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Lori T. Peterson
Cleveland State University

Eric W. Ford
Johns Hopkins University, ewford@jhu.edu

John Eberhardt
DecisionQ Corporation

T. R. Huerta
Texas Tech University

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Assessing Differences Between Physicians' Realized and Anticipated Gains from Electronic Health Record Adoption

Lori T. Peterson · Eric W. Ford · John Eberhardt ·
Timothy R. Huerta · Nir Menachemi

Abstract Return on investment (ROI) concerns related to Electronic Health Records (EHRs) are a major barrier to the technology's adoption. Physicians generally rely upon early adopters to vet new technologies prior to putting them into widespread use. Therefore, early adopters' experiences with EHRs play a major role in determining future adoption patterns. The paper's purposes are: (1) to map the EHR value streams that define the ROI calculation; and (2) to compare Current Users' and Intended Adopters' perceived value streams to identify similarities, differences and governing constructs. Primary data was collected by the Texas Medical Association, which surveyed 1,772 physicians on their use and perceptions of practice gains from EHR adoption. Using Bayesian Belief Network Modeling, value streams are constructed for both current EHR users and Intended Adopters. Current Users and Intended Adopters differ significantly in their perceptions of the

EHR value stream. Intended Adopters' value stream displays complex relationships among the potential gains compared to the simpler, linear relationship that Current Users identified. The Current Users identify "Reduced Medical Records Costs" as the gain that governs the value stream while Intended Adopters believe "Reduced Charge Capture Costs" define the value stream's starting point. Current Users' versus Intended Adopters' assessments of EHR benefits differ significantly and qualitatively from one another.

Keywords EHRs · Technology adoption · Value creation

Introduction

Healthcare policymakers have advocated Electronic Health Record (EHR) adoption as means to increase the effectiveness and efficiency of medical practices [1, 2]. Widespread EHR adoption is expected to result in better quality care and lower costs for the health system as a whole [3]. For stakeholders beyond the practice, such as public and private insurers, the advantages of EHR implementation are also readily apparent. While insurers make no direct investment in practices' EHR purchases, they are often able to garner EHR-driven cost savings through reduced payments. The savings gained by insurers as a result of better care coordination fall directly to the bottom line of the insurers. However, for physicians' practices, the gains are indirect and their Return on Investment (ROI) calculation is more complex [4, 5].

EHR technology investments are costly for medical practices and their returns result from various improvements to their organization's internal value stream [6, 7]. The costs associated with EHR adoption, in both financial

L. T. Peterson
Cleveland State University,
Cleveland, OH, USA

E. W. Ford (✉)
University of North Carolina Greensboro,
Greensboro, NC, USA
e-mail: ewford@uncg.edu

J. Eberhardt
DecisionQ Corporation,
Washington, DC, USA

T. R. Huerta
Texas Tech University,
Lubbock, TX, USA

N. Menachemi
University of Alabama Birmingham,
Birmingham, AL, USA

and workflow changes, manifest themselves as increased expenses. However, understanding the extent of the gains created from EHR adoption requires that physicians develop a more sophisticated understanding of how implementation alters their practice dynamics. Further, they must overcome mistaken preconceived notions of how EHR adoption is expected to affect practice patterns. The cognitive dissonance that arises from facing direct costs and indirect benefits, coupled with the complexity of identifying savings streams, has contributed to the slow uptake of EHR technologies among medical practices [8].

One mechanism for clarifying the complex dynamics involved in evaluating the benefits of EHR adoption is to develop cognitive maps of physician practices' value adding activities. Such maps can illustrate inaccurate expectancies that arise from mistaken preconceptions. In the case of Current Users, their cognitive maps are rooted in experience and represent their belief structures about the impact of EHR adoption on practice outcomes. In the case of Intended Adopters, such maps can also outline the expected benefits of EHR adoption. EHR marketing materials, discussions in the medical literature, interaction with peers who may or may not have EHR experiences, and individual sensemaking can all influence these beliefs [9].

This paper constructs and analyzes *Current Users'* and *Intended Adopters'* perceived EHR value streams flowing from gains in practice effectiveness and efficiency. Bayesian Belief Network (BBN) Modeling is employed to generate value stream diagrams depicting the relationship among the various perceived EHR gains (e.g., improved workflows, reduced medical record expenses and better claims management) perceived by both Current Users and Intended Adopters [10, 11]. Next, the two value streams are compared and contrasted to identify discrepancies between *realized* and *anticipated* gains that influence EHR usage patterns and adoption decisions [12].

Our results offer policymakers, health services purchasers, and EHR manufacturers insights into the mindsets of physicians who have adopted and those who plan to adopt this technology. Understanding *Current Users'* and *Intended Adopters'* different perceptions of EHR value streams help identify major gaps between *realized* and *anticipated* benefit gains. This, in turn, will allow for better-targeted development of educational materials to correct potential users' misconceptions and reinforce accurate positive EHR views. The information uncovered here will also allow system developers to make improvements to subsystems (i.e., EHR functions) that are not perceived to be contributing to practices' effectiveness and efficiency. Taken together, these steps will make EHR use better understood and help align physicians' and payers' expectations and incentives to accelerate adoption.

This paper will proceed as follows. First, the literature on value streams and decision-making is described. Next, the potential gains from EHR adoption for medical practices are defined. The [Methods](#) section presents the BBN modeling technique, the sample description and the variables used. Finally, we present the results of the study, a discussion of its implications and recommendations for future research to conclude this paper.

Background

Traditional economic models of technology diffusion rely on ROI as the main measure of success or failure. The choice of whether or not to adopt technology depends on the decision-maker's evaluations of tradeoffs between costs and benefits affecting ROI [13, 14]. Physicians describe high costs as the most significant obstacle to EHR adoption, especially when the costs are contrasted with low expected gains [15]. This is further complicated by the tangible and immediate nature of the costs vis-à-vis the intangible and longer-term nature of the benefits. The problems of valuation in such cases have been studied extensively [16, 17].

Physicians' EHR adoption decisions and implementation timing are driven by two sources of potential benefits. The first emerges from improvements in the quality of care delivered by a practice to its patients. The second arises from eliminating non-value adding activities, or increasing the value added by an activity, resulting in an increased capacity by the physician to deliver care more efficiently. The two sets of gains are not mutually exclusive. For example, an improvement in a clinical workflow may positively influence health-related outcomes as well as result in better claims management. Therefore, the gains from EHR use need to be considered in a holistic fashion in order to more clearly understand the costs and benefits related to the adoption decision.

A comprehensive review of EHR ROI models can be found in the Menachemi and Brooks [18] report to the State of Florida. EHR adoption downside risks and the cost of implementation failures have been widely reported [19]. However, ROI, Net Present Value (NPV) and other financial calculations require a detailed activity-based accounting system that is not used in most medical practices. As a result, physician decision-makers must be able to recognize potential gains more clearly if EHR adoption rates are to accelerate [20]. Thus, physician-adopters must first properly order, and then evaluate, potential gains [21]. This process can be accomplished by creating mental maps of the impact of the EHR implementation as part of a value stream model within the practice setting.

There are a limited number of studies that directly measure EHR-related savings that result from improved workflows [22]. Such studies usually do not measure the tradeoffs between the costs of a system implementation and the time lost learning and training the users of a new system [23]. The efficiency of a medical practice is difficult to value because of the complex relationship between inputs (e.g., patient case-mix), the mix of workforce efforts to properly care for individuals, and the quality of the care outcomes [24]. Further, the all-inclusive costs of EHR systems add another level of complexity that is difficult to analyze [25].

Due to the differences in the functionalities of an EHR system, the net benefits that a practice garners vary as the mode, sequence and pace of implementation all impact the payback horizon. Wang and colleagues [26] report projecting strongly positive net benefits 5 years post-implementation. However, they also project an expected net loss in the short term. In fact, the expected losses may exist for the first 2 years post-implementation, which creates an additional near-term financial burden on the practice adopting the EHR.

Management researchers have developed organizational value streams as a tool to assess a unit's processes, identify potential improvements to the system, and measure performance [27]. The activities that create value are referred to as links in a value stream [28]. The value stream model describes a series of value-adding activities connecting a medical practice's capabilities with its patients and third-party payers. Managers in other industries have used value stream models to redesign their internal and external processes to improve efficiency and effectiveness.

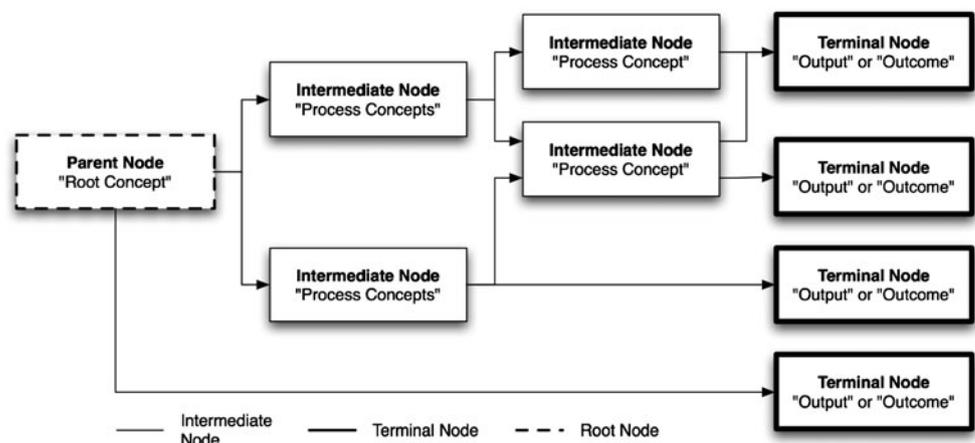
The value stream model may be defined as the activity system map visualized by users to evaluate the workflows related to implementing an organizational change. Figure 1 illustrates the three forms significant change in the value stream can take. One type of activity will impact the other

activities farther down the value stream. In other words, these activities are the 'inputs' or 'parents' of the value stream at the 'root' of the Belief Network—to use the management and Bayesian vernaculars. The second types of activities are the intermediate nodes in the value stream. They are influenced by the initial governing construct and in turn influence other workflows downstream. Typically, intermediate nodes in the value stream are work processes within the organization. The final type of workflow activity is an output. These end nodes of the value stream are influenced by both the initial governing activities and the intermediate workflow links preceding them.

To create value using EHR information, physicians must look to the healthcare market to see which processes create outputs that consumers are willing to pay a premium to obtain. Creating value in the healthcare value stream involves gathering, organizing, selecting, synthesizing, and distributing information about the workflows and processes that produce the desired end-results. Just as someone takes raw material and refines it into something useful, so a physician collects raw information and adds value through various steps to make a diagnosis and determine an optimal treatment. In healthcare, payers are particularly interested in ensuring that key standards of care are being adhered to for the treatment of costly and chronic conditions. The rise in Pay-for-Performance (P4P) programs designed to realign healthcare value streams across providers [29] is a demonstration of this phenomena. Therefore, a central purpose for developing and analyzing value streams is to better inform the technology adoption decisions for decision makers—particularly those decisions that affect the organization's work processes, information flows, and outcomes [30].

Bayesian Belief Networks (BBNs) have proven to be a powerful analytic technique for assessing decision-making under uncertainty [31]. The field of environmental development and sustainability has made extensive use of BBNs

Fig. 1 Sample Bayesian belief construct



to manage scarce natural resources [32]. Natural systems have many inputs flowing through complex environments that managers are trying to extract discreet outputs from over extended periods of time. Value streams, as conceived by management researchers, have similar characteristics to natural environments.

There are three advantages to using BBNs to map the value streams of EHRs—particularly with respect to financial decisions such as EHR adoption [33]. First, graphical value stream models depict the interdependencies that are central to improving organizational performance—in this case, promoting EHR use. Second, the technique can be applied to both experienced and predictive reasoning because of the if-then computational algorithms employed. This feature makes the exploration and comparative evaluation of Current Users' and Intended Adopters' EHR value stream perceptions feasible. Finally, input assumptions, intermediate activities, and end-results can be explored through sensitivity analyses that allow the entire value stream to be investigated. Therefore, alternative models can be directly compared. For these reasons, BBNs were chosen as the strategy for analyzing and comparing the perceived EHR value streams of Current Users and Intended Adopters.

Methods

Bayesian belief networks (BBNs)

BBNs are directed graphs that represent models for probabilistic reasoning for decision-making under uncertainty [34]. The graphs depict links between variables as nodes in a network. Each link in a BBN represents a conditional dependence between the two variables it connects in a graph.

Probabilities that determine conditional dependences are calculated using a machine-learning algorithm contained in DecisionQ's *Faster Analytics* software.¹ The algorithm calculates a posterior probability structure using a series of training data extractions. The training data, in turn, builds probabilistic inferences using a Markov Stream Monte Carlo Method [35]. This algorithm allows the computer to learn dynamically from information in the database. Prior probabilities are derived from the modeled data by calculating a distribution of discrete states, or by using equal area binning in the case of continuous variables. The machine-learning algorithms are designed

to automatically detect significant relationships between the variables without human interactions, allowing for vast amounts of complex perceptual data to be displayed in transparent network diagrams.

The classification power of a BBN can be assessed using Receiver Operator Characteristic (ROC) curves of the network nodes [36]. A ROC curve plots the percent of true positives (i.e., sensitivity) against the percent of false positives (i.e., 1-specificity) for each possible response to each item [37]. The Area Under the Curve (AUC) varies from zero to one and is a measure of overall model performance across the individual possible prediction thresholds. A ROC curve with an AUC of 0.5 ($AUC \leq 0.5$) represents a random model. AUC scores are good for comparing different models' abilities to predict consistent response across common variables. Therefore, using the ROC and AUC measures, predictive accuracy assessments within and between models can be made.

Sample description

A survey was conducted during the fall of 2005 as a joint initiative between the Texas Medical Association (TMA) and the Texas Medical Foundation Health Quality Institute to determine use or intention to use EHRs by physicians in Texas. The survey organizers were particularly interested in the status of physician implementations of EHRs, and included an inquiry into the additional services physicians would utilize in the EHR adoption and implementation process. Originally, 10,000 members of the Texas Medical Association and the Texas Medical Group Management Association were sent an invitation to complete a web-based survey via email. Additionally, 2,000 members were mailed a paper survey. A total of 1,772 responses were received, including 154 from the mail sample group, for a 17.7% response rate. Consistent with other adoption surveys, 27% of physicians responded that they are currently using an EHR and 46% of the respondents indicated they plan to adopt within the next 5 years. The remaining 27% indicated they had no intention of adopting an EHR System (See Table 1).

Variable description

The questions and answer choices used by the TMA were based on those used in other EHR surveys [38–40] so the findings could be compared to other regions and national trends. The questionnaire contained branching logic and the phrasing of the questions differed slightly depending on how the physicians answered the item assessing their EHR adoption status—currently using a system or intending to adopt. Physicians that indicated they had no intention of adopting an EHR were not asked to reply.

¹ A description of the algorithm employed can be found in the *Faster Analytics White Paper* located at http://www.decisionq.com/case_studies/index.html.

Table 1 EHR status in practice by percentage of respondents

	Number	Percentage
Total survey requests	10,000	
Total respondents	1,772	17.72%
EHR status in practice		
Currently use	462	26%
Plan to implement within five (5) years	786	44%
No plans to implement	464	26%
Did not respond to item asking “Plans to Implement an EHR”	60	3%

The root question for those physicians that have already adopted an EHR read: “What gains have you seen from EHR system implementation?...”. For physicians indicating they intend to adopt an EHR in the next 5 years the root question read: “What gains do you expect from EHR system implementation?...”. The question stem phrases, specifying the types of gains, were identical for both sets of respondents. The variables’ stems are the labels in Table 2.

Results

The AUC measures for the EHR Adopters and Intended Adopters are presented in Table 2. There are two key points to note in the table. First, the AUC measures for every variable in both models suggest good predictability of Current Users’ and Intended Adopters’ assessments of the links in their respective EHR value streams. Second, every variable in the Current Users’ EHR value stream has greater predictive power than the comparable measure in the Intended Adopters’ model, other than *Better Cash Flow*. Taken together, these two statistical paradigms indicate that the BBNs are presenting a robust model of physicians’

EHR value stream perceptions for both Current Users and Intended Adopters. The graphs also provide insights into the mechanisms that drive ROI assessments in the two EHR value stream diagrams.

The Current Users’ EHR value stream is *linear* (see Fig. 2) while the Intended Adopters’ model is *complicated* or *non-linear* (see Fig. 3) [41, 42]. Parsimony in the number of relationships (measured by the number of arrows between constructs) is an indicator of the models’ relative ease of interpretation by decision-makers [32]. Further, decision-makers more easily understand models where variables are influenced or ‘informed’ (to use the Bayesian terminology) by one, and only one, other variable. In other words, their conditional probability is directly influenced by just one other construct. The Current Users’ EHR value stream has these characteristics.

In the Current Users’ linear model, the *Reduced Medical Records Cost* variable is the ‘root’ or ‘governing’ variable, indicated in Fig. 2 as a box with a heavy dashed outline, and informs all other activities that occur downstream in the value stream. Additionally, no intermediate variable has more than one other ‘parent’ (to use the Genealogy terminology commonly applied to BBNs) or ‘upstream’

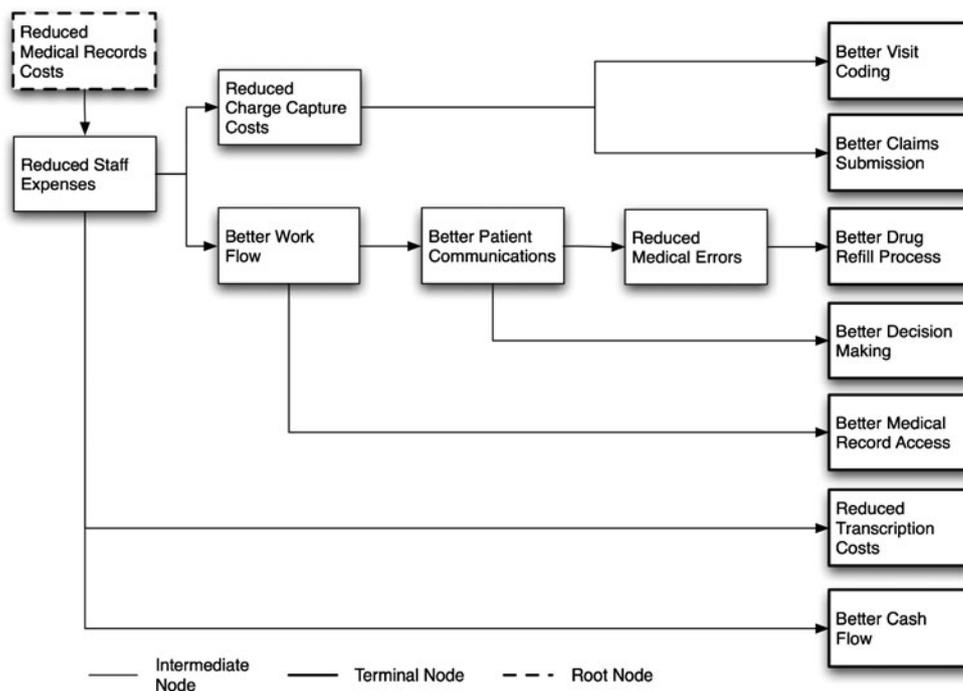
Table 2 Receiver operating characteristic (ROC) area under the curve percentages

Gain from EHR use	Current users’ average AUC	Intended adopters’ average AUC
Reduced medical records costs ^a	0.895	0.758
Better charge capture ^b	0.952	0.871
Reduced staff expenses	0.906	0.797
Better workflow	0.956	0.762
Better patient communications	0.907	0.782
Reduced medication errors	0.941	0.758
Reduced transcription costs	0.869	0.660
Better cash flow	0.739	0.857
Better visit coding	0.909	0.857
Better claims submission	0.927	0.804
Better medical records access	0.963	0.736
Better drug refill process	0.904	0.797
Better decision making	0.863	0.740
Overall average (s.d.)	0.902 (0.0582)	0.783 (0.0579)

^a Governing node for current EHR users

^b Governing node for intended EHR adopters

Fig. 2 Current users' BBN



(to use the value stream phrasing) variable that informs its conditional probability. However, an intermediate variable can have multiple ‘children’ or ‘downstream’ variables that flow out of it to a linear terminus.

The Intended Adopters’ EHR value stream is *complicated*. A complicated model has paths that are traceable from beginning to end and conditional probabilities that are calculable. However, the EHR value stream is difficult for decision-makers to interpret heuristically. That is why BBNs are being introduced into many corporate and policy settings as a decision support tool. In the Intended Adopters’ model, ten of the variables have multiple upstream variables directly informing their contribution to the value stream’s eventual outcomes. For example, examining Fig. 3, four paths of conditional probabilities inform the intermediate variable *Reduced Staff Expenses*. The paths are:

1. *Reduced Charge Capture Costs* ⇒ *Reduced Staff Expenses*.
2. *Reduced Charge Capture Costs* ⇒ *Better Cash Flow* ⇒ *Better Patient Communication* ⇒ *Reduced Staff Expenses*.
3. *Reduced Charge Capture Costs* ⇒ *Better Visit Coding* ⇒ *Better Cash Flow* ⇒ *Better Patient Communication* ⇒ *Reduced Staff Expenses*.
4. *Reduced Charge Capture Costs* ⇒ *Better Visit Coding* ⇒ *Better Drug Refill Process* ⇒ *Better Patient Communication* ⇒ *Reduced Staff Expenses*.

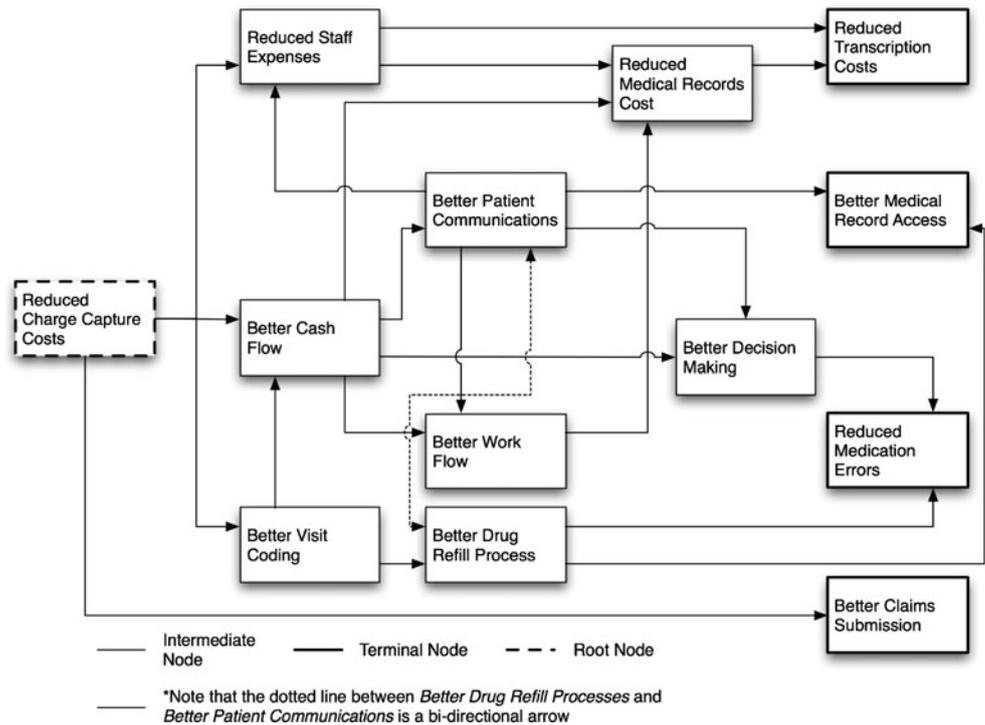
There is a potential fifth path because of the reciprocal relationship between the *Better Drug Refill Process* and *Better Patient Communications* constructs. In addition to

having several compound probabilities to calculate, the potential gain estimation is further complicated as the same variables appear in multiple paths (*Better Cash Flow*, *Better Visit Coding*, and *Better Patient Communications*). Calculating this many paths, structured in this fashion, is comparable to solving a four-equation linear optimization problem with multiple constraints. Further, the described series of calculations does not lead to an outcome, only an intermediate link in the value stream. It is beyond the capacity of most decision-makers to discern the flow of the underlying EHR value stream (make a heuristic decision) or to assess the ROI from adopting a technology (make a calculated decision) under such conditions. A comparison of the two models and the implications of their differences are discussed in the next section.

Discussion

Comparing the two BBNs depicting the EHR value stream perceptions for Current Users and Intended Adopters indicates that the perceptions of these groups differ in three significant ways. First, the perceived gain from EHR adoption governing all other potential contributors to the ROI is not the same. Second, the structures of the value streams are both qualitatively and quantitatively different. Lastly, the outcomes associated with the realized versus anticipated outcomes from EHR use differ between the Current Users’ and Intended Adopters’ perceived value streams. Each group’s model is discussed below.

Fig. 3 Intended adopters' BBN



Current users' EHR value stream

Current EHR Users' value stream model, as displayed in Fig. 2, reads from left to right. *Reduced Medical Records Costs* is the governing variable (parent node in BBN terms) of all the other gains that physicians evaluated (child nodes). The model's paths are all linear, albeit branching, from front to back. In the full model for Current Users there are seven terminal points: (1) *Reduced Transcription Costs*; (2) *Better Visit Coding*; (3) *Better Claims Submission*; (4) *Better Medical Records Access*; (5) *Better Decision Making*; (6) *Better Drug Refill Process*; and (7) *Better Cash Flow*.

For Current Users of EHR technology, *Reduced Medical Records Costs* is the governing gain from which all the other variables' values are influenced. Further, this variable directly influences only one other perceived gain—*Reduced Staff Expenses*. The impact of *Reduced Staff Expenses*, in turn, manifests itself by influencing four other variables' conditional probabilities.

Starting from the far left of Fig. 2 *Reduced Staff Expenses* directly influences two of the value stream's outcomes—*Reduced Transcription Costs* and *Better Cash Flow*. The realized savings from *Reduced Transcription Costs* associated with EHR use can be directly measured by comparing the line item before and after adoption. Transcription services are a unique and readily apparent expense that many practices incur. Any savings that are realized from reducing this expense falls directly to the

bottom line and can easily be integrated into a ROI analysis.

Staffing costs are among the largest expenses a practice typically incurs. Current Users' perception that *Reduced Staff Expense* directly influences the *Cash Flows* of their practice is an important finding. Unlike *Transcription Costs*, *Staff Expenses* are allocated across a wide variety of a practice's activities and the gains from EHR use can be difficult to attribute [43]. When physicians can parse out a distinct impact on their *Cash Flow* from staffing changes associated with EHR, the business case for adoption is greatly bolstered.

Reduced Staff Expenses also informs the perception of EHR Current Users in the variables *Charge Capture*, *Visit Coding*, and *Claims Submission* processes. Collectively, these variables can be grouped as claims management activities. One intended benefit from EHR adoption is improved claims management. As mentioned above, the financial benefit derived from better care processes generally accrues to third-party payers. Hence, *Better Cash Flow* is not in this branch of the value stream. Nevertheless, improvements in the claims management process are related to *Reduced Staff Expenses*. The reduction in staff expenses arises from less time spent in preparing claims and having to re-file claims that fail to meet the requirements of insurers and other third party payers.

The gain from the *Reduced Staff Expense* variable directly informs the physicians' perceptions of assessment of *Better Workflow* in their practices. Changing the

underlying structures and processes of care are thus major reasons for promoting EHR use [44]. That *Better Workflow* is not an end unto itself is consistent with the tenets of Total Quality Management principles [45].

The outcome directly associated with *Better Workflow* gains is *Better Medical Record Access*. Optimizing the value of EHR implementation requires that providers and staff become effective and efficient EHR users so that the file storage and retrieval of paper charts is no longer required or desired. Transitioning from paper charts to EHR systems requires new learning, significant effort, and workflow changes [46]. Ultimately, the transition to an EHR should result directly in *Better Medical Record Access* and the assessments of Current Users indicate it does.

The intermediate link in the value stream influenced by *Better Workflow* is *Better Patient Communication*. There are a wide variety of changes in *Workflows* that can lead to *Better Patient Communications* ranging from the use of e-mail for consultations to open-scheduling policies. With respect to the latter example, having an EHR gives physicians *Better Medical Record Access* to a more complete patient history—often even for patients the physician has not seen before or those who ‘walked-in’ without an appointment [47, 48]. However, *Better Patient Communication* is not intended to be an end, rather it is an intermediate step to improve care quality.

The *Better Patient Communication* variable influences one value stream outcome and one intermediate variable. The value stream directly influenced outcome is *Better Decision Making*. It has long been recognized that difficulties in the effective delivery of healthcare can arise from problems in communication between patient and provider, rather than from a failing in the physician’s decision-making process. A meta-analysis by Teutsch [49] found that improvements in provider-patient communication leads to *Better Decision Making* and have beneficial effects on health outcomes. The Current Users’ perceptions of gains from EHR benefits confirm the other findings of other studies.

The other branch of the value stream that *Better Patient Communication* influences is related to medication errors and refill processes. The *Reduced Medication Error* gain is the intermediate link between *Better Patient Communication* and *Better Drug Refill Processes* in the value stream. A great deal of the research on reducing medication errors has focused on the roles of computerized decision support and alerts. This scenario would manifest itself as *Better Drug Refill Processes* being the intermediate link and *Reduced Medical Errors* being the outcome.

Despite the imperative to adopt EHRs to reduce medical errors, innovation is inherently a double-edged sword. The introduction of new technologies has created new types of iatrogenic events [50]. The impact of EHRs and Comput-

erized Provider Order Entry (CPOE) on medication error rates has been controversial [51–54]. One view is that technology drives safety, however, a competing perspective suggests that improving medication outcomes begins with changing human performance and reducing errors in the physician–patient communication process [55]. The value stream identified by physicians Currently Using EHRs is consistent with the latter *Medication Error* reduction model.

Taken together, the Current Users’ perceptions of gains from EHR adoption are consistent with the ROI assessments of other researchers [56, 57]. In particular, gains in practice efficiency (*Reduced Staff Expense* and *Better Workflow*) and care quality (*Better Patient Communication* leading to *Improved Decision Making* and *Reduced Medical Errors*) are logically ordered in the value stream. Further, concerns that the ROI from EHR use is not strongly linked to payment mechanisms is also evident because *Better Cash Flow* is an outcome outside the claims process branch of the value stream. Increasing the financial return from third-party payers is therefore also a key to promoting EHR adoption.

Intended adopters’ EHR value stream

Intended Adopters’ perception of the EHR value stream is far more complex than that of Current Users. It would be difficult to allocate the anticipated gains from EHR adoption into discreet cost centers based on their derived representation to develop an ROI model because, as Fig. 3 indicates, the illustrated potential gains create a complex calculation that is beyond the set of tools commonly used in the decision-making processes of medical practices. Further, the Intended Adopters’ EHR value stream model is not amenable to the detailed discussion of discreet and direct paths conducted above. Therefore, a more general discussion is provided.

The governing construct for Intended Adopters’ EHR Value Chain is *Reduced Charge Capture Costs*. Intended Adopters’ focus on an element of the claims management process as the EHR value stream’s governing construct indicates that this part of the ROI calculation is critical to their decision-making. This is in contrast to the Current Users’ focus on practice management elements as governing the value stream. There is evidence in the literature that late adopters of EHR technology tend not to use the clinical functionalities to the same extent as early adopters [12]. Therefore, for Intended Adopters, improving the financial performance of their practice may be more important than aligning the value stream’s activities for greater clinical effectiveness and efficiency.

As described in the [Results](#) section, the Intended Adopters’ paths in the EHR value stream via the interme-

mediate nodes present a wide variety of options for reaching an outcome. The confusion in the value stream's intermediate constructs relationships represent uncertainty about what form the EHR investment paybacks will take. Alternatively, the model may reflect uncertainty around how the medical practices' workflows will be altered by adopting an EHR. The additional complexity in the Intended Adopters' EHR value stream model may arise from some combination of the two forms of uncertainty. Irrespective, any uncertainty in either the potential gains from EHR adoption, or workflow impacts, is a form of additional risk for the Intended Adopters and this uncertainty influences their conclusions as to the ROI question.

Conclusions

It is generally agreed that EHRs hold great promise for improving healthcare quality and efficiency. However, healthcare is decades behind other industries with respect to Information Technology adoption. Stakeholders in the medical community, including the government and third party payers, have emphasized the urgent need for physicians to adopt EHR systems. However, the efforts of government and other EHR advocates have not sufficiently accelerated the diffusion trajectory [58]. Further, the percentage of physicians using 'fully functional' EHR systems (e.g., systems with extensive clinical features) only grew from 3% to 4% between 2006 and 2008 indicating physicians are eschewing the clinical decision support features.

The findings from this study provide additional insights into the underlying physician belief systems that are driving EHR diffusion trends. Current Users of EHR systems describe the gains from adopting the technology primarily in terms of improved workflows leading to better clinical outcomes. Physicians who indicated they intend to adopt an EHR in the future are focused primarily on expected financial gains. For these Intended Adopters, the impact of EHR use on practice workflows and clinical outcomes is unclear.

For practice managers, the value stream graphics can be used to build reasonable expectations for system performance among the physicians and caregivers that will be using EHRs. In addition, the graphics also highlight how workflows within the practice will need to be reconfigured to most effectively use EHR technology. Finally, the value stream provides a clear cost benefit story that goes beyond merely being paperless. In particular, the main savings arise through the more efficient use of staff, which can then engage in better management of coding and claims processing.

If policymakers, insurers and care quality advocates wish to *effectively* accelerate physicians' technology adoption rate, they may need to change the EHR value stream perceptions physicians currently rely upon. Reconciling the dissonance between the perceptions of the Current Users and Intended Adopters regarding the EHR value stream can take three forms. First, providing Intended Adopters with accurate information on the costs and benefits of EHR implementation and ongoing maintenance, the changes required in practice workflows, and impact on patient outcomes is an essential educational step. Second, aligning the value stream beyond the ambulatory practice setting to financially reward the use of EHRs would both improve the ROI analyses and meet the governing desire of Intended Adopters. Lastly, third-party reimbursement firms (i.e., health insurers and government programs) could require information generated by EHRs to be submitted along with any claims as a condition of payment or, a penalty for not doing so could be imposed (an incentive system). The three options are not mutually exclusive and can be used in combination. However, the latter two options are problematic in that they do not address the underlying need to change the way medicine is practiced. Hence, they do not achieve the major goals of improving care quality, promoting patient safety and controlling costs. Policymakers and health advocates need more sophisticated analytic tools to identify opportunities to re-align the health system's value streams.

Scientists, policy-advocates, technology adopters, and stakeholders all share the challenge of how to draw appropriate conclusions from scientific data, individuals' prior beliefs and practice modeling. As a method for analyzing survey data, formulating EHR value stream models, and exploring the consequences of technology adoption decisions, BBNs are a valuable tool. BBN algorithms were specifically developed to address policy analysis and corporate decision-making models where the objective evidence is unclear or there is a lack of historical information available.

This study has three limitations that should be addressed through further research. First, the study was conducted in only one state, albeit, a large and diverse state in the Southwest. A larger study including more areas of the country would provide results that are more generalizable. Second, the sample was drawn from physicians who are members of the Texas Medical Association (TMA) potentially biasing the response in a systematic way. However, the TMA provides significant association benefits and over 85% of the state's physicians are members. Therefore, this is the most complete list of physicians from which to draw a sample. Third, for health services research the response rate of this study is slightly low; however, given the sample is practicing physicians, the response rate is good.

References

1. Thompson, D. I., et al., A review of methods to estimate the benefits of electronic medical records in hospitals and the need for a national benefits database. *J. Healthc. Inf. Manag.* 21(1):62–68, 2007.
2. Lorenzi, N. M., et al., How to successfully select and implement electronic health records (EHR) in small ambulatory practice settings. *BMC Med. Informat. Decis. Making* 9(15):2009.
3. Kazley, A. S., and Ozcan, Y. A., Organizational and environmental determinants of hospital EMR adoption: a national study. *J. Med. Syst.* 31(5):375–384, 2007.
4. Shekelle, P. G., Morton, S. C., and Keeler, E. B., Costs and benefits of health information technology. *Evid. Rep. Technol. Assess. (Full Rep)* (132):1–71, 2006.
5. Fenwick, E., Claxton, K., and Sculpher, M., The value of implementation and the value of information: combined and uneven development. *Med. Decis. Mak.* 28(1):21–32, 2008.
6. Burns, L. R., *The health care value chain*. Jossey-Bass: New York, 2002.
7. Porter, M. E., *Competitive advantage: creating and sustaining superior performance*. The Free Press: New York, 1985.
8. Eckermann, S., and Willan, A. R., The option value of delay in health technology assessment. *Med. Decis. Mak.* 28(3):300–305, 2008.
9. Evans, W. D., and McCormack, L., Applying social marketing in health care: communicating evidence to change consumer behavior. *Med. Decis. Mak.* 28(5):781–792, 2008.
10. Jensen, F. V., *An introduction to Bayesian networks*. Springer: New York, 1996.
11. Spiegelhalter, D. J., et al., Bayesian analysis in expert systems. *Stat. Sci.* 8(3):219–247, 1993.
12. Menachemi, N., et al., Incomplete EHR adoption: late uptake of patient safety and cost control functions. *Am. J. Med. Qual.* 22(5):319–326, 2007.
13. Fiegenbaum, A., and Thomas, H., Attitudes toward risk and the risk-return paradox: prospect theory explanations. *Acad. Manage. J.* 31(1):85–106, 1988.
14. Rahimi, B., and Vimarlund, V., Methods to evaluate health information systems in healthcare settings: a literature review. *J. Med. Syst.* 31(5):397–432, 2007.
15. Levinger, M., How much is that EHR in the window? How to build a cost model that gives the full picture. *MGMA Connex.* 8(9):48–51, 1, 2008.
16. Huerta, T. R., Simulating institutional controls on consumption patterns in the commons. *Syst. Res. Behav. Sci.* 26(4):469–486, 2008.
17. Hardin, G., The tragedy of the commons. *Science.* 162(3859):1243–1248, 1968.
18. Menachemi, N., and Brooks, R. G., *Exploring the return on investment with health information technologies: a report to the state of Florida*. Florida State University College of Medicine Center on Patient Safety 2005.
19. Middleton, B., et al., Accelerating U.S. EHR adoption: how to get there from here. Recommendations based on the 2004 ACMI retreat. *J. Am. Med. Inf. Assoc.* 12(1):13–19, 2005.
20. Ford, E. W., Menachemi, N., and Phillips, M. T., Predicting the adoption of electronic health records by physicians: when will health care be paperless. *J. Am. Med. Inf. Assoc.* 13(1):106–112, 2006.
21. Kahneman, D., and Tversky, A., Prospect theory: analysis of decision under risk. *Econometrica.* 47(2):263–291, 1979.
22. McVeigh, F. L., et al., Efficiency of automation and electronic health records in optometric practice. *Optometry.* 79(1):43–49, 2008.
23. Amatayakul, M., and Hodges, L., Don't underestimate the people costs of EHR. *Healthc. Financ. Manage.* 60(8):130–131, 2006.
24. Tinsley, R., Sides, R., and Anderson, G., *Valuation of a medical practice*. Wiley: New York, 1999.
25. Tinsley, R., Successful medical practice valuation. *Phys. News Dig.* 1–4, 2008.
26. Wang, S. J., et al., A cost–benefit analysis of electronic medical records in primary care. *Am. J. Med.* 114(15):397–403, 2003.
27. Yilmaz, Y., and Bititci, U., Performance measurement in the value chain: manufacturing v. tourism. *Int. J. Prod. Perform. Manag.* 55(5):371, 2006.
28. Rayport, J. F., and Sviokla, J. J., Exploiting the virtual value chain. *Harvard Bus. Rev.* 73(6):75–86, 1995.
29. Ford, E. W., and Scanlon, D. P., Promise and problems with supply chain management approaches to health care purchasing. *Health Care Manage. Rev.* 32(3):192, 2007.
30. Chen, I. J., Planning for ERP systems: analysis and future trend. *Bus. Process Manage. J.* 7(5):374–386, 2001.
31. Schechter, C. B., Posterior progress. *Med. Decis. Mak.* 26(5):431–433, 2006.
32. Marcot, B. G., et al., Guidelines for developing and updating Bayesian Belief Networks applied to ecological modeling and conservation. *Can. J. For. Res.* 36:3063–3074, 2006.
33. Pearl, J., *Probabilistic reasoning in intelligent systems: networks of plausible inference*. Kaufmann: San Mateo, CA, 1988.
34. Shacter, R. D., Model building with belief networks and influence diagrams. In: Edwards, W., Miles, R. F., and von Winterfeldt, D. (Eds.), *Advances in Decision Analysis*. New York: Cambridge University Press, pp. 177–201, 2007.
35. Radzikowski, P., Network models of autoregression. In: *4th International Conference on Information and Management Sciences*. Kunming, Peoples Republic of China: California Polytechnic State Univ, 2005.
36. Pepe, M. S., Cai, T., and Longton, G., Combining predictors of classification using area under the receiver operating characteristic curve. *Biometrics.* 62(1):221–229, 2006.
37. Hand, D., *Construction and assessment of classification rules*. Wiley: New York, 1997.
38. Burt, C. W., and Sisk, J. E., Which physicians and practices are using electronic medical records? *Health Aff.* 24(5):1334–1343, 2005.
39. Audet, A.-M., et al., Information technologies: when will they make it into the physicians' black bags? *MedGenMed.* 6(4):on-line, 2004.
40. Gans, D., et al., Medical groups' adoption of electronic health records and information systems. *Health Aff.* 24(5):1323, 2005.
41. Anderson, R. A., and McDaniel, R. R., Managing health care organizations: where professionalism meets complexity science. *Health Care Manage. Rev.* 25(1):83–92, 2000.
42. Begun, J. W., Zimmerman, B., and Dooley, K. J., Health care organizations as complex adaptive systems. In: Mick, S. S., and Wytenbach, M. E. (Eds.), *Advances in Health Care Organization Theory*. San Francisco: Jossey-Bass, 2003.
43. Taylor, R., Manzo, J., and Sinnett, M., Quantifying value for physician order-entry systems: a balance of cost and quality. *Healthc. Financ. Manage.* 56(7):44–48, 2002.
44. Lo, H. G., et al., Electronic health records in specialty care: a time-motion study. *J. Am. Med. Inform. Assoc.* 14(5):609–615, 2007.
45. Lang, R. D., The wow factor: the best HCI wins every time. *J. Healthc. Inf. Manag.* 20(1):2–4, 2006.
46. Zaroukian, M. H., and Sierra, A., Benefiting from ambulatory EHR implementation: solidarity, six sigma, and willingness to strive. *J. Healthc. Inf. Manag.* 20(1):53–60, 2006.
47. Kotani, K., Sakane, N., and Kurozawa, Y., The development of new communication technologies and patient–doctor interaction. *Intern. Med.* 45(5):349, 2006.

48. Andreassen, H. K., et al., Patients who use e-mediated communication with their doctor: new constructions of trust in the patient–doctor relationship. *Qual. Health Res.* 16(2):238–248, 2006.
49. Teutsch, C., Patient–doctor communication. *Med. Clin. North Am.* 87(5):1115–1145, 2003.
50. Palmieri, P., Peterson, L. T., and Ford, E. W., Technological iatrogenesis: new risks force heightened management awareness. *J. Health Care Risk Manag.* 27(4):19, 2008.
51. Shulman, R., et al., Medication errors: a prospective cohort study of hand-written and computerized physician order entry in the intensive care unit. *Crit. Care.* 9(5):R516–R521, 2005.
52. Kuperman, G. J., et al., Medication-related clinical decision support in computerized provider order entry systems: a review. *J. Am. Med. Inf. Assoc.* 14(1):29–40, 2007.
53. Zhan, C., et al., Potential benefits and problems with computerized prescriber order entry: analysis of a voluntary medication error-reporting database. *Am. J. Health Syst. Pharm.* 63(4):353–358, 2006.
54. Koppel, R., et al., Role of computerized physician order entry systems in facilitating medication errors. *J. Am. Med. Assoc.* 293(10):1197–1203, 2005.
55. Schneider, P. J., Applying human factors in improving medication-use safety. *Am. J. Health Syst. Pharm.* 59(12):1155–1159, 2002.
56. Aita, S., Implementing an EHR with ROI in mind. *J. Med. Pract. Manage.* 23(4):244–246, 2008.
57. Cooper, J. D., Organization, management, implementation and value of EHR implementation in a solo pediatric practice. *J. Healthc. Inf. Manag.* 18(3):51–55, 2004.
58. Ferris, N., Docs' EMR use is up, but users are still a distinct minority. *Government Health IT* 3(11), 2008.