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Hospital Computing and the Costs and Quality of Care: A National Study

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ABSTRACT

BACKGROUND: Many believe that computerization will improve health care quality, reduce costs, and increase administrative efficiency. However, no previous studies have examined computerization's cost and quality impacts at a diverse national sample of hospitals.

METHODS: We linked data from an annual survey of computerization at approximately 4000 hospitals for the period from 2003 to 2007 with administrative cost data from Medicare Cost Reports and cost and quality data from the 2008 Dartmouth Health Atlas. We calculated an overall computerization score and 3 subscores based on 24 individual computer applications, including the use of computerized practitioner order entry and electronic medical records. We analyzed whether more computerized hospitals had lower costs of care or administration, or better quality. We also compared hospitals included on a list of the "100 Most Wired" with others.

RESULTS: More computerized hospitals had higher total costs in bivariate analyses ($r = 0.06$, $P = .001$) but not multivariate analyses ($P = .69$). Neither overall computerization scores nor subscores were consistently related to administrative costs, but hospitals that increased computerization faster had more rapid administrative cost increases ($P = .0001$). Higher overall computerization scores correlated weakly with better quality scores for acute myocardial infarction ($r = 0.07$, $P = .003$), but not for heart failure, pneumonia, or the 3 conditions combined. In multivariate analyses, more computerized hospitals had slightly better quality. Hospitals on the "Most Wired" list performed no better than others on quality, costs, or administrative costs.

CONCLUSION: As currently implemented, hospital computing might modestly improve process measures of quality but does not reduce administrative or overall costs.

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KEYWORDS: Hospital costs; Hospital quality; Information systems

Enthusiasm for health information technology spans the political spectrum, from Barack Obama to Newt Gingrich. Congress is pouring $19 billion into it. Health reformers of many stripes see computerization as a painless solution to the most vexing health policy problems, allowing simultaneous quality improvement and cost reduction.

Such optimism is not new. In the 1960s and 1970s, 16-mm films from IBM and the Lockheed Corporation touted hospital computing systems as a means to reduce paperwork and improve care.[1,2] By the 1990s, opinion leaders confidently predicted the rapid adoption and substantial benefits of computerized patient records,[3,4] including massive administrative savings.[5,6]

In 2005, one team of analysts projected annual savings of $77.8 billion,[7] whereas another foresaw more than $81 billion in savings plus substantial health gains[8] from the nationwide adoption of optimal computerization. Today, the federal government's health information technology website states (without reference) that "Broad use of health IT will: improve health care quality; prevent medical errors; reduce health care costs; increase administrative efficien-

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cies; decrease paperwork; and expand access to affordable care."[9]

Unfortunately, these attractive claims rest on scant data. A 2006 report prepared for the Agency for Healthcare Research and Quality,[10] as well an exhaustive systematic review,[11] found some evidence for cost and quality benefits of computerization at a few institutions, but little evidence of generalizability. Recent Congressional Budget Office reviews have been equally skeptical, citing the slim and inconsistent evidence base.[12,13] As these reviews note, no previous studies have examined the cost and quality impacts of computerization at a diverse national sample of hospitals.

CLINICAL SIGNIFICANCE

- Hospital computerization has not, thus far, achieved savings on clinical or administrative costs.
- More computerized hospitals might have a slight quality advantage for some conditions.
- No reliable data support claims of cost-savings or dramatic quality improvement from electronic medical records.

MATERIALS AND METHODS

Data Sources

We analyzed data from 3 sources: the Healthcare Information and Management Systems Society (HIMSS) Analytics annual survey of hospitals' computerization; the Medicare Cost Reports submitted to the Centers for Medicare and Medicaid Services; and the 2008 Dartmouth Health Atlas, which compiles Centers for Medicare and Medicaid Services data on the costs and quality of care that hospitals deliver to Medicare patients.

We used HIMSS surveys for the years 2003 to 2007 to assess the degree of hospital computerization. The survey's methods underwent changes in 2005. It annually queries approximately 4000 hospitals on the implementation of specific computer applications. It is the largest and most comprehensive longitudinal source of information regarding hospitals' adoption of information technology.

To quantify each hospital's computerization, we created a score (range, 0-1.00) by summing the number of computer applications reported as fully implemented and dividing by the number of applications for which data were available (a maximum of 24 applications for 2005-2007, 21 applications for 2003-2004). We used similar methods to calculate 3 subscores indicative of the degree of computerization in 3 domains: clinical, patient-related administration, and other administration. Finally, we examined the impact of 2 individual applications generally thought key to improving quality and efficiency: electronic medical records and computerized practitioner order entry. **Table 1** displays a list of all applications in the HIMSS surveys and our subscore classification scheme.

We used Medicare Cost Reports available from Centers for Medicare and Medicaid Services as of January 1, 2009, to calculate hospitals' administrative costs for each year from 2003 to 2007 and to establish hospitals' ownership (nonprofit, investor owned, or public), type (eg, acute care, psychiatric), location by state, urban/rural location, and teaching status. We calculated administration's share of each hospital's total costs as previously described.[14,15] The 0.18% of hospitals whose cost reports showed implausible figures (<5% or >80%) for the proportion spent on administration were treated as missing values.

The 2008 Dartmouth Atlas[16] reports 4 quality scores based on Medicare patients cared for from 2001 to 2005 with pneumonia, congestive heart failure, or acute myocardial infarction,[17] as well as a composite quality score. It also includes data on each hospital's average costs, both inpatient and outpatient, for Medicare patients during the last 2 years of life. The methods used to develop these estimates have been described.[18]

We linked our 3 data sources using Medicare Provider Numbers. **Table 2** displays the number of hospitals included in the HIMSS and Dartmouth data for each year, as well as the

Table 1 Computer Applications Used to Construct Overall Computerization Score and Subscores, 2003-2007

Clinical applications subscore (8 applications)
Clinical data repository
Computerized practitioner order entry[b]
Data warehousing and mining, clinical[a]
Electronic medical record[b]
Laboratory information system
Nursing documentation
Order entry
Physician documentation
Administrative applications (patient-related) subscore (4 applications)
Nurse acuity[a]
Nurse staffing scheduling
Patient billing
Patient scheduling
Administrative applications (other) subscore (12 applications)
Budgeting
Case mix management
Cost accounting
Credit collections
Eligibility
Data warehousing and mining, financial[a]
Electronic data interchange
Executive information system
General ledger
Materials management
Personnel management
Staff scheduling

[a]Category not included in 2003 and 2004 HIMSS surveys.
[b]Applications also were analyzed individually.

Table 2 Number of Hospitals Included in Healthcare Information and Management Systems Society Survey of Computerization and Dartmouth Atlas Cost/Quality Data, and Numbers Matched with Medicare Cost Reports, 2003-2007

Year	HIMSS Survey*	HIMSS + Medicare Cost Report†	Dartmouth Cost and Quality Data‡	Cost and Quality Data + HIMSS§	Dartmouth Cost and Quality Data + Medicare Cost Report‖
2003	3803	3486	NA	NA	NA
2004	3881	3724	NA	NA	NA
2005	3816	3565	3089	2641	3010
2006	4025	3620	NA	NA	NA
2007	4744	2596¶	NA	NA	NA

HIMSS = Healthcare Information and Management Systems Society; NA = not available.
*Number of hospitals with valid data available from HIMSS survey.
†Number of hospitals with valid data available from both HIMSS survey and Medicare Cost Report.
‡Number of hospitals with valid quality and cost of care data from Dartmouth Health Atlas.
§Number of hospitals with valid data available from both Dartmouth Health Atlas and HIMSS survey.
‖Number of hospitals with valid data available from HIMSS survey and Medicare Cost Report and Dartmouth Health Atlas.
¶Centers for Medicare and Medicaid Services had released data from 2007 Medicare Cost Reports for approximately half of all hospitals by January 1, 2009.

number that we were able to match to a Medicare Cost Report. The hospitals included in the computerization (HIMSS) and cost/quality databases (Dartmouth Atlas) were more likely than other hospitals to be urban, teaching, and nonprofit; virtually all were short-term general hospitals. Hospitals in the Dartmouth database were larger than average.

Finally, we compared costs and quality of hospitals at the cutting edge of computerization (as indicated by their inclusion on the "100 Most Wired List" compiled by *Hospital and Health Networks* magazine for 2005 and 2007[19,20]) with those of other hospitals.

Statistical Analyses

We first examined bivariate (Pearson) correlations between each hospital's overall computerization score (as well as each of the 3 computerization subscores and the adoption of electronic medical records and computerized physician order entry individually) and the proportion of spending devoted to administration (calculated from Medicare Cost Reports) for each year from 2003 to 2007. To assess lagged effects, we examined whether computerization in 2003 was correlated with administrative costs in 2007. Finally, we determined whether longitudinal changes in any measure of computerization between 2003 and 2007 correlated with changes in administrative costs. We also analyzed the correlation between each hospital's measures of computerization in 2005 and its quality scores and Medicare costs.

We then used multiple linear regression to ascertain predictors of hospital administrative costs for each year between 2003 and 2007 and the change in administrative costs between 2003 and 2007, as well as quality scores and Medicare costs (2005 only). In these analyses, we controlled for hospital ownership and type, bed size, teaching status, urban/rural location, and location by state. The parameter estimates from these analyses estimate the change in cost, quality score, or administration's share of hospital spending if a hospital moved from no implementation of the computer application(s) to complete implementation. Given the large number of comparisons, we consider findings significant only if the P value is less than .01.

RESULTS

Hospital computerization increased between 2003 and 2004 and from 2005 to 2007. Data discontinuity precluded analysis of changes between 2004 and 2005. By 2007, the average hospital in the HIMSS survey had implemented 64% of the 24 surveyed computer applications, although only 23% had implemented computerized physician order entry. Larger urban and teaching hospitals were more computerized, whereas public hospitals were less computerized. As expected, hospitals on the "Most Wired" lists reported higher than average computerization in the HIMSS survey ($P < .0001$ in both years).

Hospitals' administrative costs increased slightly but steadily, from 24.4% in 2003 to 24.9% in 2007 ($P < .0001$). Higher administrative costs were associated with for-profit ownership, smaller size, non-teaching status, and urban location. Psychiatric hospitals had higher administrative costs than acute care hospitals. There was no association between administrative costs and any quality measure. Higher administrative costs weakly predicted higher total Medicare spending ($r = 0.09$, $P < .0001$), inpatient spending ($r = 0.06$, $P = .0007$), and outpatient spending ($r = 0.07$, $P < .0001$).

The average composite quality score for US hospitals was 86.1, whereas the average scores for acute myocardial infarction, congestive heart failure, and pneumonia were 92.3, 86.9, and 78.5, respectively. Larger hospitals and those with teaching programs scored higher on quality, and for-profit hospitals scored lower.

Table 3 Relationship Between Each Hospital's Level of Computerization and Administrative Costs as a Share of Total Costs, 2003-2007

	2003	2004	2005	2006	2007	Change, 2003-2007[a]
Bivariate correlations with proportion spent on administration (*P* value)						
Overall computerization score	−0.005 (.75)	−0.04 (.02)	−0.02 (.20)	−0.03 (.12)	−0.009 (.66)	0.09 (<.0001)
Subscores:						
Clinical systems	−0.02 (.25)	−0.04 (.02)	−0.03 (.04)	−0.05 (.004)	−0.02 (.25)	0.06 (.014)
Administrative systems (patient related)	−0.01 (.39)	−0.06 (<.0001)	−0.007 (.69)	−0.01 (.49)	−0.009 (.66)	0.03 (.21)
Administrative systems (other)	0.01 (.47)	−0.02 (.35)	−0.005 (.77)	−0.008 (.96)	−0.02 (.39)	0.08 (.0005)
Multivariate parameter estimates (and *P* values) for relationship between computerization and proportion spent on administration[b]						
Overall computerization score	−0.003 (.71)	−0.009 (.15)	−0.003 (.67)	0.001 (.86)	0.01 (.24)	0.02 (.002)
Subscores:						
Clinical systems	−0.005 (.18)	−0.006 (.14)	−0.002 (.71)	−0.006 (.13)	0.006 (.26)	0.005 (.22)
Administrative systems (patient related)	0.005 (.44)	−0.01 (.14)	0.001 (.81)	−0.0006 (.91)	−0.003 (.64)	0.005 (.34)
Administrative systems (other)	0.001 (.81)	−0.003 (.52)	−0.002 (.71)	0.008 (.15)	0.009 (.21)	0.02 (.0008)

[a]Relationship between change in administration's share of hospital's total costs and change in its computerization score, 2003-2007.
[b]Controlling for teaching status, number of beds, urban/rural location, ownership (for-profit, private nonprofit, or public), state, and hospital type (eg, acute care, psychiatric).

Administrative Costs and Computerization

Table 3 displays the bivariate and multivariate relationships between computerization and administrative costs for each year, as well as the longitudinal relationship between change in computerization and change in administrative costs.

In bivariate analyses, overall computerization score showed no correlation with administrative costs ($P > .02$ for comparisons in each of the 5 years). None of the 3 computerization subscores or 2 individual applications (electronic medical records or computerized physician order entry, data not shown) were consistently associated with administrative costs. However, in 2004 alone, one subscore, patient-related administrative tasks, was associated with lower administrative costs ($r = -0.06$, $P < .0001$), as was the use of computerized physician order entry in 2004 ($r = -0.06$, $P = .001$), 2005 ($r = -0.05$, $P = .002$), and 2006 ($r = -0.05$, $P = .002$); greater computerization of clinical functions in 2006 ($r = -0.05$, $P = .004$); and electronic medical records in 2006 ($r = -0.048$, $P = .004$). Between 2003 and 2007, a more rapid increase in computerization was associated with a faster increase in administrative costs ($r = 0.09$, $P = .0001$).

In multivariate analysis, neither overall computerization nor any of the subscores were associated with administrative costs in any year. The use of electronic medical records was associated with higher administrative costs in a single year, 2007 (parameter estimate = .004, $P = .007$). In contrast with the bivariate findings, the use of computerized physician order entry was nonsignificantly associated with higher administrative costs in all years. As in the bivariate longitudinal analysis, between 2003 and 2007, a more rapid increase in computerization was associated with a faster increase in administrative costs. We found no evidence of lagged effects; computerization in 2003 did not predict administrative costs in 2007 ($P = .71$). Administrative costs of hospitals on the "Most Wired" list did not differ from those of other hospitals in 2005 ($P = .96$) or 2007 ($P = .78$).

Quality Measures and Computerization

In bivariate analyses, higher overall computerization scores correlated with better quality scores for acute myocardial infarction ($r = 0.07$, $P = .003$) but not for congestive heart failure or pneumonia, or for the composite quality score.

On multivariate analysis (Table 4), there was a trend toward computerization predicting higher quality. Hospitals with higher overall computing scores had slightly better composite quality (parameter estimate = 2.365, $P = .013$), as did hospitals with higher subscores for clinical systems, and patient-related administrative systems. Both the use of electronic medical records and computerized order entry predicted higher composite quality scores. More computerized hospitals scored higher on care of acute myocardial infarction, but not on pneumonia or heart failure. Hospitals

Table 4 Relationship of Hospitals' Computerization to Quality Scores, Total Costs, and Administrative Costs in Multivariate Models, 2005

Computerization Variable	Total Cost Parameter Estimate (*P* Value)	Administration as Share of Hospital Budget Parameter Estimate (*P* Value)	Composite Quality Score Parameter Estimate (*P* Value)	Pneumonia Quality Score Parameter Estimate (*P* Value)	Congestive Heart Failure Quality Score Parameter Estimate (*P* Value)	Acute Myocardial Infarction Quality Score Parameter Estimate (*P* Value)
Overall computerization score	$612 (.69)	−0.0027 (.67)	2.36 (.013)	1.36 (.34)	1.93 (.15)	3.29 (.0007)
Clinical systems subscore	$1154 (.24)	−0.002 (.71)	1.39 (.02)	0.45 (.61)	1.77 (.04)	1.82 (.003)
Administrative systems (patient-related) subscore	−$4764 (<.0001)	−0.001 (.81)	1.57 (.02)	1.51 (.13)	0.96 (.31)	2.00 (.004)
Administrative systems (other) subscore	−$243 (.85)	−0.002 (.71)	1.12 (.17)	1.05 (.39)	0.13 (.91)	1.62 (.054)
Electronic medical record	$134 (.50)	0.001 (.25)	0.32 (.008)	0.38 (.04)	0.35 (.04)	0.24 (.055)
Practitioner order entry	$284 (.28)	0.0009 (.44)	0.41 (.009)	0.032 (.89)	0.95 (<.0001)	0.51 (.002)

Models control for teaching status, number of beds, urban/rural location, ownership (for-profit, private nonprofit, or public) and state.

on the "Most Wired" list showed a weak trend toward higher composite quality (parameter estimate = 1.032, $P = .08$).

Overall Costs and Computerization

In bivariate analysis, overall computerization score was associated with higher total Medicare spending ($r = 0.06$, $P = .001$), as well as spending for imaging ($r = 0.09$, $P < .0001$), outpatient care ($r = 0.13$, $P < .0001$), and diagnostic testing ($r = 0.09$, $P < .0001$).

In multivariate models (**Table 4**), overall computerization was not associated with overall Medicare spending (parameter estimate = $612, $P = .69$) or individual components of spending (data not shown). The computerization subscores were inconsistently associated with expenditures. Costs at hospitals on the "Most Wired" list did not differ from those at other hospitals (parameter estimate = $324, $P = .77$).

DISCUSSION

We found no evidence that computerization has lowered costs or streamlined administration. Although bivariate analyses found higher costs at more computerized hospitals, multivariate analyses found no association. For administrative costs, neither bivariate nor multivariate analyses showed a consistent relationship to computerization. Although computerized physician order entry was associated with lower administrative costs in some years on bivariate analysis, no such association remained after adjustment for confounders. Moreover, hospitals that increased their computerization more rapidly had larger increases in administrative costs. More encouragingly, greater use of information technology was associated with a consistent though small increase in quality scores.

We used a variety of analytic strategies to search for evidence that computerization might be cost-saving. In cross-sectional analyses, we examined whether more computerized hospitals had lower costs or more efficient administration in any of the 5 years. We also looked for lagged effects, that is, whether cost-savings might emerge after the implementation of computerized systems. We looked for subgroups of computer applications, as well as individual applications, that might result in savings. None of these hypotheses were borne out. Even the select group of hospitals at the cutting edge of computerization showed neither cost nor efficiency advantages. Our longitudinal analysis suggests that computerization may actually increase administrative costs, at least in the near term.

The modest quality advantages associated with computerization are difficult to interpret. The quality scores reflect processes of care rather than outcomes; more information technology may merely improve scores without actually improving care, for example, by facilitating documentation of allowable exceptions.

Recent reviews have concluded that custom-built systems at 3 academic centers and at Veterans Administration

hospitals have improved quality and decreased use (mostly of diagnostic tests).[10,11] In contrast, they found less evidence for positive effects beyond these 4 institutions and no reliable data to support claims for savings on costs or clinician time. Some decision support systems have improved practitioner performance, but their impact on patient outcomes remains uncertain.[21]

A recent study of 41 Texas hospitals found that hospitals with computerized physician order entry had lower mortality for coronary artery surgery but not for other conditions.[22] Facilities with automated decision support had lower costs. The impact of computerization on complication rates and length of stay was inconsistent. At Kaiser Permanente in Hawaii, implementation of an electronic medical record increased operational efficiency, defined as a decrease in outpatient visits and increase in phone and e-mail consultations.[23]

In other settings, computerization has yielded mixed results.[24] In a national study, electronic medical records were not associated with better quality ambulatory care.[25] Prescribing errors were no lower at outpatient practices with computerized prescribing,[26] and adverse events from medication errors persisted at a highly computerized hospital with computerized physician order entry.[27] A leading computerized physician order entry system sometimes facilitated medication errors,[28] and the introduction of such a system was linked to an increase in mortality at one children's hospital[29] but not at another.[30]

Although optimal computerization probably improves quality, it remains unclear whether the systems currently deployed in most hospitals achieve such improvement. Even the business case for hospital computerization is uncertain. On the plus side, a 2001 study found that hospitals with integrated information systems were more profitable.[31] Florida hospitals using more information technology had higher revenues and incomes, but higher expenses.[32] A literature review found that the use of an electronic medical record often increases billings but reduces provider productivity by increasing time spent on documentation.[33] Error reduction was inconsistent, and the author found no evidence for savings or decreased malpractice premiums.

The data we used for our analysis appear reasonably robust. Our total cost measure sums expenditures across sites, outpatient and inpatient, for patients who received the bulk of their care at each hospital. Thus, they should reflect any savings from improved coordination of care and the avoidance of duplicate tests, the type of waste that computerization might be expected to curtail.

Medicare Cost Reports provide reliable and detailed hospital financial data covering most non-federal US hospitals and are subject to extensive audit. Estimates of administrative expenses based on these cost reports jibe well with labor-force data[34] and regulatory data from California.[35]

The HIMSS survey provides the only available longitudinal data on computerization for a large sample of US hospitals. Its sponsoring organization is the largest health information technology professional group, reinforcing respondents' motivation to provide accurate data. Moreover, HIMSS scores correlated highly with inclusion on the "Most Wired" list in both 2005 and 2007. A 2008 cross-sectional survey that used more stringent definitions of computerization adoption found lower levels of implementation.[36] Even if the HIMSS survey provides an imperfect measure of computerization, the lack of cost and efficiency differences between hospitals at the extremes of computerization suggests that its salutary effects cannot be large.

Why has information technology failed to decrease administrative or total costs? Three interpretations of our findings seem plausible. First, perhaps computerization cannot decrease costs because savings are offset by the expense of purchasing and maintaining the computer system itself. Although information technology has improved efficiency in some industries (eg, telecommunications), it has actually increased costs in others, such as retail banking.[37]

Second, computerization may eventually yield cost and efficiency gains, but only at a more advanced stage than achieved by even the 100 "Most Wired" hospitals.

Finally, we believe that the computer's potential to improve efficiency is unrealized because the commercial marketplace does not favor optimal products. Coding and other reimbursement-driven documentation might take precedence over efficiency and the encouragement of clinical parsimony. The largest computer success story has occurred at Veterans Administration hospitals where global budgets obviate the need for most billing and internal cost accounting, and minimize commercial pressures.

CONCLUSIONS

Whatever the explanation, as currently implemented, health information technology has a modest impact on process measures of quality, but no impact on administrative efficiency or overall costs. Predictions of cost-savings and efficiency improvements from the widespread adoption of computers are premature at best.

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