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Modeling return on investment for an electronic medical record system in Lilongwe, Malawi

Julia Driessen,¹ Marco Cioffi,² Noor Alide,³ Zach Landis-Lewis,⁴ Gervase Gamadzi,³ Oliver Jintha Gadabu,² Gerald Douglas⁴

¹Department of Health Policy & Management, University of Pittsburgh, Pittsburgh, Pennsylvania, USA
²Baobab Health Trust, Lilongwe, Malawi
³Kamuzu Central Hospital, Lilongwe, Malawi
⁴Center for Health Informatics for the Underserved, Department of Biomedical Informatics, University of Pittsburgh, Pittsburgh, Pennsylvania, USA

Correspondence to

Julia Driessen, Crabtree Hall A614, Graduate School of Public Health, University of Pittsburgh, 130 De Soto Street, Pittsburgh, PA 15261, USA; driessen@pitt.edu

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ABSTRACT

Objective To model the financial effects of implementing a hospital-wide electronic medical record (EMR) system in a tertiary facility in Malawi.

Materials and Methods We evaluated three areas of impact: length of stay, transcription time, and laboratory use. We collected data on expenditures in these categories under the paper-based (pre-EMR) system, and then estimated reductions in each category based on findings from EMR systems in the USA and backed by ambulatory data from low-income settings. We compared these potential savings accrued over a period of 5 years with the costs of implementing the touchscreen point-of-care EMR system at that site.

Results Estimated cost savings in length of stay, transcription time, and laboratory use totaled US \$284 395 annually. When compared with the costs of installing and sustaining the EMR system, there is a net financial gain by the third year of operation. Over 5 years the estimated net benefit was US\$613 681.

Discussion Despite considering only three categories of savings, this analysis demonstrates the potential financial benefits of EMR systems in low-income settings. The results are robust to higher discount rates, and a net benefit is realized even under more conservative assumptions.

Conclusions This model demonstrates that financial benefits could be realized with an EMR system in a low-income setting. Further studies will examine these and other categories in greater detail, study the financial effects at different levels of organization, and benefit from post-implementation data. This model will be further improved by substituting its assumptions for evidence as we conduct more detailed studies.

OBJECTIVE

This study aims to model the financial benefits of implementing an electronic medical record (EMR) system for hospitals in low-income settings. To date the limited attention given to analyzing financial soundness has been couched solely in high-income settings. We quantify three areas of significant potential cost savings of an EMR system based on non-EMR data from a hospital in Lilongwe, Malawi: (1) length of stay; (2) transcription time; and (3) laboratory use.

BACKGROUND AND SIGNIFICANCE

Advocates of the use of EMR in low-income settings have primarily emphasized their potential to improve quality of care,¹ benefits that mainly accrue to patients and the community. However, these benefits are realized at a significant cost to healthcare organizations; these costs are cited as a

primary barrier to adoption of EMR in the USA, and represent a more significant obstacle in low-income settings.² So far, there has been little consideration of the financial benefits of EMR in the literature, much less their potential cost savings in low-income settings. In this paper we present a prospective analysis of some of the main categories in which a hospital-wide EMR system could generate financial benefits in a low-income setting, modeled on an EMR system in development in a hospital in Lilongwe, Malawi.

While there is interplay between clinical and financial outcomes, analyses of EMR in low-income settings have almost exclusively examined the former. EMR in these settings have been shown to reduce wait times and medication order errors.³ Financial analyses of EMR systems in high-income countries have identified cost savings due to reductions in transcription and chart pulling, drug expenditures and adverse drug events, more efficient laboratory and radiology testing, and more accurate billing.^{2 4-9} These savings can be classified as either non-personnel related, such as meals, which will generate immediate savings, or personnel costs, such as transcription time, which will not be realized immediately.

The distinction between high-income and low-income settings is important because the impact of an EMR system is a function of factors such as resource availability, scale, and existing inefficiencies in the paper-based workflow. Different requirements necessitate different EMR functionality. For example, an EMR in Lilongwe must adapt to low computer literacy rates, limited healthcare budgets, inadequate staffing, electric power disruptions, and inadequate security, none of which are significant challenges in the USA.¹⁰ These differences are all likely to contribute to a very different financial scenario for an EMR in a low-income setting. For example, financial benefits due to reductions in malpractice premiums and insurance reimbursement are more relevant in the USA, while reductions in drug stockouts are a more significant consideration in Malawi.

This paper adds to the EMR valuation literature by considering the financial, rather than clinical, benefits of an EMR system in a low-income, rather than a high-income, setting. Baseline information about the paper-based system in the Lilongwe hospital was paired with estimated cost savings from analyses of EMR in western hospital settings. In the absence of comparable data from low-income settings the model assumes western savings findings described in the literature. When multiple studies have been found we have used the most modest



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improvements to maintain the conservative nature of the model. Throughout, there is an emphasis on the economies of scale of this EMR system; each component of the EMR generates benefits beyond the immediate department.

MATERIALS AND METHODS

Kamuzu Central Hospital (KCH), located in Lilongwe, Malawi, is a government-operated tertiary referral hospital with 710 beds. Care is available to patients at no cost. In 2010, it treated 275 880 patients, with an average bed occupancy of 83%.¹¹ KCH employs 176 physicians and clinical officers (similar to nurse practitioners) and 262 nurses. The hospital has long-standing shortages of both staff and supplies,¹² factors that affect how fully the benefits of an EMR system are realized. Resource constraints are relevant to this analysis because they affect the ability of the hospital to capture the financial benefits; non-personnel savings are naturally more easily realized than personnel-related savings, and this difference is compounded by the existing staff shortages. For example, the hospital complement is supposed to have 532 nurses, indicating a shortage of over 50% in 2010.¹³ These issues are compounded by similar shortages in surrounding health centers, which increase the number of patients seeking treatment at KCH and the amount of primary care that is provided.

In 2001 the non-governmental organization Baobab Health Trust implemented a prototype of the EMR in operation at KCH.¹⁴ Over the following decade the EMR was iteratively developed, beginning with a pediatric module and expanding to include patient registration, radiology, laboratory specimen management, inpatient admission/discharge, and chronic disease management for HIV/AIDS and non-communicable diseases.¹⁵ ¹⁶ Additional modules currently under development include a laboratory management system, and computerized provider order entry for ordering medications. The KCH EMR has approximately 70 touchscreen clinical workstation appliances (workstations) deployed at the point of care in the ambulatory setting that enable health workers to retrieve medical records using barcode scanners.¹⁶ Two central servers within KCH store the EMR data on a local network supported by a centralized power backup system. We estimated a one-time cost for the full implementation of all modules of the EMR that included initial software configuration to accommodate clinical workflow, followed by routine operating costs such as electricity and consumables.

A 2010 internal analysis identified 13 potential areas of cost savings from the EMR system at KCH.¹¹ We attempted to re-analyze in greater detail the four areas with the largest potential benefit: length of stay; transcription time; adverse drug events; and laboratory use. We collected data from several departments to quantify a baseline under the paper-based system. The hospital administration provided data on patient volume and length of stay, the laboratory supplied data on test volume and supply orders, and interviews with staff such as nurses and clinical officers gave insight into the daily workflow. We chose to exclude the category of adverse drug events from this analysis, as we did not have the data to support this initial study; we are currently independently studying this category in more detail. Costs and projected savings are modeled in US\$.

We chose the hospital as the unit of analysis to capitalize on the returns to scale of the EMR system and account for the relationships among the different hospital departments. Furthermore, because the decision to invest in an EMR system was made at the hospital level, and its sustainability is the responsibility of the Ministry of Health, it seemed relevant to

analyze the effect of the EMR system on the hospital's budget. However, it is also possible to extend the theory that economies of scale are important in realizing the financial benefit of EMR and analyze potential financial benefits at a higher level of organization, such as at the district, zonal, and national levels. For example, one of the natural consequences of an EMR is the collection of large amounts of data. These data can easily be aggregated to generate routine reports required by the Ministry of Health, and thus additional cost savings may also be realized at higher levels.

Length of stay

In the USA, a business case analysis conducted by Kaiser Permanente estimated that approximately 35% of net benefits identified from the introduction of an EMR are attributable to a reduction in the average length of stay resulting from efficiency gains.¹⁷ Electronic communication of orders and results between clinical and ancillary departments (laboratory, radiology, pharmacy) are cited as a driver of efficiency gains.¹⁸ Evidence of the impact of EMR on hospital length of stay varies widely. An early study conducted on an internal medicine service in a large urban hospital in the USA showed a 0.89 day (10.5%) reduction in length of stay resulting from electronic ordering.¹⁹ The Government Accountability Office benchmark for length of stay reduction associated with an EMR is 30%.¹⁸ Thus far, we have found no study measuring the impact of EMR on length of stay in a low-income setting.

Length of stay at KCH averaged 4.82 days in 2010–11, but varied significantly by ward. For example, the male surgical ward averaged 18.6 days per stay, while it was only 2.18 days in the maternity ward. Our analysis includes all non-paying inpatient wards at KCH. While there are challenges that contribute to length of stay that the EMR system may not directly benefit, such as pharmaceutical and blood shortages, communication lapses also contribute to longer stays in the hospital; for example, if a patient's laboratory results are ready but have not been picked up in time for rounds, the patient stays admitted until the next opportunity for rounds, which may be 2–3 days due to limited rounding at the weekend (B. Gondwe, personal communication, 2012).

To maintain the conservative nature of this model, we assumed a 10.5% reduction in length of stay for inpatients and consider only cost savings associated with meal provision and time saved for clinical staff. The hospital provides meals to a patient at a cost of Malawi kwacha 350, or approximately US \$1.75, per day. In calculating a reduction in nurse and clinician time required we assume that approximately 60% of their time is spent managing inpatients (T. Bui, personal communication, 2012).

Transcription

Transcription activities are those that involve transferring information from one place to another. In the USA, EMR systems have been found to reduce transcription time by 28–50%, largely through the 'partial elimination of dictation'.² ¹⁸ Dictation is not a relevant part of the KCH workflow, but medical staff spend a significant amount of time engaged in 'indirect care', defined as discussing cases with colleagues, reading and writing patient charts, and prescribing medications.²⁰ Time is also spent in the compilation of mandatory reports for the Ministry of Health, admission registration, and chart creation. A study of three HIV clinics in Uganda found that providers spent approximately 34% less time during the workday engaging in indirect patient care after the

implementation of an EMR system.²⁰ A similar study at a rural health center in Kenya found a two-thirds reduction in inter-clinic personnel contact time as a result of the implementation of the Mosoriot Medical Record System.²¹ Anecdotal evidence of the time burden of indirect care under a paper-based system is provided for hospital antiretroviral therapy clinics in Ethiopia, where providers cite the excessive time spent in activities such as error checking with pharmacists and consultations with laboratory technicians.²² Based on interviews conducted in 2010, we estimated that doctors, laboratory technicians, nurses and some administrative staff spend approximately 1 h per working day on transcription.¹¹ The integration of barcodes and label printing into the EMR system reduces transcription time by eliminating the need to write information that has previously been entered elsewhere in the system. We attribute a reduction of 17 min per employee per working day (28%) in transcription time to the EMR system.

Laboratory

Laboratory data are involved in 70% of medical diagnoses and can significantly affect the success and cost of patient treatment.²³ In the USA, EMR have been found to reduce test orders by 7–15%.²⁴ Some of this reduction is attributed to improved access to health records; it has been estimated that 13.7% of laboratory tests are ordered because of lack of access to earlier results.²⁵ The HIV/AIDS pandemic has triggered investment in laboratory capacity building with some emphasis on information systems to improve laboratory workflow in several low and middle-income countries, including Côte d'Ivoire, Haiti, Malawi, Peru, Rwanda, South Africa, Vietnam and Zambia.^{26–29} However, for the benefits of information systems in this setting to be fully realized the management of laboratory information must extend beyond the walls of the laboratory, starting at the point the clinician requests the laboratory investigation and finishing at the time the clinician makes a decision based on the test result.²⁷ Smaller health centers must send specimens to centralized laboratories for tests to be completed, further complicating the process and creating additional delays. The increasing dependence on expensive PCR testing in HIV management in Malawi means that more laboratory testing needs to be centralized.³⁰ The 11-step process and associated information management challenges of centralized laboratory testing for early infant diagnosis of HIV has been described in this context.²⁶ Benefits resulting from the use of information systems to support the management of laboratory information have been demonstrated in low-income countries such as Zambia and Rwanda, commonly finding a reduction in turnaround time and fewer results that do not reach clinicians.^{28, 31} A 65% reduction in the delay of accessing tuberculosis results as well as the detection of duplication of laboratory testing has been demonstrated in Peru.³²

In this model we limit cost savings from the EMR system to benefits realized in two areas: fewer samples redrawn due to better labeling, and fewer tests ordered due to improved access to past test results. KCH data quantified the magnitude of incorrect sample labeling and test ordering. A study examined 3549 samples sent to the KCH laboratory for testing during a 4-week period, identifying whether they were correct and complete or needed to be redrawn; if the latter, the reason(s) the sample was inadmissible were recorded.³³ Overall, 18% of samples sent to the laboratory were discarded due to paperwork and labeling errors. Similar challenges associated with incomplete laboratory request forms and associated wastage and delays in processing laboratory specimens have been described in South Africa.³⁴

While an EMR system should completely eliminate documentation and labeling errors, the model assumed a 50% reduction in wasted samples due to documentation and labeling problems. Improving clinicians' access to medical history, specifically recent laboratory tests, should reduce the number of duplicate tests ordered. We make the conservative assumption that an EMR would reduce the number of tests conducted at KCH by 7%. Based on information provided by the KCH laboratory, we estimated the cost of a sample to be US\$1, and the cost of the test to be US\$3; both figures account for employee time and materials.

Cost

The investment cost of the EMR system is calculated at US \$337 847, and includes hardware, software configuration, project management, installation and training; these costs are outlined in table 1. In representing the costs of the comprehensive EMR system implementation, we excluded software development costs because the software is freely available and open source.¹⁶ While the level of EMR deployment at KCH is significant (approximately 70 workstations), costs described here are not incremental and assume no existing infrastructure. Costs are extrapolated from the actual installation of the EMR system at KCH, and include 151 workstations and two servers. Each workstation included a touchscreen computer, label printer, and barcode scanner. The hardware, network electronics and power backup system are described in detail in a previous publication.¹⁶ Project management cost is an estimated 1 year salary for a local project manager who coordinates the system implementation. Training includes the costs for providing half-day training sessions for clinical staff who will use the EMR, and salary for local software support staff who provide training full time for an estimated 6 months during EMR implementation. Installation includes the cost of a team of three local hardware technicians who install all system hardware over a period of 4 weeks. Software configuration includes 1 month of salary for one local software support staff and one software developer who configure the software modules to support the clinical workflow within each point-of-care setting. The yearly operating costs are estimated to be US\$29 824, and include consumables (eg, labels) (US\$9258), electricity (US\$9656), hardware and software maintenance (US\$5910), and recurrent training (US \$5000). In year 3, the operating cost is higher (US\$47 424) due to the cost of replacing the batteries (US\$17 600).

Discounting and sensitivity analysis

The benefits and costs outlined here are summarized over time in table 2, and the 5-year financial outlook is shown in table 3.

Table 1 Investment costs for the EMR system at KCH

| Name | Cost (US\$) | Unit | Total (US\$) |
|-----------------------------------|-------------|------|--------------|
| Touchscreen clinical workstations | 1365 | 151 | 206 115 |
| Electronics/power backup | 3195 | 16 | 51 120 |
| Network electronics | 225 | 16 | 3600 |
| Servers | 2000 | 2 | 4000 |
| Project management | | | 23 012 |
| Installation (labor) | | | 18 000 |
| Installation (materials) | | | 7000 |
| Training | | | 20 000 |
| Software configuration | | | 5000 |
| Total | | | 337 847 |

EMR, electronic medical record; KCH, Kamuzu Central Hospital.

Table 2 Annual savings due to EMR system

| | Expenditure | Estimated reduction (%) | Estimated savings (US\$) |
|------------------------|----------------------------|-------------------------|--------------------------|
| Length of stay | US\$1.75 per day for meals | 10.5 | 38 529 |
| | 60% of clinical staff time | 10.5 | 90 116 |
| Transcription | 1 h/day | 28 | 64 563 |
| Laboratory utilisation | US\$3 for test | 7 | 67 385 |
| | US\$1 for sample | 50 | 23 802 |
| Total | | | 284 395 |

EMR, electronic medical record.

To maintain the conservative nature of this analysis, we assume that no benefits are realized in the first 6 months of use. This choice recognizes that benefits of the EMR will accrue gradually, and that any initial efficiency improvements are likely to be offset by productivity losses. Costs and benefits are discounted on a yearly basis at a 5% annual percentage rate, the assumed cost of capital for the hospital.

The estimated reductions in the various categories are determined based on a mixed-methods approach, using the existing (western) literature, data from KCH, and interviews with KCH administration and staff. In table 4 we present variations on the assumptions in table 3 to examine how the financial outlook changes when the benefits vary. We examine two different sets of alternative assumptions. First, we examine how the outlook changes when we assume only half of Western the reductions identified in EMR in the model. Second, because savings associated with consumables are more quickly realized than those associated with personnel, we distinguish between personnel and non-personnel cost savings by removing personnel cost savings from our original analysis.

RESULTS

The calculations presented compare the known costs of deploying an EMR system with a conservative estimate of its cost savings. A breakdown of the annual cost savings is shown in table 2. Given 43 484 inpatients with an average length of stay of 4.82 days, a 10.5% reduction in length of stay would save US \$128 645 in food and personnel costs per year. Reducing transcription time by 17 min (28%) each workday for all doctors, laboratory technicians, nurses and some administrative employees is valued at US\$64 563 annually. The reductions in laboratory samples and duplicate tests would save the hospital US \$91 187 each year. The benefits from reductions in length of stay, transcription, and laboratory samples are estimated at US \$284 395 per year.

Table 3 Five-year return on EMR implementation

| Year | 0 (US\$) | 1 (US\$) | 2 (US\$) | 3 (US\$) | 4 (US\$) | 5 (US\$) |
|-------------|-----------|-----------|----------|----------|----------|----------|
| Benefits | | 142 197 | 284 395 | 284 395 | 284 395 | 284 395 |
| Costs | 337 847 | 29 824 | 29 824 | 47 424 | 29 824 | 29 824 |
| Total | (337 847) | 112 373 | 254 571 | 236 971 | 254 571 | 254 571 |
| Discounted* | (337 847) | 107 022 | 230 903 | 204 704 | 209 436 | 199 463 |
| Total | (337 847) | (230 825) | 78 | 204 782 | 414 218 | 613 681 |

*Discounted yearly at 5% to reflect the cost of capital.
EMR, electronic medical record.

Table 4 Robustness of financial gains to varying benefit assumptions

| | Scenario 1 Standard ^{2,19,24} | Scenario 2 1/2 Standard | Scenario 3 No personnel |
|----------------------------|--|-------------------------|-------------------------|
| Annual cost savings (US\$) | 284 395 | 154 098 | 129 717 |
| Break-even (month) | 24 | 46 | 57 |
| 5-Year net gain (US\$) | 613 681 | 111 611 | 17 662 |

The yearly financial return for the first 5 years of use is shown in table 3. Note that costs in year 0 reflect installation costs. Based on this, the EMR pays for itself in less than 3 years, and over a 5-year period the hospital saves US\$613 681.

DISCUSSION

This model serves as a proof of concept that EMR can have financial, in addition to clinical, benefits in low-income settings. These results highlight the coupled nature of clinical and financial outcomes, as well as the more general relationships among various hospital departments. Despite initially juxtaposing the clinical and financial impacts of EMR in motivating this research, this analysis shows that the two are clearly intertwined. For example, improvements in length of stay due to an EMR, while generating cost savings for the hospital, should raise the quality of care. Length of stay reductions also demonstrate the importance of scale in this analysis. The financial benefits build upon the natural economies of scale associated with expanding an EMR across all departments of the hospital. For example, installing the EMR laboratory system reduces length of stay in the inpatient wards by improving diagnostic efficiency and the communication of pre-surgical laboratory tests. The significant correlation among these areas, due to their tight relationships in providing care, is why this analysis focused only on small pieces of each category. For example, food and personnel costs were the only considerations in calculating length of stay savings, ignoring the contributions of other departments such as laboratory, radiology and pharmacy.

The goal of this paper was to examine the financial impact of an EMR system in a low-income setting. The model predicts a net profit in the second year of implementation. Even with discount rates as high as 31%, the break-even point would be realized in the third year of use, which is important given that discount rates in low-income settings tend to be higher than those in high-income areas.³⁵ The list of financial benefits modeled is not comprehensive, suggesting that this estimate represents a lower bound on the financial return of this EMR system. Furthermore, this analysis does not consider factors such as the residual value of the equipment. Other previously cited benefits, such as chart handling and more efficient drug procurement, are also likely to be realized at KCH, but adequate data did not exist to explore these categories. To avoid overlap and maintain the conservative nature of this analysis, the identified areas of benefit were simplified significantly. The results suggest that over a relatively short time horizon the EMR system generates cost savings for the hospital, the equivalent of the annual salaries of over 70 physicians. The next natural step is to analyze each of these areas in more detail, acknowledging the relationships among them and collecting more data to quantify these benefits better. These results can be aggregated to the level of the hospital, and can take advantage of the implementation of the EMR modules currently in development. By

acknowledging the complexity of categories such as length of stay and laboratory testing, the benefits of an EMR system in a low-income setting such as KCH will be more clearly articulated.

While we believe the role and the effects of EMR systems are different in low-income and high-income country settings, table 4 examines the robustness of our findings to other sets of assumptions. To permit better comparison, the break-even month is calculated, assuming that the annual savings and costs are realized in equal monthly increments. Over 5 years, the EMR is a net financial gain under all three benefit scenarios. Scenario 1 presents the financial analysis conducted earlier in this paper. In acknowledgement that the assumed reductions may not be realized at KCH, scenario 2 assumes that KCH realizes only half of the reductions; a net financial gain from the EMR system is realized during the fourth year after implementation.

Finally, in scenario 3 we distinguish between personnel cost savings and non-personnel cost savings by focusing on the latter. Non-personnel cost savings, such as a reduction in food expenses due to shortened length of stay, are more easily realized than personnel cost savings, such as a reduction in transcription, which imply a reduction in the work force necessary to provide the same level of service. KCH, like other health facilities in the area, faces a long-standing staff shortage. Therefore, while it may not be feasible to reduce the existing staff level, or hire additional staff, the EMR would allow employees to be repositioned into critical, currently unfilled roles within the Ministry of Health. In this way, the savings in length of stay, transcription time, and laboratory use can be thought of as a reduction in the staff time required to perform the same level of care, thus allowing that saved time to be redirected to other tasks currently affected by the staff shortage. Ignoring personnel costs significantly lowers the 5-year value of the EMR system, and profit is not realized until the fifth year of implementation.

CONCLUSION

The results of this prospective analysis suggest that EMR can be financially sound investments in low-income settings. It strove to be conservative enough in its assumptions to serve as a lower bound estimate of the financial impact of this system and required simplification of the contributing factors to avoid overlap; more comprehensive analyses of each component are planned. This paper provides a framework for these further studies, which can improve the model by substituting its assumptions for evidence; this model can also be applied to cost savings analyses of EMR in other low-income hospital settings. Understanding the benefits of EMR in low-income settings is a burgeoning area of research that so far has focused on the clinical effects, but the adoption of EMR in any setting also depends on articulating the financial soundness of the initial investment. This financial analysis showed a net profit during the second year of implementation. Although this means that implementing an extensive EMR system would require a long-term approach to budgeting, the timing of such an undertaking may be right; the objectives of the 2011 Malawi health sector strategic plan reflect a similarly long time-horizon and articulate goals that overlap well with the known strengths of EMR. These aims included interest in systems for laboratory information, revenue management, continuous monitoring and evaluation, and improved vital registration.³⁶ These results suggest that the dialogue surrounding EMR in low-income settings

should focus on how, rather than whether, to make these investments.

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