Grant Final Report

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Exploring Financial and Non-Financial Costs and Benefits of Health Information Technology: The Impact of an Ambulatory Electronic Health Record on Financial and Workflow in Primary Care Practices and Costs of Implementation

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Abstract

Purpose: This research sought to estimate the cost and workflow impact of rapid implementation of an electronic health record (EHR) in primary care practices, reducing the uncertainty that health care providers currently face when considering EHR adoption.

Scope: The potentially high cost of EHR implementation, including uncertainty regarding its impact on workflow, productivity and post-implementation revenue, is a frequently cited barrier to EHR adoption. While the literature contains estimates based on expert opinion and the experience of academic centers using "home-grown" health information technology, "real-world" data to inform decisions regarding EHR adoption are not readily available for commercially-available EHRs implemented in a relatively short-term. This study examined the experience of 26 primary care practices within a fee-for-service ambulatory care physician network that adopted an EHR between July 2006 and December 2008.

Methods: We examined pre- and post-implementation billing and administrative data to determine impact on workflow and financial outcomes, quantified costs of hardware/software purchases and system resources related to EHR implementation, and conducted key informant interviews to determine the time and effort spent by the network implementation team, the individual practice implementation teams, and the end users (physicians, other clinical staff, and non-clinical staff) preparing for and implementing the EHR, converting these to non-financial, time and effort costs by applying salary information from payroll data at the physician, clinical staff, and non-clinical staff levels.

Results:

- Specific Aim 1—Productivity (work RVUs per physician FTE) showed statistically significant decreases after EHR implementation. Productivity was lowest during the first 6 months following implementation (8% lower), but regained half this ground by 12 months. Volume (visits per physician FTE) followed a similar pattern, dropping 8% from pre-implementation levels during the first 6 months after EHR implementation, but recovering to only 4.5% lower than pre-implementation after 12 months.

- Specific Aim 2—Practice expense per work RVU showed increases of approximately $4.00 per month over and above the secular trend in each of the 3 periods examined. Based on the monthly mean of 412.3 work RVUs per physician FTE, the increased expense is approximately $1,650 per physician FTE per month. Net income per work RVU showed significant decreases during the first year following EHR implementation (11.7% to 16.5%), but the effect dissipated after 12 months. Net income per physician FTE showed a statistically significant decrease over and above the negative secular trend during the first 6 months post-implementation (16.5%); but after12 months, net income per physician FTE was not statistically significantly different from pre-implementation.

- Specific Aim 3—We estimated the electronic health record and practice teams spent 611 hours per practice for implementation, and end-users spent 134 hours per physician. For a five physician practice, we estimated implementation to be $162,000, with $85,500 in maintenance expenses during the first year.

Key Words: health information technology, electronic health records, implementation, ambulatory care, primary care, costs

Final Report

Purpose

The study's purpose was to inform "real world" health information technology (IT) implementation decisions and stimulate more comprehensive health IT implementation research in the ambulatory care setting. Understanding the work flow and financial impacts, as well as costs related to implementation of health IT is important for stakeholders at all stages in the ambulatory electronic health record (AEHR) innovation decision process[1] including adoption and implementation. For those still deciding whether to adopt a commercially available AEHR system, knowledge regarding the costs and work flow/financial effects that they can expect to encounter and realize through implementing health IT informs initial decisions of whether and how to adopt and implement. For those already engaged in AEHR implementation, this knowledge regarding impacts and costs from this study will inform decisions regarding whether and/or how to maintain use of the AEHR. Given the goal of universal electronic medical record use in the United States within 4 years[2], such knowledge is of immediate and critical importance.

To achieve the objectives of this research, the following specific aims were proposed.

- Aim 1: To estimate the effect of the AEHR on workflow outcome measures (Non-physician staff per physician full time equivalent (FTE), Work relative value units (RVU) per physician FTE, Work RVU per visit, and Visits per physician FTE with AEHR implementation.

- Aim 2: To estimate the effect of the AEHR on financial measures (Practice expense per work RVU, Practice expense per total RVU, Payment received per work RVU, Net income per physician FTE, and Net income per work RVU) with AEHR implementation

- Aim 3: To quantify financial and non-financial (time and effort) costs of Health IT implementation and maintenance, including: purchases of hardware, software and system resources; time and effort of the network AEHR team during deployment of at each practice; non-financial costs related to practice physician champions', nurse super users', and office managers' time spent overseeing AEHR implementation tasks; and time spent by individual physicians, medical assistants, and office staff preparing for AEHR use; as well as costs of maintenance.

Scope

Background and Context

Despite the potential for health information technology (IT) to improve quality of medical care, results from the National Ambulatory Medical Care Survey revealed that only 41.5% of

office-based physicians use all or partial ambulatory electronic health records in their practices.[3] Nationally, 4% of physicians report using fully functional electronic record systems, and 13-17% report having a basic system.[3, 4]

Barriers to Adoption. Perceived benefits of health IT are weighted more heavily towards patient care (improved access to medical information, workflow, patient communications, and clinical decision making) than financial performance (improved accuracy for coding evaluation and management procedures, claims submission process, and reduced medical records staff expenses). Perceived barriers to EHR adoption, however, are frequently financial, including high start-up costs, lack of capital, and paucity of reliable information about return on investment (ROI), especially for smaller practices.[5] "IT …promises to improve practices' efficiency, quality, and service despite the paucity of evidence that EHRs reliably lead to these benefits, and of evidence that having an EHR reliably improves a practice's financial performance. Although the number of anecdotes continues to increase, we are not aware of large-scale studies to document financial consequences or clinical benefits".[5] A study of 30 physician organizations with EHRs, mostly practices with 10 or fewer physicians, identified similar barriers.[6]

Two other studies report that, despite the anticipated improvement in quality with EHR implementation, financial concerns (risky investment with uncertain return) present barriers for smaller practices.[7, 8] A financially-related barrier stems from current reimbursement systems, as most benefits accrue to payers and purchasers rather than the providers and healthcare organizations investing in the EHR. The resulting dilemma of whether and how providers should implement IT is also discussed by Grove[9] and, in relation to more general quality improvement activities, by Corrigan et al.[10] To complicate the decision further, evidence exists that improved quality and efficiency is not assured with IT implementation. Bates[8] cites one study that found only an 11% improvement in performance with CPOE. He further identifies physician barriers to implementation, including lost productivity during implementation and concerns about maintenance, vendor selection, and vendor viability (i.e., going out of business). Miller and Sim[6] and Bates, Kuperman et al[11] also note the costliness and complexity of technology for improving quality. Similarly, it has been found that physicians report lack of capital resources and loss of productivity during implementation as two of the top five barriers in a survey of 34,000 medical groups; insufficient return on investment is also in the top 5 barriers for practices that have not adopted the EHR.[5] Similar barriers were described in a qualitative analysis of Boston and Denver physicians.[12] In a survey on health IT use in Massachusetts, the most cited barriers to adoption related to inadequate funding, no physician support for change, lack of technical knowledge/support, interference with workflow (including the physician patient interaction[13]), inability to find an EHR that fits needs, and less belief in the view that computers positively affect health care.[14, 15]

Lack of Evidence Regarding the Costs and Financial Impact of EHRs. Miller and Sim[6] note the uncertainty around "costs, implementation, use, and consequences of the technology", and call for research that describes the "financial, time, and quality outcomes" realized by practices using EHRs. Despite optimism about the financial benefits of EHRs, the need for investigation of the overall return on investment (ROI) of integrated clinical information systems by parties other than vendors, has been noted.[7, 16, 17] Much of the current knowledge has been derived from "academic medical centers with custom-built EMRs which have little in common with the vast majority of hospitals and physician practices".[18] Critics have further questioned the

RAND projections as the savings related to drug and radiology costs were based on "expert opinions", and those related to laboratory testing on "overstretched data."[19] An extensive review of the literature emphasized the need for "real world" data, concluding that most health IT research has studied four major benchmark organizations with systems that were internally and incrementally developed by academic research champions with lengthy implementation periods.[20] Health IT research needs to become more generalizable and focus on implementation that will occur for organizations in community settings with commercially developed health IT over much shorter implementation durations to best inform those undergoing the health IT innovation decision process.[20-22]

Setting

This study was conducted in the HealthTexas Provider Network, the fee-for-service ambulatory care provider network affiliated with Baylor Health Care System (a not-for-profit healthcare system serving patients throughout North Texas), consisting of more than 100 primary care, specialty care and senior health centers and more than 586 physicians in the Dallas-Fort Worth area. Since workflow and processes of care differ by specialty, only the 26 primary care practices (family practice and general internal medicine) that implemented the electronic health record between June 2006 and December 2008 were included in this study.

Methods

Data Sources

For the first two aims, data were collected monthly from January 2004 to December 2009, providing a minimum of 30 months pre-EHR and 12 months post-EHR data for all practices. Data related to individual patient visits and revenues were collected from the HTPN MisysPM billing system. These included patient demographic information and detailed visit component information (e.g., CPT-4 codes). Charges were captured at the procedure code level and linked to the RVU values, obtained from Ingenix. The 2009 RVU scale was used for all years to eliminate the impact of changes in the nominal RVUs values for specific CPT-4 codes. If the definitions of episodes of care and physician activities are consistently applied, such comparisons regarding resource utilization are valid across physicians, clinical departments and organizations over time.

Data related to practice expenses and staffing levels/payrolls were obtained from the general ledger and payroll systems. Payroll data include hours and pay information, along with cost centers and accounts. The collections balance to the general ledger at the visit level. Provider number is linked to the general ledger cost centers and accounts; thus, payroll cost data were merged with billing system data at cost center and practice levels. Billing system accounts receivable are reconciled to the general ledger through regular external audits.

Data were accessed through a SQLServer database, and transformed into SAS data files for analysis. From this information we created covariate data for each practice related both to patient characteristics – mean age and percentage female; and practice characteristics – number of physicians, length of time belonging to HTPN and practice type (family medicine, internal

medicine, and 'other', which represents combined primary care specialties); and year of adoption (2006/2007 vs. 2008).

For the third aim, we interviewed key leaders of HTPN's electronic health record implementation: the vice-presidents for informatics and for electronic health records and health IT, and the manager of training and work flow. Our nonfinancial cost estimates were based on time estimates provided by these key leaders in addition to corroboration from supporting planning documents, e-mail communications, and appointment calendars.[29] The financial costs of implementation include capital expenditures (typically depreciable) for hardware, which varies according to the number of physicians in a practice; and operational expenditures for software licensing, hosting, and technical support. To quantify nonfinancial costs, we also collected payroll data and time estimates for staff at the network, practice, and end-users levels. We quantified how much time pertinent individuals spent at various tasks, using that information with payroll data to determine financial costs of implementation during the 120 days prior to "Go-Live", and the 60 days post Go-Live, as well as the 12 months post "Go-Live."[23]

Specific Aims 1 & 2: To Estimate the Effect of the AEHR on Workflow Outcome Measures and to Estimate the Effect of the AEHR on Financial Measures

Outcome Measures: Specific Aim 1 (Workflow Measures).

- Non-physician staff per physician FTE
- Work RVU per physician FTE (productivity)
- Work RVU per visit (intensity)
- Visits per physician FTE (volume)

Outcome Measures: Specific Aim 2 (Financial Measures).

- Practice expense ($) per work RVU
- Practice expense ($) per total RVU
- Payment received ($) per work RVU
- Net income ($) per physician FTE
- Net income ($) per work RVU

Statistical Analysis. For Aims 1 and 2, we used a random intercept and random slope statistical model that provides the necessary flexibility for analysis of repeated data – here, 72 months of observation in 26 primary care practices. This method allows each practice to have its own intercept and own random slope for the trend variable.[24] We estimated the linear trend for

each work flow and financial measure prior to EHR implementation and assumed that these secular trends persisted after implementation. The linear trends were used to account for changes related to price (typically measured by the medical component of the Consumer Price Index) in addition to other types of historical/environmental factors, as the sensitivity of the trends provides the best method for adjusting these financial data. While financial data often require logarithmic methods with extreme distributions (e.g., log gamma[25]), we applied methods based on normal distributions because monthly data aggregated at the practice level are less likely to be distributed non-normally than micro-level (e.g., patient visit) financial data, which is also partly related to the central limit theorem. We also conducted tests of normality on the resulting residual to ensure our methods were appropriate.

We estimated the effects for the following linear model for our work flow and financial measure outcome variables:

$$Y_{it} = \beta_0 + \beta_{AEHR} * EHR + \beta_T * T_{it} + \beta_H * H + \varepsilon_{it}$$

where Y_{it} is the work flow or financial measure for practice i (I = 1 to 26 practice); at time t (in months since the beginning of our study in January, 2004) and H is a vector of patient and practice level covariates (including the practice characteristics listed in Table 1 and the adopting group, i.e., 2006/2007 vs. 2008). Importantly, β_0 represents the pre-implementation secular trend. Testing H_0: $\beta_{AEHR} = 0$ for each of the three time periods against the pre-implementation period, we can determine if EHR affects these work flow and financial measures – beyond what we would have observed if the trend had persisted post-implementation. For net income per work RVU and net income per physician FTE, the trends appeared curvilinear and we used linear regression splines with 4 knots to smooth the data rather than forcing assumptions of linearity.[26-29] The coefficients represent the shift in the intercept for the practices with parallel random slopes (parallel to the pre-implementation secular trend) for the three different time periods that we examined: 1) 1-6 months after implementation, 7 -12 months after implementation, and 3) >12 months after implementation. Specifically, we examined these 3 periods in relation to pre-implementation levels since interventions often have a "burn-in" effect. Since loss in productivity and general disruption are often cited as barriers to EHR adoption, we wanted to examine the nature of this phenomenon, including any changes over time. We also included an implementation group effect, accounting for the fact that there were early adopters and later adopters. Specifically, 2 practices implemented the EHR in the last half of 2006, 14 practices implemented in 2007 and 10 practices in 2008; we dichotomized this variable as 2006/2007 versus 2008.

Specific Aim 3: To Quantify Financial and Non-Financial Costs of Health IT Implementation and Maintenance

One-time financial costs for implementation that are fixed at the practice-level and variable (by the number of physicians) include fixed and variable capital expenditures (that are typically depreciable) for hardware and variable (by the number of physicians) operational expenditures for software licensing, hosting, and support. Non-financial costs for time and effort include system resources (i.e., salaries and consulting fees paid to the HealthTexas leaders of the EHR roll-out, corporate HealthTexas employees conducting the EHR training sessions at the practices and helping practices prepare for the EHR, and external EHR consultants). Specific payroll and

consulting data were collected in conjunction with time estimates related to each practice's implementation to quantify the financial costs. These personnel included the following: vice president of informatics, vice president of electronic health record and health IT, technical deployment manager, networking specialist, workflow and training manager, workflow analysts, trainers, and a registered nurse. Time spent in the following categories was considered for the HealthTexas electronic health record team:[23] Content Development/ Customization, Development of Interfaces (for demographics and insurance information, scheduling information, laboratory, and scanned images), Workflow Mapping/ Redesign, Training, "Go-Live" Support, Project Management, and Technical Deployment (including equipment, connectivity, network hardware, cabling, and communication).

We also considered the cost of time spent by each practice's physician champion and electronic health record practice manager, and all practice staff preparing for "Go-Live" in the categories Workflow Mapping/ Redesign, Training, Simulation [Practice Cases], "Go-Live" Support, and Post-Implementation); and the end-user physicians' and nurse/medical assistants' time under the categories Workflow Mapping/ Redesign, Pre-Loading Charts, Training, Simulation (Practice Cases), and Post-implementation. We interviewed the HealthTexas corporate team members to quantify the time spent on each of the implementation tasks for the Go-Live activity from network, individual practice, and end-user perspectives. Based on payroll data, we assigned an average hourly wage by job category for practice members (physicians, nurses/medical assistants, staff) and used these to estimate the costs of the time spent in training and preparation. Total implementation costs included all items related to the electronic health record for the 120 days prior to the implementation Go-Live through the first 60 days following the practice's "Go-Live" date. We estimated the financial impact of non-financial costs related to effort from the three perspectives based on 2009 salary levels for the different job categories.[23]

A similar analysis was performed to quantify the ongoing maintenance costs. Maintenance costs include hardware, software, and HealthTexas system resources (salaries and consulting fees paid to personnel for maintenance activities). We estimated costs for the maintenance period starting with the practice's "Go-Live" date and continuing for the first year of operations.[23]

Results

HealthTexas policy makes electronic health record adoption mandatory. All 26 primary care practices fully implemented the electronic health record and, from the "Go Live date" on, used the system for 100% of clinical encounters. Table 1 shows the patient and physician characteristics for the 26 HTPN primary care practices included in this study.

Table 1. Practice characteristics for the 26 HealthTexas Provider Network primary care practices (January 2006 – December 2009)

Table 1a. Physician variables

	Mean (SE)
No. of Physicians – n	5.20 (0.12)
Time in HTPN – years	5.96 (0.06)

Table 1b. Patient variables

	Mean (SE)
Percentage of female patients - %	61.07 (0.15)
Age of patients – years	47.67 (0.17)

Table 1c. Practice type

	N (%)
Internal Medicine	8
Family Medicine	13
Other	5

Table 1d. EHR exposure

	Practice-months (%)
0 months	1192 (64.64)
1-6 months	156 (8.46)
7-12 months	156 (8.46)
> 12 months	340 (18.44)

Specific Aims 1 & 2: To Estimate the Effect of the AEHR on Workflow Outcome Measures and to Estimate the Effect of the AEHR on Financial Measures

Table 2 shows the means and standard errors for the work flow and financial variables overall and on an annual basis from 2004 through 2009.

Table 2. Means and standard errors for the work flow and financial variables on an annual basis, from 2004 through 2009, for the 26 HealthTexas Provider Network primary care practices included in this study

	Overall Mean (SE)	2004 Mean (SE)	2005 Mean (SE)	2006 Mean (SE)	2007 Mean (SE)	2008 Mean (SE)	2009 Mean (SE)
Practice-months (n)	1844	302	312	312	312	309	297
Workflow: Staff per Physician FTE (n)	3.423 (0.025)	3.554 (0.067)	3.354 (0.060)	3.372 (0.057)	3.430 (0.063)	3.449 (0.059)	3.383 (0.057)
Workflow: Work RVU per visit (RVU)	1.052 (0.003)	1.051 (0.006)	1.064 (0.006)	1.065 (0.007)	1.045 (0.007)	1.035 (0.006)	1.050 (0.006)
Workflow: Visits per Physician FTE (RVU)	396.34 (2.425)	396.77 (6.226)	390.56 (5.892)	402.51 (5.871)	395.69 (6.048)	393.22 (5.663)	399.42 (5.951)
Workflow: Work RVU per Physician FTE (RVU)	412.29 (2.356)	412.42 (5.943)	410.77 (5.743)	423.09 (5.601)	408.65 (5.764)	403.63 (5.653)	415.21 (5.925)
Financial: Practice Expense per Work RVU ($)	70.35 (0.309)	65.61 (0.821)	66.83 (0.755)	67.79 (0.653)	71.35 (0.686)	74.94 (0.776)	75.71 (0.631)
Financial: Practice Expense per Total RVU($)	28.52 (0.103)	27.61 (0.283)	27.82 (0.755)	27.73 (0.198)	28.65 (0.224)	29.79 (0.284)	29.54 (0.224)
Financial: Payment Received per Work RVU ($)	107.44 (0.395)	102.44 (0.990)	103.69 (0.934)	103.38 (0.9520	110.26 (0.904)	109.15 (0.917)	111.78 (0.999)
Financial: Net Income per Work RVU ($)	35.28 (0.371)	34.21 (0.815)	34.38 (0.890)	37.59 (0.767)	37.85 (0.868)	33.14 (1.050)	34.41 (1.012)
Financial: Net Income per Physician FTE ($)	15,155.0 (185.59)	14,592.4 (427.89)	14,788.6 (433.29)	16,395.1 (407.91)	15,980.1 (468.55)	14,083.6 (495.11)	15,057.4 (479.79)

Table 3 shows the regression coefficients for the work flow measures at 1-6 months, 7-12 months, and >12 months post-EHR implementation. No statistically significant pre-implementation trends were observed in work flow measures (all p-values >0.10). Staff per physician FTE increased during the first 6 months post-EHR implementation before dropping closer to pre-implementation levels. Relative to the overall mean of 3.42 staff per physician FTE, the increase was small – approximately 6% in the first 6 months and 3% after 12 months exposure. Intensity (work RVUs per visit) showed no statistically significant differences from pre-implementation levels during the first 6 months following EHR implementation, or after 12 months. The 0.017 increase seen in the 7-12 month period was statistically significant but nominal compared to the overall mean of 1.05. Productivity (work RVUs per physician FTE) showed statistically significant decreases after EHR implementation. Productivity was lowest during the first 6 months following implementation (8% lower, based on the mean), but regained half this ground by 12 months. Volume (visits per physician FTE) followed a similar pattern, dropping 8% (based on the mean) from pre-implementation levels during the first 6 months after EHR implementation, but recovering to only 4.5% lower than pre-implementation after 12 months.

Table 3 also shows the regression coefficients for the financial measures. Statistically significant pre-implementation trends were seen for practice expense per work RVU ($0.21 per month, p<0.001), payments received per work RVU ($0.29 per month, p<0.001), and net income per physician FTE (-$68 per month, p<0.001). Practice expense per work RVU showed increases of approximately $4.00 per month over and above the secular trend in each of the 3 periods examined. Based on the monthly mean of 412.3 work RVUs per physician FTE, the increased expense is approximately $1,650 per physician FTE per month, which is similar to the monthly $1,425 per physician cost of EHR maintenance we reported previously.[23] We observed increasing decreases in payment received per work RVU as more time from EHR implementation elapsed, but these decreases were largely offset by the pre-implementation trend. We estimated an additional model containing trend only, which confirmed persistence of the secular trend at $0.23 per month (p<0.001) after EHR implementation. Net income per work RVU showed significant decreases during the first year following EHR implementation (11.7% to 16.5% based on the mean), but the effect dissipated after 12 months. Net income per physician FTE showed a statistically significant decrease over and above the negative secular trend during the first 6 months post-implementation (16.5%); but net income per physician FTE was not statistically significantly different from pre-implementation after 12 months.

Table 3. Regression coefficients for change in work flow and financial measures following electronic health record implementation in 26 HealthTexas Provider Network primary care practices

	1-6 months: Regression Coefficient (SE)	**1-6 months: p-value**	**7-12 months: Regression Coefficient (SE)**	**7-12 months: p-value**	**>12 months: Regression Coefficient (SE)**	**>12 months: p-value**
Workflow: Staff per Physician FTE	0.19 (0.04)	<0.001	0.10 (0.04)	0.018	0.12 (0.05)	0.007
Workflow: Work RVU per visit	-0.001 (0.006)	0.921	0.017 (0.01)	0.02	0.003 (0.001)	0.683
Workflow: Visits per Physician FTE	-31.99 (4.70)	<0.001	-29.63 (5.08)	<0.001	-17.86 (5.36)	0.001
Workflow: Work RVU per Physician FTE	-32.84 (4.49)	<0.001	-22.29 (4.86)	<0.001	-16.62 (5.15)	0.001

Table 3. Regression coefficients for change in work flow and financial measures following electronic health record implementation in 26 HealthTexas Provider Network primary care practices (cont'd.)

	1-6 months: Regression Coefficient (SE)	1-6 months: p-value	7-12 months: Regression Coefficient (SE)	7-12 months: p-value	>12 months: Regression Coefficient (SE)	>12 months: p-value
Financial: Practice Expense per Work RVU ($)	3.81 (0.66)	<0.001	4.05 (0.71)	<0.001	4.19 (0.75)	<0.001
Financial: Practice Expense per Total RVU($)	1.39 (0.23)	<.0001	1.73 (0.25)	<.0001	1.58 (0.26)	<.0001
Financial: Payment Received per Work RVU ($)	-3.03 (0.47)	<0.001	-3.51 (0.51)	<0.001	-4.70 (0.54)	<0.001
Financial: Net Income per Work RVU ($)	-3.91 (1.49)	0.009	-4.25 (1.74)	0.146	-3.92 (2.05)	0.056
Financial: Net Income per Physician FTE($)	-2494.37 (710.65)	<0.001	-1765.59 (828.86)	0.033	-1199.12 (982.89)	0.223

Sensitivity Analysis. We conducted the same analyses, excluding our largest practice (31 physicians), to see if our results differed for the remaining "small group" practices (each with ≤ 12 physicians). We observed no material difference, and conclude that our results are generalizable to smaller practices.

Specific Aim 3: To Quantify Financial and Non-Financial Costs of Health IT Implementation and Maintenance

Hardware Costs. HealthTexas' one-time infrastructure purchases amounted to $25,000 for switches, cables, and wireless internet connections for the 2-12 physician practices, and approximately $7,000 per physician for personal computers, printers, and scanners. [23]

Software and Maintenance Costs. Maintenance costs (beginning at implementation), amounted to approximately $14,700 per physician per year for software licensing, hosting and support desk (through a third party vendor), and networking. An additional $2,400 was included for support provided by the corporate team; a total of approximately $17,100 is estimated in total maintenance costs. [23]

Non-Financial Costs. Time expended during the implementation process is reported for 1) the HealthTexas electronic health record implementation team; 2) the individual practice implementation teams consisting of the physician champion, electronic health record (practice) manager, and both clinical and non-clinical staff; and 3) the end-users(physicians, nurses/medical assistants, and office staff). [23]

HealthTexas Electronic Health Record Corporate Implementation Team. The HealthTexas implementation team's costs resulted from time spent on: Workflow and Training (Manager, Workflow Analysts, and Trainers), Clinical Content and Configuration (Vice President of Informatics and a Registered Nurse), and Project Management/Technical (Vice

President of Electronic Health Record and Health IT, Technical Deployment Manager, and Networking). We estimated the team spent an approximate 468.5 hours before Go-Live and an additional 12 hours during the first 60 days post-implementation for a total of 480.5 hours per practice (see Table 4). Based on salary information, this time cost $27,372 to the point of Go-Live and $28,025 when the first 60 days post-implementation was included. [23]

Table 4. Average combined hours and cost per practice of electronic health record implementation for the HealthTexas (Corporate) implementation team[23]

Activities	Time Period: Pre-implementation: Hours	Time Period: Pre-implementation: Cost ($)	Time Period: TOTAL Hours	Time Period: TOTAL Cost ($)
Content Development/ Customization	63	5,631	63	5,631
Interfaces for other systems	29	1,486	29	1,486
Workflow Mapping/ Redesign	59	2,462	64	2,635
Training	73.5	3,067	78.5	3,241
Go-Live Support	104	4,106	104	4,106
Project Management	10	765	12	918
Technical Deployment including Networking	130	9,856	132	10,009
TOTAL	468.5	27,372	480.5	28,025

Note: Data are from the 26 primary care practices at which the electronic health record has been implemented. Members of the Corporate Implementation Team included: physician informaticist, interface manager, interface analyst, networking staff, training/workflow manager, workflow analysts, trainers, technical deployment manager, and project manager).

Practice Implementation Team. The practice implementation teams' time was spent on: Workflow and Customization, Pre-Load, Training, Simulation, Go-Live, and Post-Implementation (60 days for technology and report design). We estimated a total of 130 hours invested by each practice implementation team, with a cost of $7,857 per 2–12 physician practice (see Table 5).

Table 5. Average time and associated costs for members of the Practice Implementation Teams[23]

Personnel		Workflow Mapping/ Redesign	Training	Simulation (Practice Cases)	Post-Implementation (<60 days)	Total
Physician Champion	Hours	12	12	2	10	36
Physician Champion	Cost($)	1,778	1,778	296	1,482	5,335
Clinic Electronic Health Record Manager	Hours	12	12	0	25	49
Clinic Electronic Health Record Manager	Cost($)	376	376	0	783	1535
Clinical Support Staff	Hours	5	20	1	0	26
Clinical Support Staff	Cost($)	108	433	22	0	563
Front Office	Hours	6	6	1	0	13
Front Office	Cost($)	133	133	22	0	289
Medical Records, Communications	Hours	2.5	2.5	1	0	6
Medical Records, Communications	Cost($)	56	56	22	0	134
TOTAL	Hours	37.5	52.5	5	35	130
TOTAL	Cost($)	2,452	2,777	363	2,265	7,857

Note: Data are from 26 HealthTexas primary care practices at which the electronic health record has been implemented.

Practice End-Users. End-users' (physicians, medical assistants, and non-clinical staff performing administrative tasks) time at the practice-level was spent on: Workflow and Customization, Pre-Load, Training, Simulation, and Go-Live. We estimated a total of 134 hours expended per physician, based on the HealthTexas average of 3.3 staff per physician (see Table 6). We assumed that the physician and nurse/medical assistant evenly split the 85 hours the recommended pre-loading of 500 charts. The cost of this time was estimated at approximately $10,325.

Table 6. Average time and associated costs for end-users at the individual primary care practices[23]

Personnel		Workflow Mapping/ Redesign	Pre-Loading Charts	Training	Simulation (Practice Cases)	Post-Implementation (<60 days)	Total
Physicians	Hours	4.0	42.5	8.0	2.0	2.0	58.5
Physicians	Cost($)	593	6299	1186	296	296	8,670
Clinical Support Staff	Hours	6.0	42.5	12.0	2.3	2.3	65.0
Clinical Support Staff	Cost($)	130	920	260	49	49	1,408
Front Office	Hours	3.0	0	3.0	1.5	15.0	9.0
Front Office	Cost($)	67	0	67	33	33	200
Medical Records, Scanning, Referral	Hours	0.2	0	0.3	0.1	0.1	0.7
Medical Records, Scanning, Referral	Cost($)	4	0	6	2	2	16
Clinic Electronic Health Record Manager	Hours	0.2	0	0.6	0	0.2	1.0
Clinic Electronic Health Record Manager	Cost($)	6	0	19	0	6	31
TOTAL	Hours	13.4	85.0	23.9	5.9	6.0	134.2
TOTAL	Cost($)	800	7,219	1,538	381	387	10,325

Note: Results shown are estimates based on data from 26 HealthTexas primary care practices at which the electronic health record has been implemented.

Total Costs. Table 7 shows total costs for implementation (through 60 days past Go-Live) and costs for the first year, based on a five physician practice. Costs are shown for capital expenditures that typically depreciate, i.e., hardware (fixed at the practice-level and variable by the number of physicians); operational expenditures such as software licensing, hosting, and corporate support (variable by the number of physicians); costs for time spent by the corporate implementation team (fixed at the practice-level), the practice implementation team (fixed at the practice-level); and the practice end-users (variable by the number of physicians). We estimated that the total cost for implementation through the first 60-days after Go-Live was $162,407 for a five physician practice with an average per physician cost of $32,409. Maintenance costs for the first year were estimated to be $85,500, with an average per physician cost $17,100. The total costs through the first year were estimated at $232,297 with an average per physician cost of $46,659. The fixed and variable nature of these costs demonstrates that some marginal reductions are achieved for larger practices in comparison to those with fewer physicians. [23]

Table 7. Total cost of implementation of an ambulatory EHR through 60 days of go-live) in the primary care setting based on a 5 physician practice[23]

Expenditures	Implementation Costs through 60 days of Go-Live	First Year Costs	Total Cost
Capital Expenditures (Depreciable): Hardware Costs (Fixed)	$25,000		$25,000
Capital Expenditures (Depreciable): Hardware Costs (Variable)	$35,290		$35,291
Operating Expenditures: Software License, Hosting, etc. (Variable)	$14,250	$85,500[a]	$85,500
Non-Financial Costs for Effort: Corporate Implementation—Team (Fixed)	$28,025		$28,025
Non-Financial Costs for Effort: Practice Implementation Team (Fixed)	$7,857		$7,857
Non-Financial Costs for Effort: Practice End-User (Variable)	$51,626		$51,626
TOTAL: Practice	$162,047	$85,500	$232,297[b]
TOTAL: Per Physician	$32,409	$17,100	$46,659

Notes: Results shown are estimates based on data from 26 HealthTexas primary care practices at which the electronic health record has been implemented. [a] Includes costs for first 60 days; [b] Row does not sum to total due to overlap in first 60-days for maintenance costs.

Discussion

The purpose of this study was twofold: 1) to inform "real world" health IT implementation decisions especially in the context of the current national prioritization of electronic health record adoption;[30] and 2) to stimulate more comprehensive health IT implementation research in the ambulatory care setting by increasing the understanding of the costs related to electronic health record implementation. In particular, this research addressed commonly perceived (but seldom fully investigated) barriers to health IT implementation in primary care practices related to impact on workflow and financial performance, and uncertain costs related to implementation.

It appears that, while fears of increased expenses and decreased productivity during the initial period following EHR implementation are justified, the effects are not as large or persistent as physicians citing financial barriers to EHR adoption might expect. Practice expense per work RVU increased post-implementation and beyond 12 months, corresponding closely to the monthly per physician expenditure for EHR maintenance.[23] The other contributing expense appears to be increased staff per physician FTEs: while the 6% increase seen immediately post-EHR implementation did not persist, a 3% increase did. We also observed decreased productivity and patient volume after EHR implementation – another frequently cited barrier to EHR adoption – but by 12 months post-implementation, performance was only ~4% below pre-implementation levels. This finding suggests full recovery could be seen with longer follow-up. Net income per physician initially decreased but rebounded in the >12 months period, suggesting little (if any) long-term detrimental effect. As intensity of services (work RVUs per visit) did not change significantly, we can conclude the initial drop in net income was related to increased expenses and decreased productivity with EHR implementation, rather than a change in case mix. While payment per work RVU decreased following EHR implementation: this decrease was offset by an increasing secular trend so annual contracting rates likely played an impactful role. The overall lack of change in payment per work RVU over the study period suggests a flattening of reimbursement rates (best seen in Table 2 for years 2007-2009), such that these should have had little impact on changes in net income per work RVU and net income per physician FTE.

Our results show both consistencies and inconsistencies with other recent evaluations of productivity and financial impacts of ambulatory EHR adoption. Similar to the 2010 MGMA Electronic Health Record Impacts on Revenue, Costs, and Staffing report, we saw increased costs related to equipment and software maintenance and support staff salary expenses post-EHR implementation.[31] While we did not observe the revenue increases MGMA reports, this could be attributable to the much shorter post-EHR time in our study (generally < 2 years compared to the >5 years). Increased revenue was also reported at 2 years post-EHR implementation at an academic pediatric primary care center, there explained by a 13% increase in visit coding for detailed level visits and a 7% decrease in problem-focused visits.[32] While we did not look at visit coding in our study, visit intensity (measured as work RVU per visit) did not change significantly, suggesting no similar change in coding in our study, while also noting that HTPN has had similar billing practices and standards in place throughout the course of our study. The different effects on revenue observed could therefore either be the result of differential impact of EHR implementation and less likely due to changes from pre-implementation coding and documentation practices. A similar question arises in comparing our results to those reported by the Weill Cornell multi-specialty physician group: Weill Cornell saw significantly higher average monthly patient visits and work RVUs per physician with EHR adoption, neither of which we saw in the HTPN practices.[33] However, Weill Cornell also observed a statistically significant decrease in work RVU per visit, which led the authors to speculate that the EHR was capturing and recording low intensity services such as counseling visits, laboratory visits, and vaccination visits that had gone undocumented and unbilled under the paper system, making it appear that visit volume and productivity had increased when actual work had not changed.[33] A final interesting comparison is to the report of EHR implementation in 5 ambulatory care practices (3 primary care, 1 pediatric endocrine, and 1 dermatology), with a total of 28 providers, within the University of Rochester Medical Center.[34] Using a staged EHR implementation (from November 2003 to March 2004) and data from the third quarters of 2003 and 2005, these practices reported a neutral impact on efficiency and billing (similar to very small effects seen in HTPN on visits per physician FTE and payments received per work RVU), but total savings of $14,055 per provider, ongoing annual savings of $9,983 per provider, and reductions in support staff from 2.5 per physician FTE to 1.5 per physician FTE.[34] The most dramatic benefits reported were the reduction in chart pulls and salary savings of support staff, which accounted for 63% and 23% respectively of the total savings observed.[34] Since we did not separate chart pulls from the time and activities accounted for under our work flow measure of 'staff per physician FTE', it is difficult to compare the reported savings with any of our measures. The different effects of EHR implementation on need for support staff at the University of Rochester practices (decreased from 2.5 staff per physician to 1.5 staff per physician)[34] with the increased need for support staff observed in HTPN practices (from 3.42 staff per physician FTE pre-implementation to 3.54 at >12 months post-implementation) suggests that support staff play different roles in these practices, and detail on their activities and responsibilities would be needed to truly determine the impact of the EHR. It is important to note the University of Rochester represents an academic medical setting, in large contrast to our study's 26 HTPN primary care practices located throughout North Texas.

Limitations

Specific Aims 1 and 2. As our study was observational without the benefit of randomization, it carries the inherent limitation of possible imbalance in unobserved differences that could be confounded with the outcomes of interest in the study populations. However, since all the practices ultimately crossed from the pre-EHR group to the post-EHR group, and we included at least 12 months of data for each practice both pre- and post-EHR, we have minimized any imbalance to the extent possible in the context of this "real world" EHR implementation. Additionally, the interrupted time series design with switching replications used here is well-suited to quality improvement research.[35] The threat of historical events to internal validity and causal interpretation is reduced compared to single-group pre-post test designs, since the intervention occurs at different times across the full set of included practices; and the design's application to evaluations in "real world settings" that are generalizable to other settings, provides external as well as internal validity.[36] Similarly, the threat to internal and external validity that arises from selection bias is avoided when all practices receive the treatment. The careful application of these time-series methods adheres to proposed guidelines for stronger evidence in the field of quality improvement.[37]

Specific Aim 3. Our study was conducted in a single large physician practice network of 26 primary care practices which may limit its generalizability to small, isolated practices or other practice settings; it is perhaps best viewed as a "best-case" scenario in which substantial corporate support is given to individual primary care practices for implementation, addressing many of the perceived barriers to electronic health record implementation. Our example can also potentially be viewed as an "excessive-case," as more resources than necessary may have been provided to by the corporate implementation team as part of the overall infrastructure. Our non-financial cost estimates are based on time estimates provided by key personnel from supporting and planning documents, e-mail communications and calendar appointments, and interviews, rather than concurrent time recording within each of the activities considered. [23] While an ideal research project might require such time recording for accuracy, the exploratory and observational nature of this work combined with the practical difficulties of requiring all the personnel and end-users involved to record time separately under the various activity categories made such an approach difficult to take, resulting in the inability to inform the stakeholder community.

Conclusion

Based on our results and other recent reports of financial and productivity effects of EHR implementation in ambulatory care settings, it does not appear that physician practices considering EHR adoption need to be overly concerned about substantial decreases in productivity or financial performance. While short-term decreases are likely (and likely inevitable), we saw substantial recovery in both work flow and financial measures after 12 months post-implementation and other studies report gains in productivity and patient volumes, and decreases in various practice expenses. The different results we observed compared to other reports in the literature suggest that the effects a practice sees following EHR implementation may depend on the roles played by support staff (and how these can be redefined to assume

additional and different work flow activities created by the EHR), and costs of ongoing EHR maintenance

With respect to the estimation of EHR implementation on financial and non-financial costs, our results are consistent, in so far as they overlap, with the direct costs of EHR extension reported per physician in large community extension projects in Massachusetts and New York City ($34-39,000 total direct cost, encompassing software, IT/hardware, project staff support, and quality improvement).[38] These results should be encouraging to physician practices that have yet to implement electronic health records when contrasted with the recent CDW Healthcare "Physician Practice EHR Price Tag" study which, based on a survey of 200 practices not yet on electronic health records, estimated the total cost (outlay plus lost revenue) at approximately $120,000 per physician in year one, with annual recurring costs of $30,000 per physician.[39]

Significance

Our study made important progress towards filling the identified need for health IT research to become more generalizable to "real-world" implementations.[20-22] Understanding the impacts of and costs related to implementation of health IT is important for stakeholders at all stages in the electronic health record innovation decision process including adoption and implementation,[1] particularly in the context of national prioritization of electronic health record adoption and "meaningful use," as well as other support initiatives through the HITECH Act. [30] Those still deciding whether to adopt a commercially available electronic health record system should feel much more informed related to the information regarding the costs they can expect to encounter through implementing health IT, and the effect it will likely have on their productivity, costs, and income. Specifically, physicians should be more informed regarding initial decisions of whether and how to adopt an electronic health record. Non-physician stakeholders such as the government and private payers should be also be more informed regarding the strategies they can invoke to support the diffusion of health IT. For example, the establishment of Regional Extension Centers by the Department of Health and Human Services to assist provider adoption of electronic health records appears to be a viable strategy to address the capacities and challenges of health IT adoption,[30] although the "mismatch" between who pays for electronic health record implementation and maintenance (the health care providers) and who reaps (potential) cost-saving and health benefits (largely the third-party payers and patients)[40, 41] remains a substantial barrier throughout much of the industry. The strategy of 'meaningful use' incentives is another viable approach to support EHR adoption,[30] as an example of how the financial burden of adopting health IT can be shared. Other factors such as competition in the market place may also serve to drive down the cost of commercially available EHRs. These factors all provide the current economic realities, despite the Institute of Medicine having identified the necessity of aligning financial incentives (payment policies) with quality improvement activities, including the creation of an information infrastructure with the elimination of hand-written clinical notes, more than a decade ago.[10]

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List of Publications and Products

1. Fleming NS, Culler S, McCorkle R, Becker ER, Ballard DJ. Financial and Non-financial Costs Associated with Electronic Health Record Implementation in the Primary Care Setting. *Health Affairs* (Millwood), 2011 Mar;30(3): 481-9.

2. Fleming NS, Culler S, McCorkle R, Ballard DJ. Financial and Non-financial Costs Associated with Electronic Health Record Implementation in the Primary Care Setting (poster presentation). AHRQ Health Information Technology Grantee and Contractor Conference, June 2-4, 2010 in Washington, D.C.

3. Fleming NS, Culler S, Ballard DJ. Costs and Productivity Effects of Health IT Implementation in a Primary Care Setting (poster presentation). ISQua 27th International Conference, 11 October 2010, Paris, France.