On The Economic Role of RIS/PACS in Healthcare: An Empirical Study

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Abstract

The integration of electronic patient data records with digital images in PACS is the only way today to provide high-quality clinical services. Such integration enables clinicians to access both systems' data reliably and consistently, as part of their regular working environment. This work extends the literature on RIS/PACS systems by focusing on changes in process dynamics as a source for ongoing firm-level performance improvements. A case discussion of viaHealth/Rochester General Hospital (RGH), a medical center that implemented RIS/PACS and subsequently experienced benefits through gains to its continuous improvement efforts, is examined in light of theorized impacts of such implementations on process dynamics. Analyses of longitudinal data suggest that performance along a key metric motivating the RIS/PACS initiative (i.e., clinical process lead-time) showed a significant improvement immediately after system deployment. The data further suggest that the system implementation gave rise to ongoing trend of performance improvement, in contrast to a stable performance trend prior to go-live. Finally, we present a general framework for capturing the actual tangible and intangible benefits of RIS/PACS implementation at a major hospital.

1. Introduction

Enterprise systems are one of the most important information technology (IT) categories to emerge in the last decade [1]. Even in stable industries such as banking and insurance, organizations must continuously invest in new IT infrastructure to keep up with growing demand and competition [2]. In the healthcare service, especially in hospitals, medical images are currently created digitally and stored in the radiology department’s Picture Archiving and Communication System (PACS). Reports are usually stored in the Electronic Patient/Medical Record (EPR or EMR) of the Hospital Information System (HIS), and particularly in the Radiology Information System (RIS), which is designed to store, manipulate, and retrieve information for planning, organizing, directing, and controlling administrative activities associated with the provision and utilization of radiology services and facilities. High quality services can only be provided, however, if EPR data is integrated with the digital images in PACS. Clinicians should be able to access both systems' data as part of their regular working environment, whether HIS or RIS. A combined RIS/PACS should allow for teleconferencing with other users, e.g., for consultation with a specialist or technologist in the radiology department.

PACS consists of image acquisition devices, storage archiving units, display workstations, computer processors, and databases. These components are integrated by a communications network and data management system. Combining RIS with PACS produces an integrated desktop to enhance diagnostic efficiency and productivity, and streamlining patient information and access. [3]. Radiologists can quickly view a patient's complete clinical position for fast, accurate exam interpretations. Images can be automatically displayed on the workstation’s diagnostic monitors, complemented by an RIS side monitor for viewing patient text information. Simple mouse clicks access a comprehensive tool set, exam data, clinical data (such as laboratory reports), patient histories, and voice dictation. Activating embedded native tool sets such as 3-D, MPR, MIP, and vessel analysis combined with automated prior image selection is just as quick and easy. Ordering exams is fast, flexible, and accurate with RIS. Requesting physicians can enter orders directly into the RIS through an HL-7 HIS via secure Web communications reducing entry tasks and possibilities for error. Orders can also be entered manually, or scanned in from paper documents, at the radiology reception desk. It all adds up to a more efficient workflow for the radiology unit and better service to referring physicians, as well as expanded marketing options.

In this paper, we provide grounds for supporting or rejecting, some of the claims being raised in relevant professional literature regarding the benefits of implementing a RIS/PACS system, based on real-world data acquired through a field study. The benefits as well as costs of such system implementation have
both tangible and intangible characteristics, and our study of these provides a methodology for examining the value of implementation in any healthcare provider that considers going digital. Prior to the implementation, we looked at 150,000 studies (radiology procedures) in terms of charges and revenues collected, and for a sample we identified report turn-around times (TAT) and process bottlenecks. We repeated these inquiries after the RIS/PACS implementation. In addition, we used a survey instrument to measure the changes in the satisfaction levels of radiologists, technology staff, and referring physicians.

2. Related Research

Film and film-related savings that are associated with PACS implementation come from the elimination of (a) the film library, (b) film processors, (c) darkroom and film library personnel, and (d) film costs for specialties (number of procedures, sheets, etc.). Investments in new digital modalities continue, even in small enterprises [4]. One way to increase revenue is to increase the volume of healthy covered individuals (capitation contracts) or to compete for large contracts’ “carve-out” services and tertiary care. Another way is to expand the hospitals geographic competitive reach. Recent studies have shown that a softcopy department will be somewhat more expensive to operate than a conventional one, and that radiologists initially will be slightly less productive when using the new technology. In the long run, however, reports have shown that PACS can be cost effective by allowing for a significant increase in workload and volume of examinations without a corresponding increase in the number of radiologists and technologists.

2.1. Tangible Benefits and Costs of RIS/PACS

In general, tangible benefits and costs are commonly known and easy to recognize. Tangible benefits are usually measurable in terms of cost reduction, which is associated with improving business efficiency, and generation of additional sales, which creates additional revenue. Tangible costs put users in control of their expenses, as they are easy to quantify.

First obvious benefit is savings on purchase and handling of film. PACS implementations achieve an average 80% reduction in film usage within the first year [5]. In addition, there are reports of reduced costs for film handling, storage, and couriers. The interim steps of prepping jackets, completing paperwork, and locating prior images are eliminated with digital image management. In RGH’s Dept of Diagnostic Medical Imaging, films were in use until 15 months after implementation of RIS/PACS. This situation changed only after the head of the department realized that his radiologists hardly used them. According to the department’s radiologists, PACS could replace films in every modality except mammography, where radiologists preferred to use films.

Another benefit is increased productivity. Interestingly, academic radiology departments across the United States do not employ a standardized set of productivity and financial indicators to measure their performance, although the radiology literature states that an integrated RIS/PACS help increasing patient throughput and workflow productivity [3]. Examination volume is used most frequently to measure productivity, but eight other productivity indicators are also common: examination volume, examination volume per modality, technical relative value units (RVUs), professional RVUs, technical RVUs per FTE employee, professional RVUs per FTE employee, gross charges by modality, collections by FTE employee, and examination volume by resource or device. General expenses are commonly used as indicators of financial status [6]. Still, among all indicators, productivity indicators are the most frequently used [7]. Thus, we chose to measure productivity by testing the hypothesis that the RIS/PACS improves the billing system and increases the operational revenues of a diagnostic imaging service provider. Specifically, we examine following hypothesis:

H1: Implementing RIS/PACS results in a rise in the ratio of charges per procedure, due to a rise in (a) process efficiency, (b) a more accurate coding, and (c) faster and more reliable billing.

Another benefit is the reduced turnaround time that, for radiology practices, is a priority for any radiology service seeking to boost profitability and increase referrals [3]. An important measurement of efficiency in radiology service is the promptness in producing a final report [8]. Some practices document times approaching 30 hours or more for the entire workflow process. One study, conducted in April 2001, found that a RIS measurably and significantly decreases report turnaround and transcription time, resulting in faster bill processing and enabling an increase in the number of procedures performed per month (RIS Logic in www.merge-efilm.com). The study was based on a random telephone survey of 150 radiologists and business administrators from diagnostic imaging centers and hospital radiology departments (among hospitals with 200 and fewer beds). As a result, we specifically outline our second hypotheses as follows:

H2: RIS/PACS will improve the flow time of the diagnostic imaging service provider by reducing both
Examinations are associated with the appropriate referring MDs based on information received from the RIS. By interfacing the PACS with RIS/HIS, data entry time is reduced, errors are eliminated, and a single source for access to patient and examination data is provided. One study investigated such an interface in a Department of Defense hospital and found that data mapping during installation saves significant amounts of time, improves productivity, and increases user acceptance during PACS implementation. In addition, the PACS and RIS/HIS interface reduce the amount of manual data entry into multiple automated systems.

Improved interaction among departments is also a benefit, as PACS can bring substantial benefits to many departments of the health-care facility (e.g., ED, ICU, Operations, etc.), improving clinical care and turnaround times. Improved cooperation and interaction between departments, however, are not necessarily a given. Hospitals that pay close attention to the needs of the various departments before, during and after PACS implementation are most likely to realize better results.

Finally, costs of cooperation between departments have to be taken into account. On the other hand, increased cooperation usually entails the costs of collaborative effort as well, and it requires an analysis of the department’s workflows and image-viewing needs to devise an optimal solution. Components to consider include the types of workstations and monitors, viewing locations and conditions, training and tools to facilitate communication between radiologists and clinicians.

2.3. IT Productivity and Benefits

A significant body of literature examines the strategic aspects of Electronic Data Interchange (EDI) [13], [14], and [15]. However, there have been only a few systematic empirical assessments of the strategic benefits of this technology. Prior work has primarily considered the impact of EDI, e.g., one study found that EDI leads to a range of benefits for an industrial supplier, depending on how technology choices are made by its trading partners. Among others, they found that advanced EDI significantly reduces the probability of rework and delay [16]. Several works try to measure the benefits of information technology using empirical techniques. However, most of the articles carry out empirical investigation at the industry or the economy level. One study explored the effect of computerization on productivity and output growth, and found that computerization makes a contribution to measured productivity and output growth in the short term that is consistent with normal returns to computer investments. Moreover, the productivity and output growth
contributions associated with computerization are up to 5 times greater over several years [17]. However, the observed contribution of computerization is accompanied by relatively large and time-consuming investments in complementary inputs, such as organizational capital, that may be omitted in conventional calculations of productivity.

Recent empirical research has already suggested that implementing firms realize productivity and market capitalization benefits [18], and studies of operational performance suggest that ERP positively influences performance over time [19]. In addition, a case of a firm that implemented ERP and subsequently experienced benefits through gains to its continuous improvement efforts. The case [15] was examined in light of theorized impacts of such implementations on process dynamics. Analyses of longitudinal data suggest that performance along a key metric motivating the ERP initiative (i.e., order fulfillment lead-time) showed a significant improvement immediately after system deployment. The data further suggest that the system implementation gave rise to an ongoing trend of performance improvement, in contrast to a stable performance trend prior to go-live. In addition, evidence on gains for Just-in-Time systems can be substantially increased by modern information technology support [20].

Compared with conventional film-screen operation, filmless operation using computed radiography was associated with a significant decrease in technologist examination times in the performance of general radiographic examinations. They inferred that the decrease in technologist examination times in a filmless environment offers the potential for increased productivity with resulting personnel savings and improved operational efficiency [21]. However, they put primary focus of productivity enhancements on technologists, without considering the effects on radiologists, which might be found unjustified, as our study suggests. Overall, there is very little empirical research at the firm level, and literature lacks a quantification of the impact of the implementation of a large healthcare IT system, like RIS/PACS, on the operations of the healthcare provider.

The combination of image-centric PACS and information-centric RIS enables hospitals and imaging centers to simultaneously manage and archive medical images. Relevant prior examinations are prefetched from the archive for comparison immediately. A worklist-enabled modality allows the technologist to select the scheduled examination from an existing list, avoiding the redundant entry of information. This automation eliminates costly typing errors that may cause examinations to be filed with the wrong identification. Moreover, referring physicians can log in and view studies, including all images and completed reports.

3. Context Specification and Data

To validate our hypotheses, we measured process times and revenues and conducted satisfaction surveys of the staff and customers of the viaHealth/Rochester General Hospital (RGH), a medical center in Rochester, NY, during the years 2004-2006. We emphasize that no major incidents happened during the period of study, other than the implementation of RIS/PACS - even the number of clinicians stayed the same and only few administrative employees were fired.

Figure 1. The Clinical Process in the Department Before it Goes Filmless.

Figure 1 depicts the clinical process in the department before it goes filmless. Delays occurred mostly in those cases in which a study was not successful. Upon such occasions in the film-based process, the technologists had to spend time—at least a couple minutes—replacing films and reloading the machines, whereas with PACS both deleting and reloading is done in seconds. However, this is just
aspect of shortening the process lead-time. A careful examination of the flow revealed a substantial bottleneck shift in the process. With specific reference to Figure 1, this process effect describes a sequence of activities targeted at temporary bottleneck alleviation at the transcription, i.e., “subordination to bottlenecks” [22], ultimately giving rise to a transformational effect on the fulfillment process, i.e., “swifter” fulfillment [23].

3.1. Billing Turnaround

Figure 2 displays the billing process in the Diagnostic Imaging Department before and after RIS/PACS implementation. Phases that have been eliminated from the “After” process are shadowed. The two shadowed phases represent the frequent need of the department’s billing unit to go looking for about 10% of the studies again, based on the clinical report they got after the “Sign-2” phase. Often, this would bring the operation to the edge of failure, as the department just barely complied with the hospital’s rule requiring billing of inpatient services within three days after the exam and of outpatient services within eight days. The head of radiology operations estimated that this had also contributed to the level of studies not billed by the department.

We hypothesized that integrated RIS/PACS improves the billing system of a service provider and thus results in faster billing. We first examined whether the department’s total revenues increased after implementation. Figure 3 shows the results per modality. This figure and Table 1 provide patterns for one of the main five modalities of the department—CT—as well as totals for the whole department (5 modalities: (1) Diagnostic (Regular X-ray, CR, DR); (2) CT; (3) Invasive; (4) Nuclear Medicine; and (5) Ultrasound). Our results clearly show that an increase in the revenue per procedure followed the RIS/PACS implementation for all procedures, with the exception of the CT modality. Moreover, the growth rate of revenue per procedure in the department has more than doubled, from less than $2 per procedure per month to $4!

<table>
<thead>
<tr>
<th>Modality</th>
<th>Before RIS/PACS</th>
<th>After RIS/PACS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostic</td>
<td>0.57** 0.23</td>
<td>0.90 0.43</td>
</tr>
<tr>
<td>CT</td>
<td>7.02** 4.87</td>
<td>9.16 7.4</td>
</tr>
<tr>
<td>Invasive</td>
<td>4.52 5.01</td>
<td>14.60 0.05</td>
</tr>
<tr>
<td>Nuclear Med.</td>
<td>-4.17** -5.20</td>
<td>-3.15 0.81</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>1.01** 0.30</td>
<td>1.72 0.35</td>
</tr>
<tr>
<td>Total</td>
<td>1.75** 0.76</td>
<td>2.74 4.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Modality</th>
<th>Before RIS/PACS</th>
<th>After RIS/PACS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostic</td>
<td>0.60** 0.43</td>
<td>0.94 0.72</td>
</tr>
<tr>
<td>CT</td>
<td>3.68** 1.98</td>
<td>5.38 0.63</td>
</tr>
<tr>
<td>Invasive</td>
<td>38.50* 1.23</td>
<td>75.70 0.78</td>
</tr>
<tr>
<td>Nuclear Med.</td>
<td>-0.27 -2.04</td>
<td>1.50 0.91</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>0.74 -0.79</td>
<td>2.27 0.08</td>
</tr>
<tr>
<td>Total</td>
<td>4.04** 2.76</td>
<td>5.33 0.78</td>
</tr>
</tbody>
</table>

* p < .05, ** p < .01
3.2. Turnaround Times

Since process-changes tend to extend the implementation time-frame, the opportunity exists for additional information gains to yield ongoing process change and performance improvement [24]. One of those dimensions of process improvement is turn around time. Thus, we measured the time required for the generic process conducted in the radiology department of viaHealth/RGH. Our benchmark was similar data collected in June 2004, before the RIS/PACS implementation at RGH, by a team of researchers from Kodak. Their data consisted of 400 representatives TAT measurements. After RIS/PACS was implemented, in August 2004, we retrieved data on each procedure directly from the RIS. We tracked the time performance during the period August 2004 – October 2006. We collected data on the duration of the four main phases of a generic service: (a) Exam done; (b) Dictation; (c) Transcription; and (d) Sign-1 (residents) and/or Sign-2 (attending physicians) for final approval. Figure 4 describes the results of the average duration per phase across all modalities for the Diagnostic Imaging Department.

The results confirm our hypotheses regarding significant reductions in diagnostic examination times. Within a year, the time required for approval of a transcribed report went down from about 50 hours to less than 20. Moreover, improvement was detected in all phases of the process. The most impressive improvement was achieved in the transcription phase, where cycle time was reduced from about 60 hours prior to RIS/PACS implementation to about 4 hours immediately after implementation, and further to less than an hour within a year!

Improvement was not always immediate, however. Our results suggest that the time required for dictation increased from 8 hours to 25 immediately after implementation. Eventually, as radiologists gained experience with the system, this figure decreased to below the original value, down to 4 hours. In fact, although significant cycle-time improvements were achieved for all phases, only transcription experienced shorter durations immediately. A learning period of a couple months was required before the department could achieve broader improvements.

Figure 4(b) provides the aggregate learning curve of the department. Using the classical logarithmic model (e.g., [25]): \( kn = k_1 \cdot n^b \), where \( k_1 \) is the TAT at month 1, we find that \( b = -0.665 \). This implies that the learning rate is \( r = 10^{(-0.665 \cdot \log 2)} = 63\% \) during the first year after implementation. The aggregate 80% total TAT reduction, down from about 100 hours upon implementation to around 20 hours after 10 months, is indeed phenomenal. However, as the national benchmark for the service duration is 12 hours, the department must still effect additional improvements in cycle time, using the wealth of information now provided by the RIS/PACS system.

The Pareto charts in Figure 5 suggest that the exam phase made a negligible contribution to the total TAT both before and after RIS/PACS implementation. Transcription, which used to make up half the total TAT, has been dramatically reduced to a very small part (5%). Sign-1 and Sign-2 went up from a 40% share to more than 70%, so these offer the greatest potential for operational improvement.
3.2. Customer Satisfaction

To validate our two hypotheses on the effect on customer satisfaction, we conducted a survey. Once again, the pre-implementation data were collected at viaHealth/RGH in June 2004 by a research team from Kodak. They used a satisfaction questionnaire distributed among staff and customers. With a response rate of approximately 40%, the survey yielded data from 150 referring physicians (see Appendix A).

In August 2004, the RIS/PACS system was implemented in the department. We waited for implementation to be completed at the referring physicians’ sites to conduct a second survey. We anticipated that we would witness a dramatic change in their satisfaction with the diagnostic imaging service. We likewise expected notable improvements in staff satisfaction within the radiology department. This ex post survey was conducted in October 2006, with over 70 responses from referring physicians (Appendix B). The customer - referring physicians - survey focused on four dimensions of the process: time, workflow, quality, and interaction with the radiology staff. The results are summarized in Table 2.

Table 2: Satisfaction with the Department Among Customers Before RIS/PACS Implementation.

<table>
<thead>
<tr>
<th>Question</th>
<th>No.</th>
<th>Median</th>
<th>Principal Comp.</th>
<th>Principal Comp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1 Prel. report</td>
<td>136</td>
<td>3 [2.5]</td>
<td>.396</td>
<td>.265</td>
</tr>
<tr>
<td>2 Final report</td>
<td>140</td>
<td>3 [2.4]</td>
<td>.334</td>
<td>.196</td>
</tr>
<tr>
<td>Availability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 In the Dept</td>
<td>126</td>
<td>3 [2.5]</td>
<td>.326</td>
<td>.501</td>
</tr>
<tr>
<td>4 Outside</td>
<td>110</td>
<td>4 [2.5]</td>
<td>.376</td>
<td>.677</td>
</tr>
<tr>
<td>Workload</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Order exams</td>
<td>138</td>
<td>4 [3.5]</td>
<td>.329</td>
<td>.201</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Radiologists</td>
<td>142</td>
<td>6 [4.6]</td>
<td>.351</td>
<td>.314</td>
</tr>
<tr>
<td>8 Tech/Admin</td>
<td>142</td>
<td>5 [4.6]</td>
<td>.347</td>
<td>.207</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>45.1%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The table presents the number of responses received for each question, and the median, lower and upper quartile values. In order to identify patterns in the data and highlight their similarities and differences, we use the Principal Components Analysis (PCA) methodology. The table presents the results of the PCA analysis, specifying the main eigenvectors of the normalized covariance matrix of the data and their percentage explaining the responses’ variance.

The results show that referring physicians were satisfied with their level of interaction with the department personnel—mainly with the radiologists (median = 6), and somewhat less with the technologists and administrative staff (median = 5). The customers were indifferent (median = 4) regarding the workflow and the quality of the service, but they were not satisfied with the time it took to produce a radiology report. Indeed, the time required to receive a final report led many respondents to act according to the preliminary report without waiting. We anticipated that implementing the RIS/PACS system would improve customers’ level of satisfaction from the diagnostic imaging service. Indeed, the “after” results were significantly higher. Figure 6 shows the median, lower, and upper quartile values for each question.

Figure 6. Referring Physicians’ Satisfaction Level After RIS/PACS Implementation.

We computed one-way ANOVA to test whether data from compared questions have a common mean. Our results clearly show that they do not. Table 3 quantifies the differences in referring physicians’ satisfaction levels before and after RIS/PACS implementation.

Table 3: Multiple Comparison: Before and After RIS/PACS Implementation.

<table>
<thead>
<tr>
<th>Question</th>
<th>Difference</th>
<th>Median</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final radiology report</td>
<td>2.133**</td>
<td>2.399</td>
<td>1.327</td>
<td></td>
</tr>
<tr>
<td>Images/films availability</td>
<td>1.524**</td>
<td>2.391</td>
<td>0.688</td>
<td></td>
</tr>
<tr>
<td>Ordering/scheduling exams</td>
<td>0.839*</td>
<td>1.642</td>
<td>0.086</td>
<td></td>
</tr>
<tr>
<td>Departmental communication</td>
<td>0.906*</td>
<td>1.732</td>
<td>0.081</td>
<td></td>
</tr>
<tr>
<td>Interaction with Radiologists</td>
<td>0.247</td>
<td>1.056</td>
<td>0.561</td>
<td></td>
</tr>
<tr>
<td>Interaction with Staff</td>
<td>0.187</td>
<td>1.010</td>
<td>0.063</td>
<td></td>
</tr>
</tbody>
</table>

* p < .05, ** p < .01

To validate our hypothesis that referring clinicians who use the new technology are more satisfied with the service than those who do not, we establish a predictor, “Usage of technology”. We add to the model another predictor, “Time to receive a signed final report”, which the literature suggests is associated with overall
satisfaction. We construct a model of total satisfaction \((TOT)\), which takes the following form: \(TOT = b_0 + b_1 \cdot FNR + b_2 \cdot TCU + \text{err}\). Results are summarized in Table 4. We see that satisfaction is even higher among those referring physicians who actively use the technology fully with PACS at their own or the hospital’s site. The results are statistically significant at \(p < 1\%\).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>25%</th>
<th>75%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost (%), FNR</td>
<td>1.275**</td>
<td>0.603</td>
<td>1.947</td>
</tr>
<tr>
<td>Final Radiology Report (FRR), TCU Usage</td>
<td>0.736**</td>
<td>0.607</td>
<td>0.867</td>
</tr>
<tr>
<td>Technology Usage (TCU)</td>
<td>0.556**</td>
<td>0.101</td>
<td>1.012</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.716</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(F)</td>
<td>77.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(p)</td>
<td>0.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Var(Err)</td>
<td>0.792</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: * \(p < .05\), ** \(p < .01\)

4. Discussion

Some works documented in detail new information technology (IT) implementation in a single manufacturing organization [15], as opposed to more general studies that analyze data from many organizations. However, this work is amongst the first to study a service organization, particularly in healthcare, with IT impact. Therefore, here intangibles, like satisfaction, are as important as tangibles, such as turn around time (TAT) or the financial impacts on the service provider - and those were documented in detail. As we observed, the rapid improvement, that does not coincide with the common “productivity paradox” [26] is a direct result of the fact that the bottleneck in our case was the most prone to technology usage, and happily adopted his part in the system implementation. Having such an outstanding improvement on the spot fueled the improvement process of the whole organization, and enabled significant gains in productivity.

From a managerial perspective, case examination at the end of the study period showed that the bottom-line impact of the lead-time improvements was significant for viaHealth/Rochester General Hospital (RGH). We observed a phenomenal 63% year-long learning rate after the RIS/PACS systems were implemented. During that period, TAT shrunk by 80%, indicating that most of the benefits of RIS/PACS take time and added effort to be fully realized. The billing process became more authentic and reliable, as all preps, procedures, and exams could be captured, and the rate of lost studies decreased from 10% to less that 1%. We documented a steady increase in revenue of more than $3 per procedure per month. Taking into consideration an average rise in charges rates of about 5% annually, this gives a pure rate of billing improvement of 1% per month per procedure, not to mention the 20% rise in number of procedures during the first year. Finally, the satisfaction level of referring physicians went up dramatically from around 3 to 6 on a 7-point Likert scale!

4.1. Limitations

Implementation of RIS/PACS results in significant cycle-time improvements over the long term throughout the imaging process, and immediate results in the transcription phase offset, in the short term, by increased time requirements while staff learn the new software. These trends drive down costs and enhance revenues under most conditions, although cycle-time reductions may not be sufficient to enable the department to attain industry performance targets. Under such circumstances, however, the abundance of information and reporting options within the integrated system make possible financial analysis that can highlight profitable segments of the practice. Practice analysis tools could then uncover new ways to maximize profits by indicating which insurance programs and referring physicians are most profitable. This possibility remains to be studied, based on data from a hospital’s financial department.

4.2. Implications

Several interesting managerial and theoretical implications emerge from our findings. First, good integration of workflow and information system forms the essential basis for any operational improvement on the part of the health-care provider. Having well-defined and well-understood processes gives the ability to respond to changes in market conditions. While defining the metrics and measuring and tracking the process, we could detect improvements in both cycle times and customer satisfaction. We witnessed a significant cycle-time improvements achieved in all phases after implementing RIS/PACS by the department. However, transcription showed an immediate and sharp improvement, while all the rest experienced longer processing durations immediately after implementation. This also expands literature as it focuses on the bottleneck alleviation of the process, the transcription, ultimately giving rise to a transformational effect on the service process. Tanscriptionists are more professional in using computers than the rest of the staff, so that might explain this rapid pace of improvement. However, as
we witnessed, not before long improvements were achieved in all other phases!

Another important implication of the study is the potential for post-implementation improvements, such as an enhanced interface between the radiology department and other hospital departments and referring physicians. The use of information systems' capabilities should lead to developing complementary procedures in all departments, which could elevate the service of the entire health-care facility. A practical managerial take away for radiology, and more generally for IT Implementations at large, is that trained customer's level of satisfaction from a service is dramatically improved given that she actually use the new technology, or get trained and understand process adaptations. We believe that investing in such customer of customer's training, not just customers - bares great potential for product success and customers full utilization of product's benefits.

Appendices

We conducted a satisfaction survey in RGH’s Diagnostic Imaging Department, with the objective of assessing the attitudes and opinions of services (postdigital) provided by the department. The survey consists of 7-point rating scale questions with verbal anchors: Very Dissatisfied (1 point) – Very Satisfied (7 points).

A. Referring MDs “Before” Survey

How satisfied are you with the following?
1) Length of time it takes to provide you with a preliminary (not final) radiology report?
2) Time to receive a signed final radiology report?
3) Prompt availability of films when you visit the file room?
4) Availability of films important for patient care and/or management outside of radiology (e.g., OR, ICUs, ED, etc.)?
5) Process for ordering and scheduling exams?
6) Patient status and information provided by the Radiology Department?
7) Interactions with the RGH radiologists?
8) Interactions with the RGH radiology staff?

B. Referring MDs “After” Survey

How satisfied are you with the following at this time?
1) Process for ordering and scheduling exams?
2) Communication with the Diagnostic Imaging Department regarding patient status, and patient information provided by the department?
3) Interactions with the department’s radiologists?
4) Interactions with the department’s technologists?
5) Interactions with the department’s administrative staff?
6) Time to receive a signed final radiology report?
7) Image availability?
8) Ability to share electronic patient images with other physicians for conducting teleradiology consultations?
9) General impression of PACS?
10) Service provided by the Diagnostic Imaging Department?

Miscellaneous:
1) How do you receive feedback from the Diagnostic Imaging Department (oral/documentined)? If documented, by which media (PACS; e-mail; CD-ROM; Internet viewer on the Web; film; hand delivery of printed reports; hospital terminal; other).
2) From your perspective, what are the major benefits of RIS/PACS?
3) What additional features and/or system changes would increase the value of RIS/PACS for your practice?
5. References


