involves adding CPOE to an EHR. However, CPOE often functions as part of the EHR, which can include an increasing array of other components, such as notes, order sets, and billing functions. Some but not all of the EHR implementation cost could, arguably, be attributed to CPOE. Because few, if any, studies have quantified the clinical benefits and costs of other EHR components, we handled this "joint production" problem in three ways. First, we defined the analytical problem narrowly, focusing exclusively on the clinical effects (pADEs) and costs most clearly linked to CPOE. Second, we considered a range of costs in our models (18 scenarios that represented costs equal to 0.2 to 8 times the values used in the base case scenario), examining incremental cost and incremental cost-effectiveness as functions of CPOE implementation costs. Third, in a sensitivity analysis we attributed all EHR costs to CPOE.

For implementation costs, three studies met selection criteria for the base-case analysis; there were no nationally representative analyses. Zimlichman et al. described CPOE capital expenditures and maintenance costs in 2011–2012 at four hospitals, each with 100–300, and reported cost per admission.[21] Ohsfeldt et al. provided two equations that use bed size to estimate CPOE capital expenditures and maintenance costs; the equations were based on data from 2001 for one vendor and 74 hospitals.[22] The Congressional Budget Office estimated CPOE capital expenditures and maintenance costs as functions of bed size on the basis of a study of five hospitals in 2001.[23,24] Because of the timeliness of the Zimlichman et al. data, these estimates were used in the base-case analysis. A RAND report estimated EHR implementation costs at 27 hospitals in 2003[25]; no other eligible studies were identified. Figure 1 shows CPOE and EHR implementation costs, as derived from these sources, as a function of bed size.

Next, we examined CPOE's effects on the work flow of interns, nurses, pharmacists, and attending physicians. Incremental annual costs were calculated as the follows:

(time lost or gained per provider per day) × (providers per hospital) × (days worked per year) × (hourly wage plus benefits).

Finally, because CPOE with CDS can reduce laboratory test and medication expenditures, creating cost offsets,[26,27] equations in the model accounted for these effects.

Medication Event Rates and Outcomes.: To estimate baseline rates of medication errors, pADEs, and outcomes of pADEs, we used data from control groups in the studies of CPOE effectiveness included in the meta-analysis (Appendix Section 4). The median proportion of patients in the control groups that experienced medication errors was 0.47 across 13 studies (range, 0.05–1.0), and the median proportion of errors that caused pADEs was 0.11 across seven studies (range, 0.02–0.43). Proportions of pADEs resulting in various outcomes were based on these and similar sources: fatal (median, 0.008; range, 0.006–0.01); life-threatening (0.135; 0.02–0.20); permanently disabling (0.0023; 0.0015–0.003); serious (0.355; 0.09–0.70); significant (1 – sum of other proportions).[20] We adjusted the fatal pADE rate for pre-event life expectancy.[28]

Medication Event Costs.: A separate systematic search of the same data sources addressed the costs associated with ADEs. Regarding ADE costs, Hug et al. reported hospitalization costs for life-threatening, serious, and significant ADEs in five community hospitals[10]; we extrapolated costs for life-threatening ADEs to fatal and disabling ones. Other studies of ADE costs provided ranges for probability distributions (Appendix Section 6). To estimate the cost of inpatient physician and lifelong postdischarge care, we extrapolated from a study of adverse events.[11] We used ADEs' effects on length of stay to estimate patients' time in care and family members' time providing informal care.[10]

Because we took the societal perspective, we did not include lost revenue (from reduced laboratory testing), subsidies (which compensate hospitals for a portion of implementation costs), litigation (a transfer of costs), or lost productivity (encompassed by health-related quality of life).[16]

QALYs Lost to Medication Events.: To estimate QALYs lost per fatal pADE, we used the ages of people experiencing pADEs,[7] life-table data,[29] health-related quality-of-life data,[30] and population data (Appendix Section 6).[31] For permanently disabling pADEs, we used these sources and estimated changes in health-related quality of life used in a previous analysis.[32] For fatal pADEs, we calculated the added cost of premature funerals (using life tables and the present value of future funeral expenses).[32] Other outcomes are, by definition, temporary so attributable QALYs are modest (Appendix Section 6).

Modeling

To estimate incremental effectiveness, incremental costs, and incremental cost-effectiveness ratios (ICERs) across a wide range of potential CPOE implementation costs, we performed 18 simulations for each of the four different bed-size quintiles. The incremental costs and effectiveness discussed above occurred during the useful lifespan of the new CPOE systems, as well as during the remaining lifetimes of patients who were admitted while the systems were in use. Each simulation involved 10,000 Monte Carlo trials, thereby representing conditions across 10,000 hypothetical hospitals in each bed-size quintile. On the basis of the results of each simulation, we determined the probability that implementing CPOE would be effective and cost saving (incremental cost < 0), cost-effective (incremental cost-effectiveness ratio < $200,000), or neither (incremental cost ≥ 0 and incremental cost-effectiveness ratio ≥ $200,000).

Analyses were performed in TreeAge Pro 2012, R2.1 (TreeAge Software, Inc; Williamstown, Massachusetts). Probabilistic (Monte Carlo) analyses accounted for variability and uncertainty in model parameters; these required developing probability distributions for each parameter. We obtained data for 2009, the year the HITECH Act passed, and then inflated results to 2012 dollars for ease of interpretation.

We used triangular distributions of probabilities for most parameters (apex = median value, range = low to high values observed across studies) to account for variability in parameter estimates across different data sources. For bed size, Quintiles 2 through 4 were uniformly distributed, and Quintile 5 had skewed distribution that was best fit by a log-normal distribution. Most cost parameters were estimated as functions of bed size, as noted above (Appendix Section 5). We did not create distributions when only one data source was available for a parameter. With routine maintenance, CPOE has a useful lifespan of about 10 (range, 8–20) years.[34,35] We discounted future costs and QALYs at a rate of 3%.[16]

The base case scenario used a willingness-to-pay threshold of $200,000 per QALY, on the basis of empirical studies.[35]

One-way Sensitivity Analyses

We varied parameter values from the low to high end of ranges used in the base case scenario and examined effects on incremental cost and incremental effectiveness. For willingness-to-pay, sensitivity analyses considered $50,000 and $100,000.

Nationwide Effects

We estimated baseline CPOE adoption rates using 2009 data,[5,37] and assumed that 85% of hospitals would adopt CPOE by 2015, on the basis of national surveys.[38]

Results

Study Hospitals

Table 1 describes the characteristics of hospitals in Quintiles 2 through 5.

Component Costs

Table 2 presents component costs derived during the base case modeling steps, including CPOE implementation costs as well as costs related to changes in provider work flow, the ordering of medications and laboratory tests, and medication events. As seen in the table, changes in work flow for physicians resulted in costs, whereas those for nurses and pharmacists resulted in cost offsets.

Incremental Cost, Effectiveness, and Cost-Effectiveness

In the base case scenario, CPOE dominated paper ordering, meaning that it was, on average, less costly and improved health. Per hospital in each of the four quintiles, mean savings—in millions—were $11.6 (standard deviation [SD], $9.30), 34.4 ($21.2), $71.8 ($43.8), and $170 ($119) , respectively, and mean QALYs gained were 19.9 (SD, 16.9), 53.7 (38.7), 109 (79.6), and 249 (205).

Sensitivity Analyses

Figure 2 shows the results of altering model parameters values from lower to upper end of ranges used in the base case analysis for Quintile 2, the bed-size category least likely to find CPOE cost saving or cost-effective. Parameters that had the largest effect on both incremental costs and incremental effectiveness included the proportion of medication errors leading to pADEs, the baseline proportion of hospitalizations affected by medication errors, and bed size. Incremental effectiveness is lower and costs are higher when hospitals have low baseline rates of medication errors or pADEs, when CPOE is less effective at reducing errors, and when the useful lifespan of CPOE is shorter.

Nationwide Effects

Considering results for the base case scenario and assuming that 85% of hospitals will adopt CPOE nationally, the financial savings to society would equal $133 billion and 201,000 QALYs would be gained over the long term.

Probability of Savings

In Figure 3, each of the four graphs (one for each quintile) depicts the probability that implementing CPOE will be cost saving (and effective; that is, dominate) or cost-effective as a function of CPOE implementation costs. Each data point represents results for 10,000 hypothetical hospitals.

Across the four bed size quintiles, the probability that implementing CPOE in an individual, hypothetical hospital would be cost saving to society exceeds 99% using base case implementation costs. The probability of savings remains above 95% across all four quintiles even if implementation costs are doubled. With rising implementation costs, the probability of savings declines more rapidly for the smaller hospitals, particularly those in Quintile 2; that is, larger hospitals experience economies of scale.

The mean cost of EHR implementation would be $11.2 million for Quintile 2, $22.8 million for Quintile 3, $50.1 million for Quintile 4, and $140.8 million for Quintile 5. Including these costs, the probability of CPOE dominating paper ordering declines substantially but remains above 50% (not shown).

Discussion

The cost-utility analysis reported in this article estimated, for acute care hospitals with at least 25 beds, the probability that implementing CPOE as a component of an EHR system would be cost saving or cost-effective, relative to using paper ordering systems. Across a range of previously reported estimates of CPOE implementation costs, the probability that CPOE would generate savings in addition to improving health outcomes exceeds 70% to 99%. Implementing CPOE could generate an average of $11.6 million to $170 million and 20 to 249 QALYs per hospital, depending on hospital size. Yet the standard deviations on these effects were wide, indicating that results are likely to vary greatly across individual hospitals. Also, sensitivity analyses revealed that incremental effectiveness and costs are less favorable in certain circumstances, such as when implementation costs are high, baseline rates of pADEs are low, or CPOE is less effective. Extrapolating mean estimates nationwide, society could save $133 billion and gain 201,000 QALYs, relative to rates at which CPOE was implemented before the HITECH Act was announced. Savings would be greater at larger hospitals.

Our findings build on three previous studies that examined whether CPOE results in savings from the hospital or health care payer perspective,[39] for which the conclusions were mixed. At Brigham and Women's Hospital (Boston), a homegrown CPOE system with extensive clinical decision support saved about $42 million (inflated to 2012) over a 10-year period, with net savings first occurring after five years.[40] At three University of Toronto hospitals, a commercial CPOE module cost the hospitals $21,335 (inflated to 2012) per ADE prevented over a 10-year period, on the basis of effectiveness data from Brigham and Women's Hospital.[34] Implementing CPOE in a 400-bed hospital would cost the United Kingdom National Health Service $15,403 to -$658 million (converted to 2012 dollars) in a five-year period, with costs much more likely than savings.[32] However, these studies did not consider the substantial costs associated with effects on provider time use or costs that occur after hospital discharge. A study examining the value of CPOE from the perspective of a midsize ambulatory clinic did consider provider efficiency—and found that CPOE dominated paper ordering.[40] However, no previous study has revealed CPOE's value to society, as our study has. The estimated $133 billion in net savings to society from hospital-based CPOE alone is greater than the HITECH Act's investment of $30 billion.

HITECH incentive payments are relevant to what economists call "externalities" in the market for CPOE. Despite the fact that CPOE appears likely to improve health and saves society money over the long term, hospital adoption rates remained low for many years, because of hospitals' concerns about questionable returns on investment, high upfront costs, technical and logistical issues, and physician resistance. [40–42] Under HITECH, each hospital attaining meaningful use can receive up to $7.7 to $17.8 million in incentive payments.[43] Adoption of EHR systems with CPOE has accelerated substantially in recent years, although many hospitals still have not adopted.[5,6] One potential deterrent may be ongoing physician resistance, particularly given the high cost of the time that physicians spend using CPOE systems. However, our systematic review of the literature and modeling efforts indicate that the costs associated with decreases in physician efficiency are smaller than the savings from efficiency gains among nurses and pharmacists. Further, a majority of physicians are now employed by hospitals, which may affect who bears the cost of using CPOE systems.[44] Similar types of issues related to externalities are likely to exist for other patient safety and quality improvement interventions.

Limitations to our analysis include the fact that little recent and no national data exist on CPOE implementation costs, and few, if any, studies address the clinical benefits and costs of other EHR components; however, we considered a wide range of implementation costs. Also, we have underestimated the benefits and savings from implementing CPOE because clinical decision support does more than prevent medication errors occurring during hospitalization.[44–46] For example, we did not include effects on radiological imaging.

We excluded pediatric hospitals, where only Medicaid incentives apply, and hospitals with ≤25 beds, most of which admit < 1,150 patients per year and, therefore, are eligible for smaller HITECH subsidies[42]) When estimating nationwide effects, we used data from periods after adoption had already started to rise, thereby underestimating potential benefits. One study documented an increase in mortality after CPOE implementation; therefore, harms are possible.[47]

Conclusion

The probability that implementing CPOE in acute care hospitals would, on average, yield cost savings to society exceeds 99% using available estimates of implementation costs. Even at small hospitals, which do not enjoy economies of scale, the probability of savings exceeds 70% unless implementation costs are more than twice as high as reported. Results are likely to vary greatly across individual hospitals, however, and less favorable effects can occur in certain circumstances. Over the lifetimes of patients admitted to the hospitals using these systems nationwide in the United States, it appears likely that society would more than recoup the shorter-term implementation costs.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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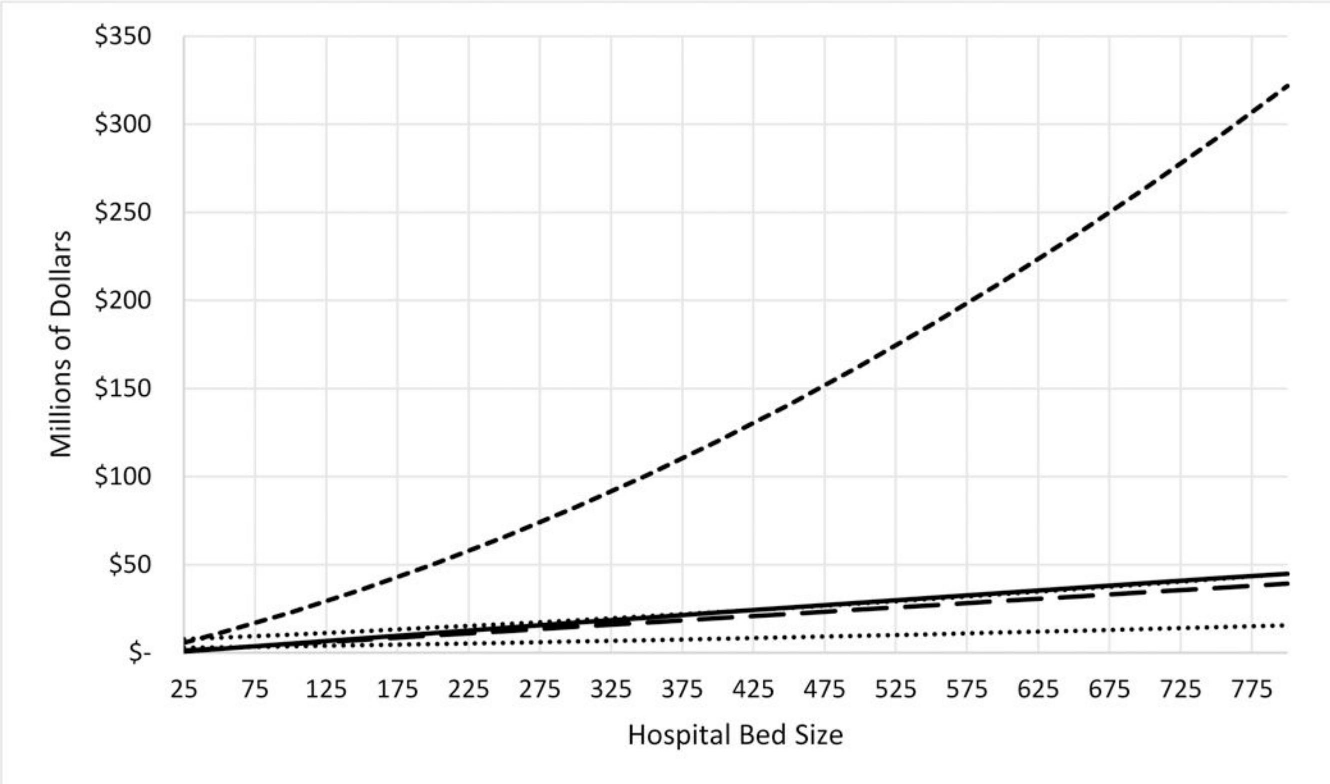


Figure 1. Computer Provider Order Entry (CPOE) and Electronic Health Record (EHR) Implementation Costs per Hospital.

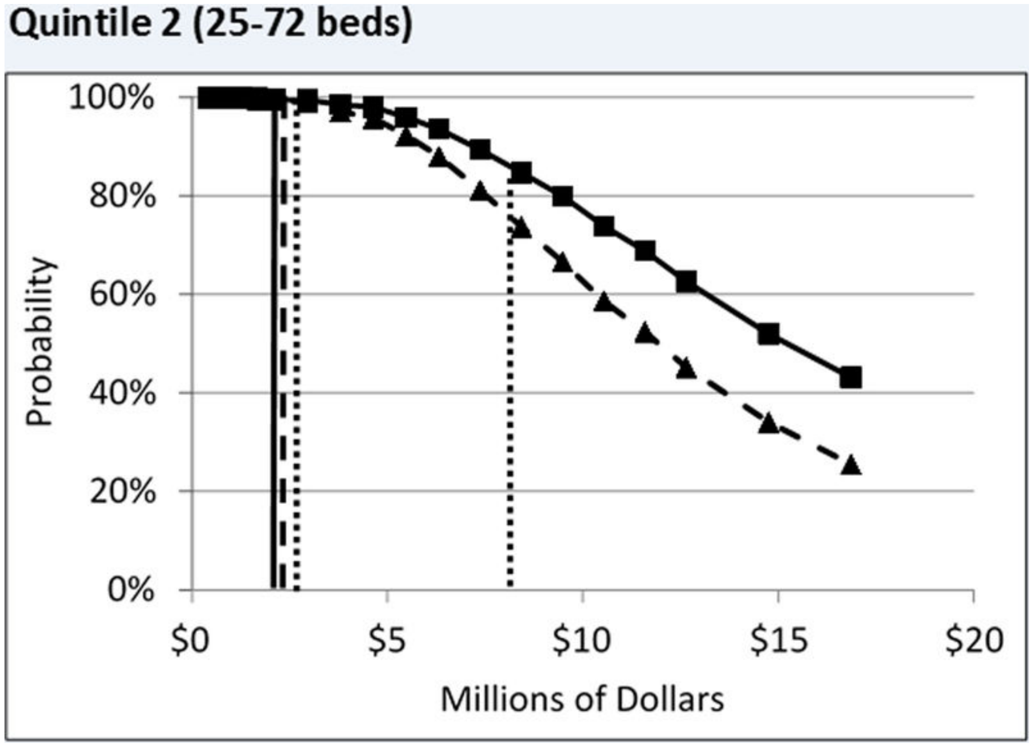
Sources of CPOE and EHR Implementation costs, as derived from these studies, are shown as a function of bed size.

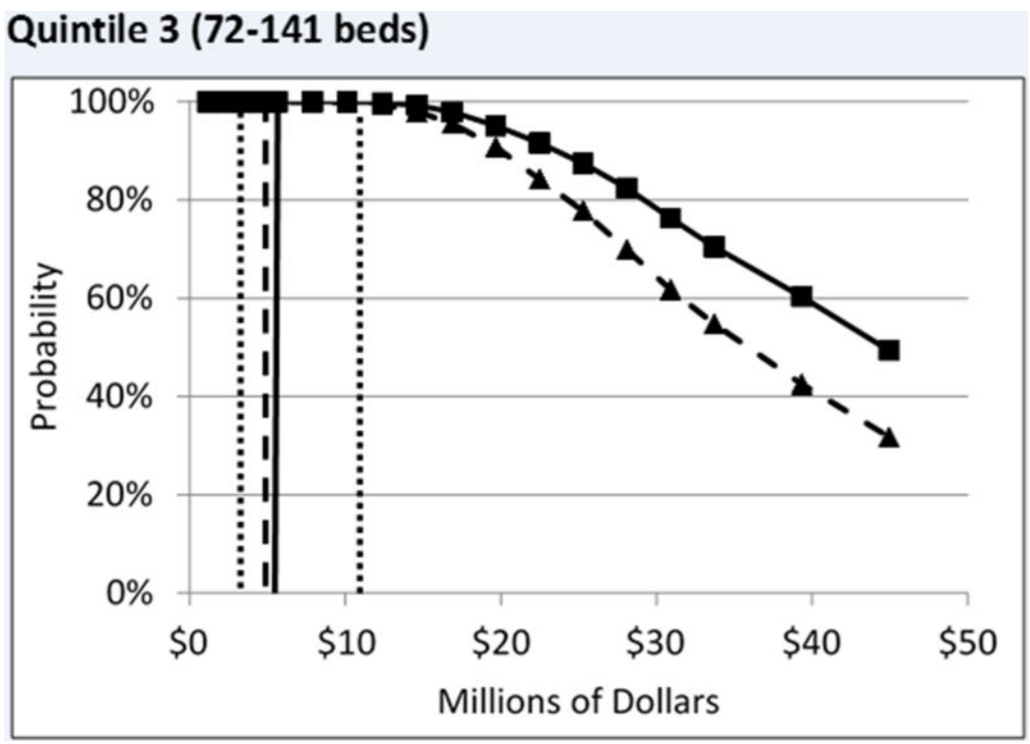
━━━━━ = CPOE (Zimlichman 2013 Base Case Scenario) (Reference 21)

— — — = CPOE (Congressional Budget Office 2008) (Reference 23)

▪▪▪▪▪▪▪▪▪ = CPOE (Ohsfeldt 2005 (Low & High) (Reference 22)

▬ ▬ ▬ ▬ = EHR (RAND 2003) (Reference 25)


Quintile 2 (25-72 beds)
Probability
100%
80%
60%
40%
20%
0%
$0
$5
$10
$15
$20
Millions of Dollars


Quintile 3 (72-141 beds)
Probability
100%
80%
60%
40%
20%
0%
$0
$10
$20
$30
$40
$50
Millions of Dollars

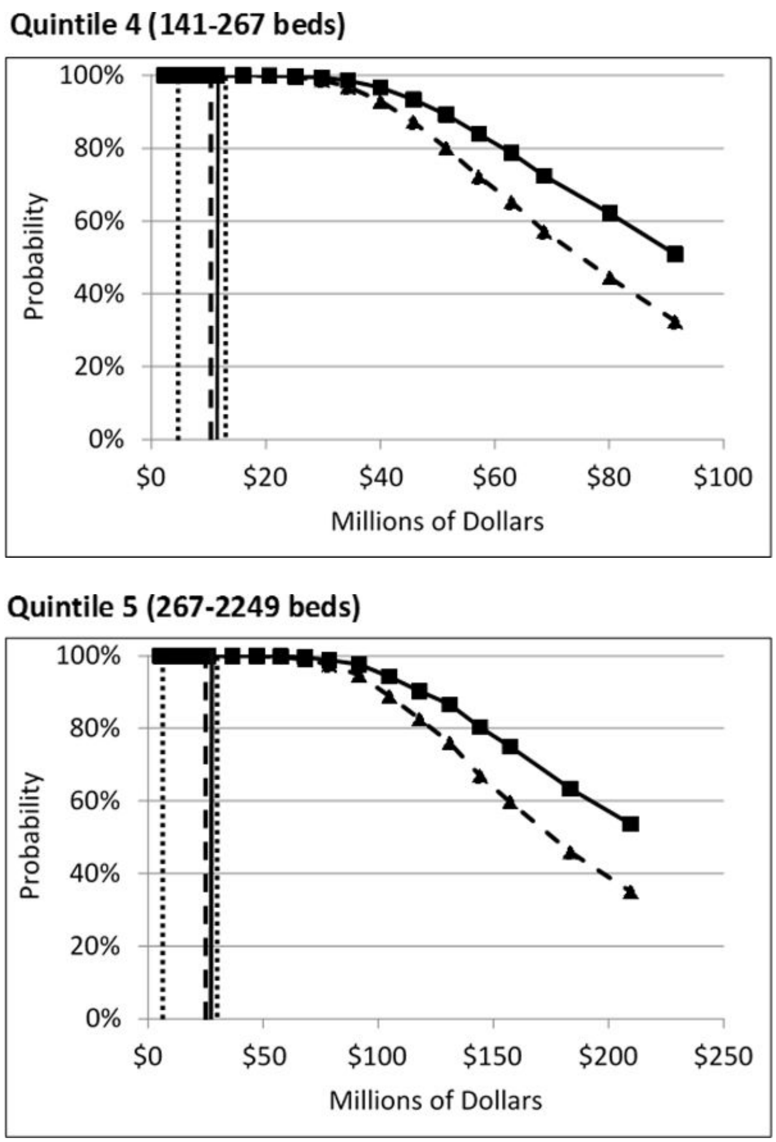


Figure 2: Main Results: Probability that Implementing Computer Provider Order Entry (CPOE) Will Be Cost Saving or Cost-Effective as a Function of Total Implementation Cost in Hospitals in Four Bed-Size Quintiles.

Each of the four graphs (one for each quartile) depicts the probability that implementing CPOE will be cost saving (and effective; that is, dominant) or cost-effective as a function of CPOE implementation costs. Each data point represents results for 10,000 hypothetical hospitals. Probabilities are related to the base case scenario. Quintile 1 (≤ 25 beds) was excluded because cost data were limited.

—■— Cost Effective if Willing to Pay up to $200,000 per QALY

– ▲ – Dominant: Cost Saving and Effective

▬▬▬ = Zimlichman 2013 (Base Case Scenario)

▬ ▬ ▬ = Congressional Budget Office 2008

▪▪▪▪▪▪▪▪▪▪ = Ohsfeldt 2005 (Low & High)

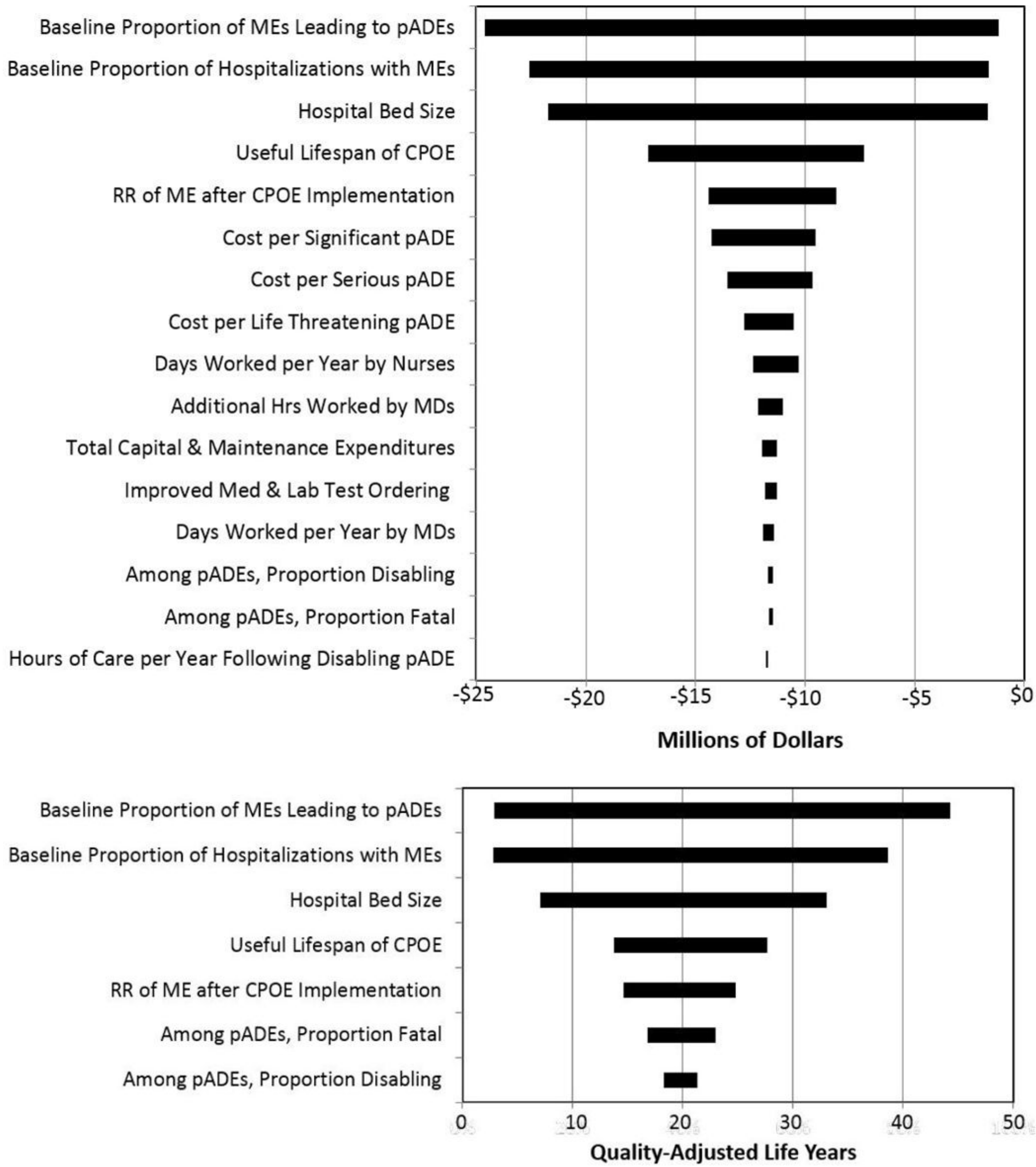


Figure 3: Sensitivity Analysis: Incremental Cost and Effectiveness of CPOE Versus Paper Ordering in Quintile 2 Hospitals, Varying Model Parameters from Lower to Upper End of Ranges Used in Base Case Analysis.

The figure shows the results of altering model parameters values from lower to upper end of ranges used in the base case analysis for Quintile 2, the bed-size category least likely to find

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computer provider order entry (CPOE) cost saving or cost-effective. The proportion of medication errors leading to preventable adverse drug events (pADEs), the baseline proportion of hospitalizations affected by medication errors (MEs), and bed size had the largest effect on both incremental costs and incremental effectiveness. RR, relative risk; hrs, hours

Table 1.

Characteristics of Acute Care Hospitals in the United States for Each of Five Equally Sized Quintiles*

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
	(N = 979)	(N = 978)	(N = 978)	(N = 978)	(N = 978)
Hospital Characteristics					
Bed Size†					
Range	Up to 25	25–72	72–141	141–267	267–2,249
Mean (SD)	21.2 (5.3)	48.6 (13.2)	104 (19.7)	198 (35.5)	464 (223)
Region, *N* (%)					
New England & Mid-Atlantic	43 (4.4%)	65 (6.6%)	113 (11.6%)	180 (18.4%)	199 (20.3%)
South	348 (35.6%)	410 (41.9%)	373 (38.1%)	354 (36.2%)	383 (39.2%)
North Central (Midwest)	413 (42.2%)	273 (27.9%)	284 (29.0%)	234 (23.9%)	218 (22.3%)
Mountain	113 (11.5%)	102 (10.4%)	73 (7.5%)	59 (6.0%)	52 (5.3%)
Pacific & Territories	62 (6.3%)	128 (13.1%)	135 (13.8%)	151 (15.4%)	126 (12.9%)
Total	100%	100%	100%	100%	100%
Urban, *N* (%)	22 (2.2%)	51 (5.2%)	73 (7.5%)	179 (18.3%)	378 (38.7%)
Profit Status, *N* (%)					
Not-for-Profit	461 (47.1%)	451 (46.1%)	535 (54.7%)	631 (64.5%)	688 (70.3%)
For-Profit	120 (12.3%)	181 (18.5%)	224 (22.9%)	185 (18.9%)	104 (10.6%)
Public	398 (40.7%)	346 (35.4%)	219 (22.4%)	162 (16.6%)	186 (19.0%)
Teaching, *N* (%)					
Medical School	47 (4.8%)	82 (8.4%)	139 (14.2%)	313 (32.0%)	610 (62.4%)
Accredited Residency	5 (0.5%)	28 (2.9%)	72 (7.4%)	221 (22.6%)	552 (56.4%)
Special Designations, *N* (%)					
Critical Access Hospital	824 (84.2%)	286 (29.2%)	148 (15.1%)	16 (1.6%)	1 (0.1%)
Rural Referral Center	0 (0%)	13 (1.3%)	99 (10.1%)	138 (14.1%)	58 (5.9%)
Sole Community Provider	27 (2.8%)	169 (17.3%)	145 (14.8%)	86 (8.8%)	29 (3.0%)
Full-Time Providers per Hospital, Mean (SD)					
Nurses	28.9 (17.5)	59.3 (40.6)	121 (73.7)	249 (126)	708 (512)
Pharmacists	0.8 (1.5)	2.5 (4.1)	4.8 (5.5)	10.0 (8.8)	28.5 (25.1)
Hospitalists/Intensivists	0.2 (1.0)	1.2 (11.1)	2.0 (3.9)	4.7 (10.6)	15.3 (23.4)
Residents	0.04 (0.5)	0.7 (3.4)	3.4 (26.6)	10.6 (39)	87.1 (185)
Patient Characteristics					
Admissions, Mean (SD)	693 (451)	1,669 (1,098)	3,994 (2,248)	8,853 (3,737)	21,419 (11,505)
Inpatient Days, Mean (SD)	2,821 (1,684)	8,867 (4,323)	21,823 (7,934)	46,420 (13,683)	119,707 (67,586)
Payer, Mean % of Discharges (SD)					
Medicare	56.6 (17.9%)	49.8 (16.9%)	46.7 (14.3%)	43.9 (13.2%)	38.9 (13.8%)
Medicaid	10.5 (8.1%)	15.4 (10.2%)	17.2 (9.3%)	17.7 (10.0%)	19.3 (11.8%)
Other Payer	32.9 (18.1%)	34.8 (18.9%)	36.2 (16.0%)	38.4 (16.4%)	41.8 (17.0%)

SD, standard deviation.

*Includes general medical and surgical acute care hospitals that do not restrict admissions primarily to children. **Source:** American Hospital Association. Annual Survey Database for FY2009. Health Forum, LLC. 2010.

†The number of total facility beds that were set up and staffed at the end of the reporting period (end of 2009).

Table 2.

Results for Base Case Scenario: Mean Component Costs and Cost Offsets over the Useful Lifespan of Computer Provider Order Entry (CPOE) Systems, Hospital Bed Size Quintiles 2–5*

	Quintile 2	**Quintile 3**	**Quintile 4**	**Quintile 5**
Hospital Bed Size Range	25–72	72–141	141–267	267–2,249
CPOE-Related Costs				
Implementation Costs	$2,108,000	$5,618,000	$11,441,000	$26,196,000
Provider Work Flow				
Nonphysician Providers	−$4,941,000	−$13,532,000	−$28,151,000	−$67,392,000
Physicians	$2,001,000	$2,576,000	$3,570,000	$6,343,000
Ordering of Medications and Laboratory Tests	−$688,000	−$1,834,000	−$3,736,000	−$8,553,000
Medication Events	−$10,259,000	−$27,369,000	−$55,451,620	−$126,082,000

*Quintile 1 (≤ 25 beds) was excluded because cost data were limited; these hospitals serve 2% of patients nationwide. Source: American Hospital Association. Annual Survey Database for FY2009. Health Forum, LLC. 2010.