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Introducing PACS to the Late Majority. A Longitudinal Study

Petter Hurlen,[1,2] Truls Østbye,[3,4] Arne Borthne,[2,5] and Pål Gulbrandsen[1,5]

The purpose of this study was to study whether the benefits from introducing a picture archiving and communication systems (PACS) reported by innovators and early adopters also can be achieved by a hospital belonging to the "late majority" and to see whether such benefits are sustained, using report turnaround time (RTAT) as an indicator. Activity-related data was retrieved from the radiology information system (RIS) over a 2-year period. The median RTAT for preliminary reports was initially reduced from 12 to 2 h then increased to 3 h. For final reports, the median RTAT was initially reduced from 23 to 13 h then gradually reverted back to 22 h. Innovators and early adopters demonstrate not only that positive results can be achieved but also the importance of involving key personnel. We believe that such involvement and the focus on wider organizational concerns are important when introducing PACS to the late majority, both for achieving and sustaining positive results.

KEY WORDS: Radiology information systems (RIS), radiology reporting, radiology workflow, PACS, cost effectiveness, medical informatics applications

INTRODUCTION

Conventional film and paper-based information systems are currently being replaced by information technology in many hospitals and imaging centers. *Radiology information systems* (RIS) typically support administrative functions, frequently also reporting of results, while *picture archiving and communication systems* (PACS) typically acquire, store, transmit, display, and process digital images.

The potential of this information technology has been well documented,[1–16] primarily by groups that, according to the diffusion of innovation theory,[17] can be categorized as innovators and early adopters. But, will the hospitals that follow in their footsteps, referred to as "the late majority" using this theoretical framework, achieve the same results without the presence of the innovators but building on their experience? And, are these results sustained? Previous studies typically have compared one period before the introduction of information technology with one period after the introduction.[5,18–26]

The purpose of the current study was to monitor the impact of introducing PACS to a hospital belonging to the late majority, using report turnaround time (RTAT) as an indicator of the immediate impact as well as the long term effect.

MATERIAL AND METHODS

This study was performed at a university-affiliated county hospital in the Eastern Norway Health Region. The hospital was one of the last in the region to introduce PACS.

[1]*From the Helse Sør-Øst Health Services Research Centre, Akershus University Hospital, Mail Drawer 95, NO-1478, Lørenskog, Norway.*

[2]*From the Centre for Diagnostic Imaging, Akershus University Hospital, Lørenskog, Norway.*

[3]*From the Department of Community and Family Medicine, Duke University Medical Center, Durham, NC, USA.*

[4]*From the Duke-NUS Graduate Medical School, 2 Jalan Bukit Merah, Singapore 169547, Singapore.*

[5]*From the Faculty Division, Akershus University Hospital, University of Oslo, Lørenskog, Norway.*

Correspondence to: Petter Hurlen, Helse Sør-Øst Health Services Research Centre, Akershus University Hospital, Mail Drawer 95, NO-1478, Lørenskog, Norway; tel: +47-6796-4587; fax: +47-6792-9469; e-mail: petter.hurlen@ahus.no

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Approval for the conduct of this study was obtained from the Norwegian Social Science Data Service and the Regional Ethics Committee and exempted from review by the Duke University Medical Center Institutional Review Board.

Case Description

The first PACS system in the Eastern Norway Health Region was installed in 1999.[27] Several regional hospitals followed suit, and in 2002, the Regional Health Authority decided to introduce PACS to the remaining hospitals. After a joint selection process, Siemens was chosen as the preferred vendor for supplying RIS (MagicSAS®) and PACS (MagicView®) to these hospitals.

During the first phase, RIS replaced administrative radiology-related functions in the hospital information system. This replacement was introduced in a similar fashion to a software upgrade, i.e., training sessions were organized for all related personnel, but no substantial organizational changes were made. This phase took place in the spring of 2004.

During the second phase, PACS was implemented. A radiologist with medical informatics experience was appointed as project manager for this phase. Based on recommendations from the literature,[11,28,29] a workflow analysis was performed. New and improved routines were established in collaboration with key personnel. These individuals were also involved in the implementation of the new system and the new routines. The department did not only introduce PACS in May 2005 but it also introduced "a new way of working."

After PACS implementation, the initial project team was dissolved, maintenance was left to regular IT personnel, and the project manager went back to working as a radiologist.

The Regional Health Authority wanted to play a more influential role in the continuation of the process, in particular around contractual issues. A regional board of managers was established for these tasks, and there was no longer any direct contact between the users of the systems and the decision makers.

Workflow Changes

Until May 2005, the radiologists' reading and reporting was organized around film alternators, paper documents, and audiotape-based dictation. Secretaries assembled and sorted film from various film printers, fetched referral forms from the labs, and retrieved historical images and reports from the central film library. Images were displayed on image alternators. Paper documents were placed in front of the alternator next to the tape recorder. Once these tasks were completed for a given study, a secretary would enter the study on the radiologist's paper work list. The work list implicitly defined the expected amount of work for the radiologist assigned to the reading room.

The department practiced "double reading" as this is known to reduce error rate.[30,31] Initially, a radiologist read the images, compared them to previous studies if necessary, and dictated the reports. Secretaries assembled tapes, transcribed the radiologists' dictations, made printouts of preliminary reports, and placed them next to the images at the film alternator for a "second reading."

The second reading was always performed by a specialist in radiology, typically when preparing for "radiology rounds" the next morning. During morning radiology rounds, both images and the radiologist's interpretation were presented to clinicians. If the specialist agreed with the preliminary result, he or she would sign the document as the final radiology report. If not, corrections were made on the paper printouts or dictated on tape. Secretaries assembled the corrected preliminary reports and tape, made updates, and printed the final reports for a final signature.

The introduction of PACS and the integration of RIS and PACS enabled radiologists to modify their workflow and eliminate several work steps. Images from the modalities and historic images from the digital archive were transferred immediately to the radiologists' reading rooms. The images could be opened directly from automatically generated work lists together with referral information and previous reports. It was decided to retain the practice of "double reading" for quality purposes. However, preliminary reports were corrected and signed directly in RIS. The radiologists mostly continued to dictate the findings, but during evening and night shifts, radiologists typed preliminary reports themselves for examinations they were involved in.

The plan was to discontinue the daily radiology rounds and instead offer less frequent but more focused "clinical conferences" discussing selected

cases. However, clinicians insisted that most radiology rounds should continue every morning.

Data Material and Statistical Methods

This study was a retrospective review of reporting-related data retrieved from the RIS. Information about the staff was taken from the radiologists' work schedule.

Information was retrieved during six separate weeks. The selected weeks represented typical daily-work situations, avoiding holidays and other periods of reduced activity. The "pre-PACS period" was represented by one observation week 4 months before the PACS introduction in May 2005. Similar datasets were then retrieved for five separate observation weeks during the "post-PACS period": 4, 8, 12, 16, and 20 months after the PACS introduction, the latest week being the second week of February 2007. Consequently, observation weeks 8 and 20 months post-PACS were exactly 1 and 2 years after the first pre-PACS observation week. There was no database, software, or reporting routine change at any point during the observation period.

Report Turnaround Time RTAT,[32] in this study defined as the time from image acquisition to report availability, was chosen as the primary outcome measure for this project. RTAT can be regarded as a measure of quality, as earlier availability of reports in some cases can lead to earlier or better clinical decision. However, RTAT also reflects the overall productivity. If the radiologists are not able to cope with the number of examinations over a period of time, the RTAT will increase. To calculate RTAT for preliminary and final reports, we used (1) the image acquisition time recorded in RIS, (2) the time the first version of a preliminary report was available in RIS, and (3) the time the final report was signed.

The median RTAT was reported since the final reporting of a few examinations sometimes is delayed for days or weeks, i.e., their distribution was skewed with the long tail to the right. In addition, the mean RTAT was included in the tables.

Examinations were classified as either "emergency"—examinations that should be performed immediately, or "routine"—all other examinations. Patients were classified as either in-patients, patients admitted to the hospital, or out-patients.

Results were grouped by the following modalities: computerized and digital radiography (CR); computerized tomography (CT); ultrasound (US); and "Other." The "other" modality group includes mammography, intervention, and magnetic resonance.

RTAT from early adopter hospitals in our region was not available. However, from the review of previous literature,[5,15,18,20,22–25,33] we expected the RTAT to be reduced initially. We had no hypothesis on how the RTAT would evolve subsequently. The statistical analysis of the datasets was consequently done in three steps. First, the initial hypothesis was tested comparing the pre-PACS and the first post-PACS week. Then, the post-PACS trend was identified using the datasets for the first four post-PACS observation weeks. Finally, this trend was tested comparing the first post-PACS observation week with the fifth and last post-PACS observation week.

The RTAT for the selected observation weeks were compared using a two-sided nonparametric Mann–Whitney U test. Significance levels (predetermined at $\alpha<0.05$) are reported. SPSS (v. 15.0.1, © SPSS Inc.) was used for data management and analysis.

RESULTS

The department performed 2,023 examinations in the pre-PACS observation week, 1,954 examinations in the first, and 2,191 examinations in the last post-PACS week. There were 19 radiologists (17 full time equivalents (FTE)) at work in the pre-PACS week, 20 radiologists (16 FTE) in the first, and 21 radiologists (17 FTE) in the last post-PACS observation week. In a survey from 2005, this department had the highest number of examinations per specialist among all university hospitals in Norway.

Figure 1 shows the median RTAT for preliminary and final reports. There was an 84% reduction in median RTAT for preliminary reports, from 12 h 15 min to 1 h 55 min, and a 44% reduction for final reports, from 22 h 47 min to 12 h 47 min. Over the observation period, there was a 69% increase in RTAT for both report categories; for preliminary reports to 3 h 14 min, for final reports to 21 h 39 min.

Table 1 describes the median and mean RTAT for preliminary and final reports for the three

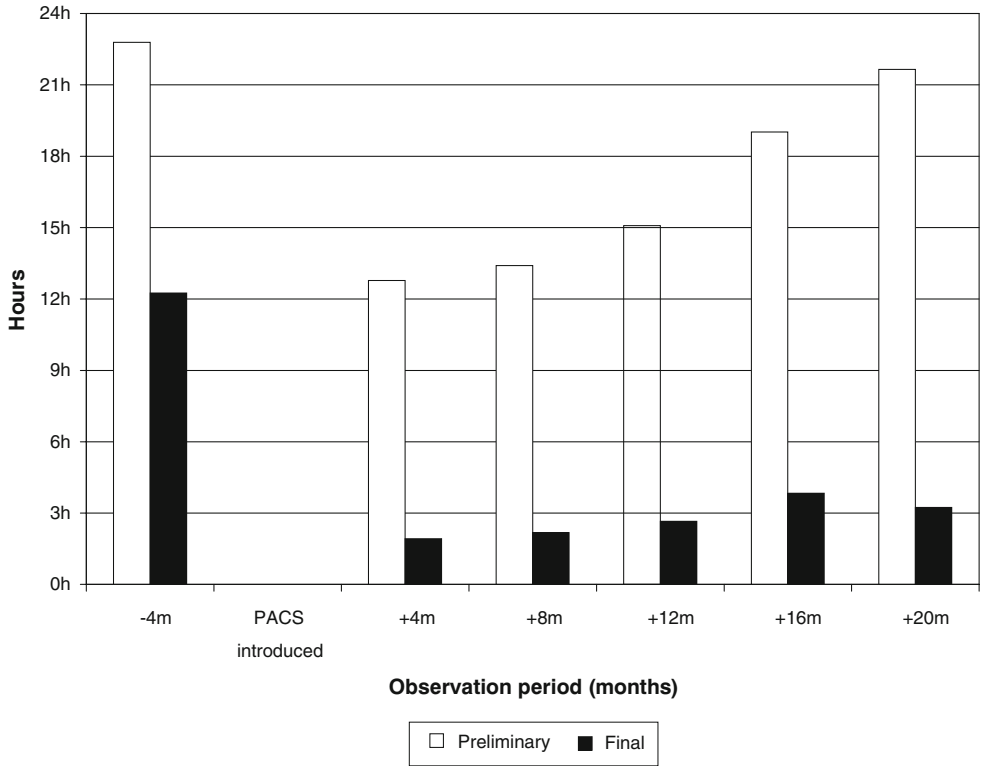

Fig 1. Median report turnaround time for preliminary and final radiology reports.

largest modality groups. There was a major and significant reduction ($p<0.01$) in RTAT for preliminary and final reports from the last pre-PACS observation weeks to the first post-PACS observation week for all modalities, e.g., for final CR reports, the median RTAT decreased by 59%, for US by 93%, and for CT by 10%. There was a significant increase ($p<0.01$) in RTAT from the first to the last post-PACS observation week for all modalities and both report categories, except for preliminary CT reports where the increase was not significant ($p=0.14$).

Figure 2 illustrates the availability of preliminary reports for the clinical afternoon round, defined as 4 PM the day of the examination. Only in-patient cases were included (6,576 examinations). The availability of preliminary reports improved after the introduction of PACS and continued to improve over the observation period.

Table 2 shows the RTAT for emergency in-patient cases (4,493 examinations) for the three largest modality groups. There was a significant decrease ($p\leq0.03$) in RTAT for all preliminary and final emergency reports for all modalities from the

Table 1. Median (and Mean in Parentheses) Report Turnaround Time for the Three Largest Modality Groups, in Hours and Minutes

		Pre-PACS period	*Post-PACS period*				
Modality	Report	−4 months	+4 months[a]	+8 months	+12 months	+16 months	+20 months[a]
	Preliminary	16:09 (30:12)	2:04 (23:22) $p<0.01$	2:14 (10:16)	2:43 (12:29)	4:52 (10:22)	5:48 (12:12) $p<0.01$
CR	Final	22:52 (39:45)	9:19 (27:59) $p<0.01$	10:42 (15:59)	11:52 (21:05)	17:33 (19:24)	20:56 (25:02) $p<0.01$
	Preliminary	3:31 (16:01)	1:21 (19:03) $p<0.01$	1:38 (33:27)	2:18 (18:47)	2:16 (13:24)	1:46 (11:24) $p=0.14$
CT	Final	22:36 (33:52)	20:16 (45:59) $p<0.01$	18:59 (46:24)	19:24 (31:12)	20:01 (25:55)	22:14 (28:27) $p<0.01$
	Preliminary	1:55 (17:36)	0:08 (36:19) $p<0.01$	0:10 (8:51)	0:50 (14:19)	1:09 (7:45)	0:48 (6:08) $p<0.01$
US	Final	22:55 (45:02)	3:27 (46:17) $p<0.01$	05:36 (29:25)	12:01 (42:53)	18:33 (34:36)	20:38 (4:02) $p<0.01$

[a]Significance levels are reported for changes from the pre-PACS to the first post-PACS observation week, and from the first to the last post-PACS observation week

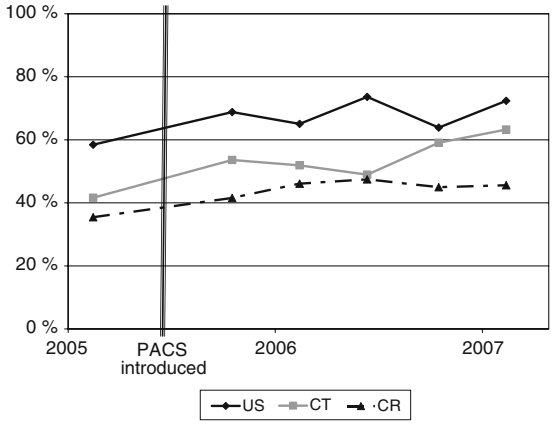

Fig 2. Percentage of preliminary reports available at 4 PM the same day, for each modality group, in-patient examinations only.

pre-PACS observation weeks to the first post-PACS observation week. Comparing the first and last post-PACS week, there was no significant change in RTAT for preliminary US reports or for preliminary and final CT reports. There was, however, a significant ($p<0.01$) increase in RTAT for all CR reports and for final US reports over the observation period.

DISCUSSION

Information technology may offer benefits in many areas. Some are caused by the technology itself, such as decreased film and storage cost, decreased film handling, improved availability of images to clinicians, etc. We would expect the early adopters as well as the late majority to gain these benefits, given adequate system performance. Others, such as number of examinations, RTAT, and error rate, depend on the health professionals as well as the technology. These are areas where we might expect to find differences between early adopters and the late majority. For this study, we retrospectively chose RTAT as the indicator. We hope to be able to address error rate in future studies. It may be possible to improve RTAT further by presenting and discussing its trend over time, may be through the use of dashboard-like systems. This was not done during the study period.

Our initial hypothesis was that the RTAT would be reduced after the introduction of PACS and the workflow reorganization. This hypothesis was confirmed for almost all report categories (Tables 1 and 2). The intermediate post-PACS results indicated that the initial gain was reduced over time, and this was statistically confirmed for the last observation week for most report categories (Tables 1 and 2).

The initial gain was larger than what could be expected just from the eliminated work steps, e.g., the median RTAT for preliminary CR reports was reduced by 14 h and final CR reports by 13 h. A detailed time–motion study was not performed. However, the total duration of the redundant work steps was typically 5–15 min, seldom more than 1 h, per study.

The increased flexibility may have contributed to this effect. In the pre-PACS period, the radiologist's work day was defined by a manually kept work list at a reading room. When the work list was empty, the radiologist was free to take a

Table 2. Median (and Mean in Parentheses) Report Turnaround Time for Emergency In-Patient Examinations Only, for the Three Largest Modality Groups, in Hours and Minutes

		Pre- PACS period	*Post- PACS period*				
Modality	Report	−4 months	+4 months[a]	+8 months	+12 months	+16 months	+20 months[a]
	Preliminary	15:20 (25:33)	07:40 (11:56) $p<0.01$	7:08 (10:03)	2:36 (9:08)	9:11 (9:48)	12:06 (12:57) $p<0.01$
CR	Final	19:58 (35:30)	13:51 (17:09) $p<0.01$	13:20 (15:45)	13:24 (17:27)	16:44 (19:07)	20:26 (22:06) $p<0.01$
	Preliminary	1:58 (9:16)	0:43 (3:02) $p<0.01$	0:50 (10:32)	0:36 (3:55)	1:26 (7:30)	0:42 (02:17) $p=0.62$[b]
CT	Final	21:04 (27:24)	18:32 (31:41) $p=0.03$	16:49 (25:19)	16:36 (17:22)	18:05 (21:46)	16:52 (18:15) $p=0.07$[b]
	Preliminary	0:30 (5:16)	0:06 (1:06) $p<0.01$	0:06 (1:55)	0:06 (0:33)	0:06 (2:37)	0:07 (1:01) $p=0.49$
US	Final	18:30 (23:25)	13:29 (12:20) $p<0.01$	13:53 (14:06)	10:55 (12:14)	15:41 (15:48)	18:25 (18:43) $p<0.01$

[a]Significance levels are reported for changes from the last pre-PACS to the first post-PACS observation week, and from the first to the last post-PACS observation week.

[b]These results were contrary to the initial hypothesis.

break, review literature, or perform other necessary tasks. After PACS, all radiologists had access to all images and all work lists, with an instant status report regarding unfinished work for the whole department. These "never-ending work lists" enabled, may have encouraged, and may even have pushed the radiologists to do more work and work more efficiently.

However, we believe that the most important factor was the implementation strategy. From the literature, we knew not only that a considerable reduction in RTAT was possible[5,19–25] but also that it was important to involve key personnel directly. Many of the innovators and early adopters have not only reported positive results but they have also been directly involved in achieving these results. Law and Zhou[34] prescribe the active and sustained involvement of key actors with complementary skills and interests as a critical success factor for a high-quality implementation strategy. Lindhardt[26] describes how PACS can be used not only to handle images but also to enable organizational changes. Paré and Trudel[35] stress the importance of focusing on the wider organizational and human concerns and advices against an implementation strategy centered on technological considerations. Neither technology nor humans nor the organization could or should be considered separately from each other.[36,37] Our implementation strategy attempted to conform to these recommendations.

While the initial gain was larger than expected, there was a decline during the next 2 years for most of the report categories. None of the innovators or early adopters has, to our knowledge, performed a longitudinal study on the effect on RTAT. Jackson and Langlois[20] presented data from four different months over a 2-year period. This case was, however, a newly opened hospital where many extraneous factors could have influenced the results. It is, nevertheless, interesting that they observed an initial increase in efficiency followed by a decline at the end of the observation period.

There may be many reasons for the decline we observed, e.g., the increase in number of examinations was almost, but not fully, compensated by an increase in FTE. Also, some of the initial effects may have been only temporary. The pure novelty of the new PACS may have encouraged reading by radiologists as they became familiar with the system. Once the novelty wore off, the interest in improving efficiencies may also have diminished. A "never-ending" work list may initially be a driving force but something the radiologists adapt to. For final in-patient reports, the radiology rounds may have influenced the RTAT. Since these rounds were not discontinued as originally planned, the most efficient routine was to do the second reading in the morning as preparation for the radiology rounds.

In this study, we did not assess whether the diagnostic quality changed during the observation period, e.g., in addition to all the desired functionality, RIS and PACS introduced an option for signing the final reports without looking at the images and even without looking at the reports. Such practice has been reported, but we do not know to what extent these mechanisms were used to cope with the never-ending work lists and whether such practice changed over the observation period.

It is also possible that an initial focus on efficiency prevented the radiologists from using the new tools to improve quality or even resulted in a temporary reduction in quality. The radiologists may gradually have shifted the focus from improved RTAT towards improved quality and only given priority to RTAT when considered clinically important. In emergency cases, preliminary reports may be of particular importance since there is often no time to wait for the final report. In particular, many clinicians may not feel competent to interpret CT and US images themselves. For the other in-patient cases, a preliminary report for the afternoon clinical round may be important. This is consistent with our observations. As indicated by Table 2, the initial gain in RTAT was retained and possibly improved for emergency US and CT cases, and the percentage of preliminary reports available for the afternoon clinical round illustrated in Figure 2 increased over the observation period.

However, we believe that there are also organizational reasons for the decline. The key actors that were important for the successful initial implementation went back to their previous tasks and positions. Their involvement, and the focus on wider organizational and human concerns in the implementation process, was a local strategy, not a request from the Regional Health Authority. By establishing the board of directors, the Regional

Health Authority changed the focus from the organizational and human concerns to contractual and formal matters and removed the local personnel's influence on succeeding decisions. Problems that could be solved and improvements that could be implemented locally in close collaboration with the vendor in the implementation phase now had to be reported through a longer chain of command before they were addressed. In our opinion, factors that are important for achieving positive results, involvement of key personnel and focus on the wider organizational and human concerns, are also important for sustaining them.

CONCLUSION

When reviewing the literature where innovators and early adopters describe the benefits they have achieved from introducing information technology, it is important to remember that not only the technology but also the direct involvement of these usually enthusiastic authors have contributed to the benefits. We believe that the involvement of key actors and the focus on wider organizational concerns are important both for achieving and for sustaining positive results when introducing PACS to the late majority of hospitals and imaging centers.

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