Economic Outcomes of a Dental Electronic Patient Record

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Abstract: The implementation of an electronic patient record (EPR) in many sectors of health care has been suggested to have positive relationships with both quality of care and improved pedagogy, although evaluation of actual results has been somewhat disillusioning. Evidence-based dentistry clearly suggests the need for tools and systems to improve care, and an EPR is a critical tool that has been widely proposed in recent years. In dental schools, EPR systems are increasingly being adopted, despite obstacles such as high costs, time constraints necessary for process workflow change, and overall project complexity. The increasing movement towards cost-effectiveness analyses in health and medicine suggests that the EPR should generally cover expenses, or produce total benefits greater than its combined costs, to ensure that resources are being utilized efficiently. To test the underlying economics of an EPR, we utilized a pre-post research design with a probability-based economic simulation model to analyze changes in performance and costs in one dental school. Our findings suggest that the economics are positive, but only when student fees are treated as an incremental revenue source. In addition, other performance indicators appeared to have significant changes, although most were not comprehensively measured pre-implementation, making it difficult to truly understand the performance differential—such pre-measurement of expected benefits is a key lesson learned. This article also provides recommendations for dental clinics and universities that are about to embark on this endeavor.

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Digitizing patient information and health records has been on the agenda for health care organizations since the 1980s, but became a higher priority following the National Institutes of Health's Institute of Medicine report on computer-based patient records in 1991.[1] Since this time, patient records have evolved into the fields of optometry, medicine, veterinary medicine, and dentistry. Although each of these fields has coined a different phrase for the system that digitizes patient records and vital information (such as "electronic health record," "electronic medical record," or "electronic dental record"), we will use the term electronic patient record (EPR) throughout this article.

The use of electronic records is hypothesized to improve clinical quality and patient safety through reduction of medical and medication errors, since improved legibility should improve communication. These systems also allow records to be easily accessed by multiple parties, which is especially useful in a multiprovider clinic where patients might see different dental providers on each visit. Electronic records also should standardize the documentation of care, which could lead to improvements such as streamlining manual processes and eliminating paper.

Accordingly, many practicing dentists and dental schools are beginning to embrace the concept of the electronic patient record and move from paper charts to more expensive and comprehensive commercial systems and applications. The American Dental Association (ADA) and the ADA's Standards Committee on Dental Informatics have set out a number of specifications and technical reports to ensure confidentiality, interoperability, and sound data architecture. The ADA and the American

National Standards Institute have also developed Specification Number 1001 to help dental schools ensure appropriate designs of software for educational purposes, although it is not customized for the dental domain.[2]

Very little empirical research (i.e., research that is not anecdotal) is available to estimate or predict the actual total cost of implementing an EPR for dentists and dental schools. Our colleagues in medicine, however, provide a useful comparison. Electronic record systems in physicians' offices have been studied frequently and are suggested to range in cost from $15,000 to $50,000 per physician.[3] If we assume that these systems have comparable costs for dental offices, this becomes quite a substantial investment. Under most cost-effectiveness guidelines, one would expect technology investments to cover their expenses or produce some value in return, in the form of safety, quality, or clinical, operational, or financial benefits.[4,5]

Unfortunately, many comprehensive evaluations of electronic systems, primarily performed on large medical systems, have found evidence that EPR systems have costs that are greater than their combined benefits. Such studies have concluded that EPRs often do little more than automate an already existing record process and thus do not have a significant impact on outcomes, yet their costs are often measured in millions of dollars of investment and are met with widespread resistance from providers and staff.[6]

One of the most often-cited studies on electronic medical records (EMR) and benefits was conducted by the RAND Corporation to estimate the adoption and benefits of current systems.[7] This study, published in 2005, found adoption of electronic records was somewhere between 15 percent and 25 percent, depending on the size, organizational type, and other factors. Using a number of data sources, the authors attempted to evaluate the potential savings impact of these technologies over a fifteen-year period, which they considered to be the typical adoption period based on studies of innovation, and to suggest a framework for identifying performance areas, defining costs and efficiency, and using financial modeling to compare these benefits against costs. Another recent national study has suggested physician adoption of the EMR is around 17 percent for limited functionality and only 4 percent for a fully functioning system, with the main barrier to further adoption rates being the high financial costs.[8] In our research, we build upon the RAND framework for assessing integration of EPR into dental school clinics.

The electronic dental record has experienced mixed results similar to that of the electronic medical record. In general, there are extremely low adoption or penetration rates for a comprehensive EPR in dental offices, estimated by one research study at between 0 and 10 percent.[9] It is assumed that dental schools have higher penetration, but no empirical studies have been reported. Although computing and technology systems have begun to make limited progress at chair-side and as instructional tools in the dental classroom, most have not yet achieved paperless status.[10]

If there are clearly documented gains in performance—whether in reduction of errors, improvement in the quality of care or teaching, or higher safety—this could be enough to justify the large investment in an EPR. Most institutions that implement the EPR claim that the systems are "quality initiatives" and not undertaken to make profits. Quality changes in dentistry could include improvements in the following:

1. unfavorable events,
2. remakes/redos,
3. infection control rates,
4. billing complaints or rebills,
5. patient satisfaction,
6. students' educational experience,
7. insurance claim rejections, and
8. preservation (storage, security) of patients' confidential data.

In the absence of clearly documented gains in these areas, however, it is easy to question the actual value (i.e., cost-benefit) of the system.[11] At a minimum, most institutions should expect to fully recover costs and typically should expect to earn at least marginal positive economic outcomes in the long run. Typical ways that costs can be recovered are by reducing labor costs, reducing cycle time of manual processes, and eliminating paper and film expenses, among others.

In a recent article, Atkinson et al. discuss a comprehensive set of criteria, features, and functionality for dental EPR systems.[12] Their research, which evaluated the commercial EPR systems for dentistry, augments the ADA's Technical Report of EPR criteria with practical applications of the data contained in the repository for improving research, education, service, and clinical activities. That study did not, however, provide guidance on how to evaluate whether a system implementation was able to recover costs or produce substantial gains in performance.

Besides initial costs, resistance of the health care provider has been identified as one of the primary barriers or obstacles to adoption and usage of these systems. A number of failed implementations have been widely discussed, such as the Cedars-Sinai EMR debacle in which staff rebellions led to basically unplugging the system in 2002, after running up costs of nearly $34 million.[13] In the dental community, most of the barriers are similar to those experienced in other health care environments: finding a way to make the technology accessible, quick, and usable; incorporating the right features and criteria; and ensuring the underlying data model incorporates appropriate terms, taxonomies, and structures.[14] Legal issues, including patient security and confidentiality through HIPAA, also have been widely discussed as barriers to implementation success.[15] These types of challenges to the EPR could effectively mitigate any savings or benefits otherwise derived from the implementation.

The literature on value and outcomes attributable to electronic patient records in dentistry is very limited. There are few, if any, empirical findings exploring the relationship between benefits and costs of the EPR in a dental environment and, more specifically, the use of the EPR in a dental school. Based on the literature and theoretical foundations, it was evident to us that an evaluation should be performed to compare the theoretical value of the dental EPR versus actual results. While benefits can come from many areas, we specifically wanted to comprehensively evaluate a single implementation of an EPR and focus primarily on two key factors: 1) economic value, attributable to increases in revenues and efficiency or decreases in cost, which was explored in the study reported here; and 2) provider satisfaction, to estimate the support or magnitude of barriers to implementation success, which this research team is exploring in a current study to be reported in a future article. The findings from this evaluation should prove useful to other dental schools embarking on their own digital record implementations.

Methodology

In this research, we adapted an economic evaluation methodology used for systems evaluations,[16] which is essentially a case study pre-/post-research design with probability-based bootstrapping simulation model. This combines a case study research design with the use of Monte Carlo simulation modeling. Case study research methodology is a qualitative form of research, primarily applied in organizational and social sciences, which allows researchers to robustly examine an organization's processes, much more so than through surveys or other forms of research design. A case study is defined as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident."[17] Case study research methods are best applied when research questions being explored are attempting to address issues of "how" and "why." Case study research is the most frequent methodology used in systems evaluations because the data collection process requires normalization and standardization that otherwise would make results less valid or reliable. Our case study design included detailed development of the following:

- protocol (including timeline, research questions, data variables we were trying to capture, questionnaire and interview formats and design),
- fieldwork procedures (for reviewing documentation, collecting data, and note taking), and
- use of evidence (including convergence of themes and responses to interviews).

This protocol was augmented by the gaps identified in the literature necessary for conducting a comprehensive EPR implementation, as described above. The evaluation was conducted for a single case study dental environment, and Institutional Review Board approval was granted. Details about the organization that was studied follow the methodology section. This EPR included a picture archiving and communication system (PACS) as well as the electronic dental record system, which together we refer to as the EPR. We systematically evaluated the impact of an electronic patient record on clinical and operational outcomes one year post-implementation, which is the first of a multiphase evaluation process to be conducted over the next several years. To do this, we followed a six-step methodology aimed at uncovering the value of the system during this initial time frame. Figure 1 shows a summary of the methodology.

In the first phase, we attempted to gather the historical project information, primarily to understand the scope of work, and expectations about benefits, investments, and ongoing costs. We reviewed all available project information in written form,

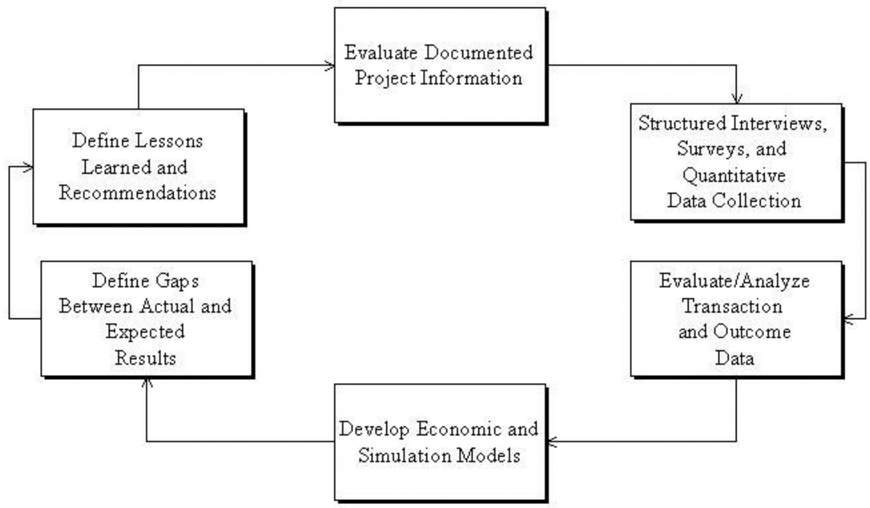

Figure 1. EPR evaluation methodology

including exploring the project's original expected deliverables, timelines, and charter. While no formal "business case justification" document was prepared, there was an original project charter and project plan, with information detailing expected benefits, costs, goals, and process workflow expectations. All of these data are essential to performing a comprehensive review, although in most cases the data are not available for all variables, as was the case here. For example, details about the volume of remakes or redos and number of patient complaints are important details, but there are no reporting mechanisms in place to capture and report these data.

Data Collection and Sources

Based on these documents, we identified the data to be collected, as well as their sources or repositories for both baseline and current data. Here, we obtained the existing data and explored gaps. There were a number of data sources that we relied upon. Structured, qualitative interviews with project participants, managers, and other stakeholders were performed. User perception surveys were also administered, using identical pre- and postsurvey designs. Other data relied upon were costs, productivity, revenues, process workflow, and space utilization. A number of other variables that we attempted to explore, such as reductions in medical errors or increase in quality or safety, were difficult to assess because our institution did not have existing performance metrics in these areas that were measurable. Although student admissions have increased annually, there was no specific evaluation of the quality of students' educational experience, beyond a survey of their satisfaction with the system.

Ideally, all data should be available for at least twelve to twenty-four months pre-EPR implementation, to serve as baseline comparison against the post-implementation outcomes. As such, the research design we used was essentially a one sample, pretest-posttest design. Development of the baseline information for comparison was paramount. To do this, we looked retrospectively for two years prior to implementation and forward twelve months post-implementation. Twelve months was sufficient for an initial evaluation and to establish a methodology for future iterative reviews, but is insufficient to gauge long-term efficacy results. Figure 2 shows the timeline used for this study.

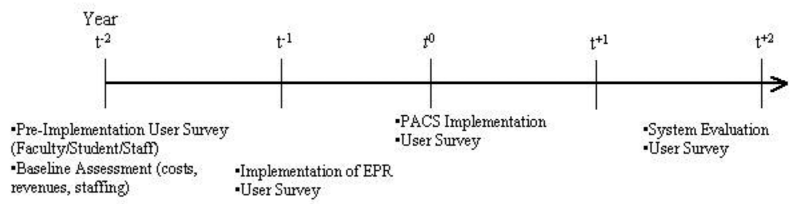

Figure 2. EPR timeline in case study

Economic Methods

In our methodology, we used trend analysis to identify patterns or behaviors that developed with these data over time. We used trends to define the relevant range of expectations and assumptions, which will be used in the economic evaluation. This took the form of a net present value (NPV) analysis. Net present value is a technique for analyzing the present value cash flows, discounted by the cost of capital, incorporating all of the EPR investment, annual or ongoing maintenance, and other costs, as well.

One of the primary disadvantages with traditional economic evaluations, however, is its reliance on a single estimate of value. To improve on this, we performed advanced bootstrapping using Monte Carlo simulation analyses in Crystal Ball software. Bootstrapping is a form of computer simulation in which repeated computation of results is performed as sample parameters are changed simultaneously or as the sample is replaced by other observations.[18,19] Bootstrapping is a widely used technique to evaluate a range of scenarios and outcomes and to incorporate risk and probability into otherwise static or deterministic models. It has been used to evaluate hypotheses and inferences in a variety of areas, including medicine and other aspects of health care.[20]

We analyzed the values of the data collected, and estimated variances and standard deviations for key parameters using descriptive statistics. Most of the data followed assumptions of normality in their distributions. Using Monte Carlo simulation, we tested 1,000 iterations (i.e., trials), applying sensitivity changes in several of the key parameters. These parameters included cost of capital (ranging from 6 to 10 percent); inflation rates (ranging from 2 to 5 percent); annual incremental labor costs (ranging from \$0 to \$60,000); and many others, which will be discussed in the Results section. Finally, we compared qualitatively and quantitatively the benefits, features, and savings expected prior to implementation against the actual results. Gaps, or differences between these, serve as recommendations for enhancements as well as lessons learned for future systems implementations.

Case Study Institution

The University of Texas Health Science Center at Houston Dental Branch (UTDB) is located in Houston, Texas, and is one of the fifty-seven U.S. dental education programs accredited to award the D.D.S./D.M.D. by the Commission on Dental Accreditation of the American Dental Association. Founded in 1905 as the Texas Dental College, it joined the University of Texas System in 1943 and serves as the only dental school in the Houston area. There are currently about 450 students, enrolled in one of many degree programs, including the D.D.S., M.S., B.S. in Dental Hygiene, and Dental Hygiene Certificate programs.

UTDB purchased an EPR in 2006. The EPR included scope of both imaging (PACS) and digital patient records. Two commercial systems were purchased and integrated, although for purposes of this research this is not a vendor evaluation and so we will keep this "vendor-neutral" or "-agnostic." By that we mean that the specific vendor or application was not important for this analysis, but rather the generic process of implementing any EPR system, so we will not discuss vendors here. The combined

EPR system was primarily purchased to automate the relatively large clinical practice that occurs in the main facility, which provides nearly 150,000 treatments annually for the community. However, the solution also serves as an educational delivery tool, in which images and records can be shared throughout the "simulation classrooms" to improve pedagogy. Benefits of the planned acquisition, as stated in the institution's original documents, included

- more accurate and legible information accessible by multiple providers simultaneously,
- common integrated application for digital imaging and decision making,
- improved patient safety,
- reduced costs and reduced staffing,
- higher quality (through higher completion of "patient encounter forms"), and
- improvement in the scheduling and reservation process.

Other potential benefits that could have been added to this original list include a) the opportunity to mine data for clinical research, which is only recently starting to happen at this institution; b) improved patient experiences, through higher satisfaction levels in clinics; and c) extending the use of the EPR in preclinical simulation to improve student transition to real patient care.

In most of these areas, however, there was not a specific, quantifiable target for the improvement, which would make it easier to evaluate post-implementation. Additionally, these figures should have been used to define a pre-investment "business case." The organization did document existing workflow, identify potential changes, and establish "to be" versions of clinical and academic processes. Additionally, not all ideal data around transactions (processes) and outcomes (performance) were available because of system or process limitations. Table 1 summarizes the data sources and their availability.

One of the most challenging parts of an EPR implementation is finding funding sources. In the case of our institution, part of the funding came from a technology grant from the system level and partially from an increase in student fees. Student technology fees primarily were to cover the ongoing operational and maintenance costs and were raised significantly, a tenfold increase in the first year. This increase was part of an overall initiative by our institution to support not only the EPR but also electronic curricula and clinical simulation. The total initial investment for the comprehensive systems, which included all internal and external costs, was around $600,000, or $6,700 per full-time-equivalent faculty provider. Internal costs are defined here as private costs borne

Table 1. Outcome and transactional data sources

Data Element	Data Source	Available	Not Available	Partially Accessible
Original business case/proposal	Project Files		X	
Initial cost-benefit/ROI analysis	Project Files		X	
Project plan, deliverables, and charter	Project Files	X		
Transactional/productivity cost data	Accounting System			X
Initial "Investment" data	Invoices	X		
Clinical outcomes (e.g., quality, errors)	N/A		X	
Operational outcomes (e.g., cycle time, staffing ratios, capture rates for procedures)	Observations			X
Financial outcomes	Accounting System	X		
Educational outcomes (e.g., student satisfaction, faculty perceptions, improved pedagogy)	Zoomerang Survey tool			X
User perception survey (faculty, student, staff)	Zoomerang Survey tool	X		
Stakeholder expectation and feedback	Interviews	X		

directly or indirectly by the organization, primarily in terms of resources consumed such as hiring of labor or material usage. External costs are costs paid to outside vendors (such as the application vendors or consultants) required for implementation, training, or ongoing maintenance.

Results/Findings

Results suggest that the economic outcomes of the EPR in this case study were positive. Specific, quantifiable benefits observed in this study include the following:

- The mean number of procedures charged for each unique patient, across all disciplines, increased from 4.5 in the baseline to 4.7 post-implementation (3.66 percent increase). This could be attributable to many things, but the previous paper recording system made it difficult to document and report procedures performed in real time.
- Revenues were projected using regression models in the baseline, and the differential between the actual and the projected represented a 4 percent increase in clinical revenues, part of which was attributed to the EPR. We used a conservative figure of 25 percent of these benefits, or 1 percent, to represent the EPR benefit. This assumption was based on previous systems evaluation research, which suggests that all of the benefit gains between periods should not be attributed to the system entirely.[21] In addition, previous empirical examinations suggest valid ranges for this assumption in the range of 25 to 50 percent.[22] Improved documentation helped to reduce the "unspecified" procedures by 99 percent, allowing better coding of accurate charges to patients after implementing EPR at the dental school.
- There was not a statistically significant change in the faculty-student staffing ratios. The ratios varied between 3.7 and 4.0 adjusted full-time-equivalent students for every adjusted full-time faculty member before and after EPR implementation, which did not suggest efficiency gains due to the new technology.
- Average monthly expenses for forms, record jackets, file folders, and other supplies used to maintain paper records fell significantly by nearly 66 percent, representing almost $20,000 annually.
- Since the UTDB is based in the highly concentrated, densely occupied Texas Medical Center, space is at a premium. Although there are approximately 325,000 gross square feet in the Dental Branch, only about 54,000 is usable for patient care activities. Approximately 1,500 square feet were used for storage of patients' dental records, which are now being gradually digitized and eliminated. This process will potentially increase revenue-generating space for patient care or research by nearly 3 percent in the future, although it was not possible to estimate the impact of future revenues in this evaluation.
- There was a staff reduction in the records department of two full-time-equivalent employees. However, there was a corresponding increase of two full-time-equivalents in the information technology department to support the initiative. Salaries of both job positions were in the same grade; therefore, the net cost was identical. In the model, however, we projected a probability of increasing one more employee at 50 percent. This increase in headcount was included because our interviews found that it was highly likely that the demand for additional reporting and system changes would necessitate the hiring of an additional employee sometime over the next five-year period.

Incorporating all of these benefits into a deterministic model over a five-year period, with the basic assumptions and distribution parameters from our data collected, the net present value was estimated at $425,191, which indicates fairly significant economic value. In most project evaluations of this size, a five-year NPV of this magnitude would be seen as quite a success. The reality, however, is that a large number of factors or variables influence this figure, and making a small change in simply one area has a huge impact on the outcome; thus, for each variable operationalized, there is a range of estimates and likely patterns of behavior. For example, a small increase in the cost of capital (or average cost to fund investments at a specific institution; for example, if bond rates yielded higher debt service payments) from 7 to 8 percent would have a 26 percent reduction on total net present value. To accommodate this variability, we used a bootstrapping simulation approach, which required us to make choices about variances and standard deviations of our assumptions and data and incorporated a greater degree of probability into each of the predictor variables. Table 2 shows each of the dynamic predictor variables in which we incorporated distribution models. Note that the static data (e.g., initial license costs, initial hardware) and certain other data are not listed because they are considered static and are not subject to change.

Running 1,000 iterations of the simulation model, randomly replacing values for each of the variables shown in the table above given risk and probabilities, the mean economic value (NPV) was computed to be significantly different—at $293,856 (median of $297,029). Still, the combination of positive source of cash inflow (student fee increases, clinical procedure revenue, paper/supplies savings) considerably outweighed the costs (initial investment, ongoing labor, recurring systems costs), given a cost of capital in the 7.5 to 8.5 percent range and inflation growth of 2 to 5 percent. The payback of the initial investment was a mere 2.5 years. Figure 3 presents the range of estimates for economic value produced in the simulation models.

When building comprehensive financial models, analysts need to incorporate all revenue (cash inflows) and expenses (cash outflows) that exist in the specific context. Clearly, a dominant revenue source in a dental school is clinical patient revenue, but equally as important are student tuition and fees. Tuition and fees represent the "pricing" variable in higher education, which reflects the implicit value that consumers perceive in the quality of the service being delivered,[23] similar to pricing decisions for clinical services. As such, they are an important strategic decision variable in the financial management of any institution. As a result, they are generally included in financial models and net present value analyses.[24]

To test a scenario, we ran the same set of data using the same distributions for these variables, with one exception—we eliminated the cash inflow due to student fees. This way, we could better answer the question: would EPR produce positive economic outcomes if the dental school (or any other school) was not able to have fee increases designated for this purpose? (The UTDB was in a good position to raise fees, since the previous level was quite low in comparison to fees typically paid by students in other professional programs.) The answer to this question was "no," at least within the same five-year horizon. Without this sizeable benefit from student fees, the value of the EPR is significantly reduced. There is not enough clinical revenue generated (or quantification of other benefits, such as reductions in errors) to maintain a positive NPV without student fees as a benefit. The median net present value falls to -$74,575, which indicates that during the first five-years post-implementation this project would not have sufficient value. In the scenario in which student fees are excluded, and the analysis is extended to ten years (which is roughly equivalent to our projection on the payback period), then the project would break even financially. In this scenario (with no increase in student fees), the range of economic value produced in these simulation runs was between -$410,000 and +$160,000. Figure 4 presents this scenario.

What this range of estimates shows is that, given a few small changes in expected values, only if a small number of scenarios held true would the system provide economic value. One way to use this

Table 2. Dynamic (nonstatic) variables in simulation model

Variable	Description	Simulation Estimate (mean)	Min	Max	Probability Function	Contribution to Variance
E1	Incremental, recurring annual labor expenses	22000	0	60000	Bernouli p(.5)	.5163
E2	Cost of capital	.079	.075	.085	Gaussian	.2573
Y1	Incremental clinical procedure revenue	24000	0	50000	Uniform	.1214
Y2	Incremental student fee revenue	256000	239000	270000	Gaussian	.0201
Y3	Incremental annual cost savings	15871	0	35000	Triangular	.0531
X1	Annual inflation growth	.041	.035	.050	Triangular	.0269
Z1	Net Present Value	293856	125000	440000	Gaussian	-

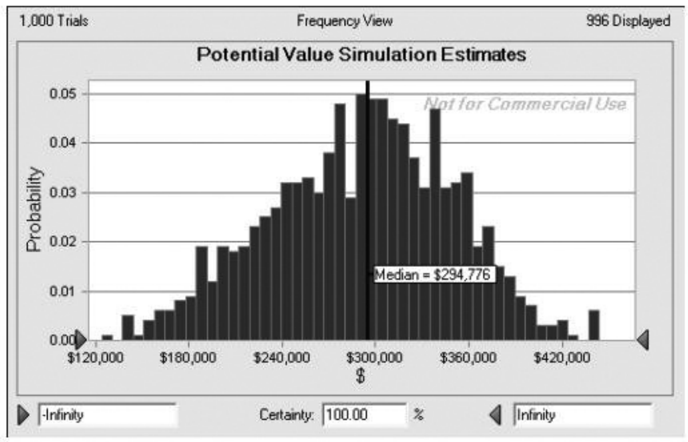

Figure 3. Bootstrap simulation model of net present value savings

result is to understand which parameters drove the values on the right side of the chart, and make policy or managerial decisions to ensure greater chances of success. Without intervention, it is nearly inevitable that the system will not produce positive economic value, if that is a key criterion for the investment.

Discussion

In this single case study research design, we sought to evaluate the economic outcomes of a dental electronic patient record, using a case study pre-post research design with probability-based bootstrapping simulation models. In this specific environment, where a combination of revenue sources was relied upon, the electronic patient record system was shown to "pay" for itself in only a few years. The range of estimates of value is quite large, but all positive, over a five-year period. If student fee increases were excluded, however—in the case of a school that does not have the ability to control the size of fees—the EPR requires a much longer time period to pay for itself (around ten years).

One of the key findings, or lessons learned, from this case is the need for comprehensive, quantitative expressions of the potential benefits up front, prior to the purchase and implementation of any system. Many institutions claim that they purchase an EPR for its potential impact on quality outcomes or safety, such as reduction in clinical errors or remakes, which is one contributing factor for why the Health Insurance Portability and Accountability Act (HIPAA) is helping to boost implementation rates of electronic systems in many health organizations. In addition, EPR has the potential to impact students' educational process, although we were not able to specifically measure any changes in this study except to say that, in the survey process, the students' perception of their education has increased due to the system and that they felt the system would improve their ability to practice after graduation. Without quantifiable estimates and measures for each benefit area, plus detailed views of initial and ongoing costs, the probability of creating positive outcomes is fairly minimal. Our institution did a good job of documenting many aspects of the project, but failed to concretely define precise values in many areas. With quantitative benefits documented, post-implementation decisions can be made to evaluate where and how the process and system should be changed. Without it, there is no clear rationale for implementing an electronic patient record.

Similarly, each of these benefits represents an outcome, or dimension of performance. If a clini-

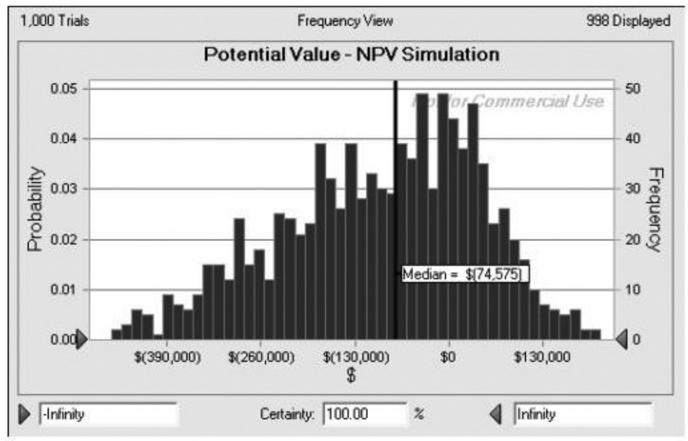

Figure 4. Simulation results with no student fee increases

cal benefit is an improvement in patient safety, and if it is expressed in quantitative terms, there must be a systematic process for routinely measuring this metric pre-, during, and post-implementation. Relying on single points in time, without consistent measurement techniques, is a recipe for disaster. Our institution had certain metrics clearly defined and measurable at most points in the baseline period, but not all. This causes problems because one can really never look back and determine if the EPR produced any differential effect on those areas.

The final lesson learned is that while some benefits produce economic value, there are many others that do not. For example, the EPR in this study has the potential to improve student learning and educational processes. The ability for a faculty member to review a student's work (e.g., case notes based on images on file) is very difficult to assign values to, but presumably (hopefully) these capacities result in higher-quality students and academic outcomes at some point. In addition, the "forcing functions" that support embedded rules and choices (e.g., choosing specific procedures or treatments in a drop-down list) also presumably (in a "makes sense" deductive appraisal) improves quality of care and reduces error, but is similarly difficult to quantify.

Revenue inflows at dental schools are fairly limited. Sources include tuition, grants, clinical revenue, state appropriations (for some schools), and student services fees. The issue of including any of these sources, beyond clinical revenue, can be debated for a number of reasons. For instance, if funds are secured through appropriations from the state specifically to purchase the system, is that really an incremental cash flow that should be attributed to the system? Accountants and economists typically view those as "unearned" and sometimes leave them out of analyses, as we did here with one exception—student fees. As we stated above, student fees reflect pricing decisions, similar to tuition, which are quantitative expressions of value received. If students perceive high value from the educational process, they are (perhaps or hopefully) more willing to pay higher prices. We realize that the UTDB case study was somewhat unique in that the current fees were low at approximately $95 per student/year, and a survey of the students indicated they would be able and willing to pay more if the technology was implemented. In other institutions, obtaining student support for enhancing fees might be more difficult to accomplish. One suggestion for institutions that are considering increasing fees to offset EPR costs would be to utilize economic simulation models, as described here, to understand the economic impact of a range of fee schedules. Such simulation would help to minimize the fees, but ensure they were sufficient to keep long-run net present value positive.

Dental schools and practicing dentists who are either considering or currently implementing electronic patient records should think carefully about the performance benefits to the practice (i.e., the expected benefits that the system should produce). A "scorecard" or dashboard is useful for improving management of resources and for aligning decisions with changes in outcomes. Performance management also ensures that benefits, costs, savings, and outcomes are known *prior* to embarking on the journey. Ensuring that data for transactions and outcomes are defined, documented, accessible, measurable, and quantifiable is essential. Understanding the process workflow, and redefining the workflow to take full advantage of the system, is also a key lesson learned.

A process and system for ensuring complete views on performance data, such as current dental error rates, really should become a higher priority. It has been suggested that the EPR improves safety in a number of ways: for example, by ensuring treatment plans are being followed; by reducing duplicative or contradictory tests and procedures; by reducing the time between an error and its discovery; by monitoring a patient's allergic or other reactions to specific medicines; or by documenting all services performed to allow for quality assurance and monitoring. Although we have not seen any published empirical findings on these safety and quality dimensions in dental schools, the ADA and the Centers for Disease Control and Prevention have found increased prevalence and have issued reports and guidelines for monitoring infection control and other adverse events.[25] Therefore, each institution should develop its own process for tracking and monitoring these metrics; the EPR could help in this area. Clearly, one could hypothesize that digital charts improve legibility, and reviewing students' diagnoses and notes allows faculty to detect errors faster and minimize patient impacts. These benefits, if real, could produce significant value that needs to be quantified. Absent a process for clearly defining and tracking these incidents, however, no organization can clearly delineate the true impact of the EPR.

While there are no universal rules or assumptions that will apply to all institutions, in this particular case study, there were positive economic outcomes from the electronic patient record, even given a thousand iterative changes in probabilities and other risks, but enhancement of student fees was a key component in positive value outcomes. Continuing to expand and refine these evaluation models over a longer time period, and with a broader sample of institutions, is one suggestion for future research in this domain.

REFERENCES

1. Dick RS, Steen EB, Detmer DE, eds. The computer-based patient record. Committee on Improving the Patient Record. Washington, DC: Institute of Medicine, 1991.
2. ADA Standards Committee on Dental Informatics. At: www.ada.org/prof/resources/standards/informatics.asp. Accessed: April 22, 2008.
3. Miller R, Sim I, Newman J. Electronic medical records: lessons from small physician offices. San Francisco: University of California, San Francisco/California Health Foundation iHealth Report, October 2003.
4. Chambers DW, Bergstrom R. Financial management and dental school strength, part I: strategy. J Dent Educ 2004;68(4):433–8.
5. Muenning P. Cost-effectiveness analyses in health: a practical approach. San Francisco: Jossey-Bass, 2008.
6. Lapointe L, Rivard S. Getting physicians to accept new information technology. CMAJ 2006;174:1573–7.
7. Hillestad R, Bigelow J, Bower A, Girosi F, Meili R, Scoville R, Taylor R. Can electronic medical record systems transform health care? Potential health benefits, savings, and costs. Health Aff (Millwood) 2005;24(5):1103–17.
8. DesRoches C, Campbell E, Rao S, Donelan K, Ferris T, Jha A, et al. Electronic health records in ambulatory care: a national survey of physicians. New Engl J Med, June 18, 2008. DOI: 10.1056/NEJMsa0802005.
9. Schleyer TK, Thyvalikakath TP, Spallek H, Torres-Urquidy MH, Hernandez P, Yuhaniak J. Clinical computing in general dentistry. J Am Med Inform Assoc 2006;13(3):344–52.
10. Hendricson WD, Panagakos F, Eisenberg E, McDonald J, Guest G, Jones P, et al. Electronic curriculum implementation at North American dental schools. J Dent Educ 2004;68(10):1041–57.
11. Hoffman T. Health care goes digital with instant image access. Computerworld, May 5, 2007.
12. Atkinson JC, Zeller GG, Shah C. Electronic patient records for dental school clinics: more than paperless systems. J Dent Educ 2002;66(5):634–42.
13. Connolloy C. Cedars-Sinai doctors cling to pen and paper. Washington Post, March 21, 2005:A01.
14. Reynolds P, Harper J, Dunne S. Better informed in clinical practice: a brief overview of dental informatics. Br Dent J 2008;204:313–7.
15. Szekely DG, Milam S, Khademi JA. Legal issues of the electronic dental record: security and confidentiality. J Dent Educ 1996;60(1):19–23.

16. Langabeer JR. Health care operations management: a quantitative approach. Boston: Jones and Bartlett Publishers, 2008.
17. Yin RK. Case study research: design and methods. Thousand Oaks, CA: Sage Publications, 2003.
18. Efron B. Bootstrap methods. Ann Statistics 1977;7(1):1–26.
19. Charnes J. Financial modeling with crystal ball. New York: John Wiley & Sons, 2007.
20. Manly B. Randomization, bootstrap, and Monte Carlo methods in biology. London: Chapman Hall/CRC Publishing, 2007.
21. Renner K. Cost-justifying electronic medical records. Healthcare Financial Manage 1996;50:63–4.
22. Wang S, Middleton B, Prosser L, Bardon C, Spurr C, Carchidi P, et al. A cost-benefit analysis of electronic records in primary care. Am J Med 2003;114:397–405.
23. Hill F. Managing service quality in higher education: the role of the student as primary consumer. Quality Assurance Educ 1995;3(3):10–21.
24. Managerial analysis and decision support: a guidebook and case studies. Washington, DC: National Association of College and University Business Officers (NACUBO), 2004.
25. Centers for Disease Control and Prevention. Guidelines for infection control in dental health care settings. Washington, DC: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, December 19, 2003.