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Impact of PACS on Dictation Turnaround Time and Productivity

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This study was conducted to measure the impact of PACS on dictation turnaround time and productivity. The radiology information system (RIS) database was interrogated to calculate the time interval between image production and dictation for every exam performed during three 90-day periods (the 3 months preceding PACS implementation, the 3 months immediately following PACS deployment, and a 3-month period 1 year after PACS implementation). Data were obtained for three exam types: chest radiographs, abdominal CT, and spine MRI. The mean dictation turnaround times obtained during the different pre- and post-PACS periods were compared using analysis of variance (ANOVA). Productivity was also determined for each period and for each exam type, and was expressed as the number of studies interpreted per full-time equivalent (FTE) radiologist. In the immediate post-PACS period, dictation turnaround time decreased 20% ($p < 0.001$) for radiography, but increased 13% (ns) for CT and 28% ($p < 0.001$) for MRI. One year after PACS was implemented, dictation turnaround time decreased 45% ($p < 0.001$) for radiography and 36% ($p < 0.001$) for MRI. For CT, 1 year post-PACS, turnaround times returned to pre-PACS levels. Productivity in the immediate post-PACS period increased 3% and 38% for radiography and CT, respectively, whereas a 6% decrease was observed for MRI. One year after implementation, productivity increased 27%, 98%, and 19% in radiography, CT, and MRI, respectively. PACS benefits, namely, shortened dictation turnaround time and increased productivity, are evident 1 year after PACS implementation. In the immediate post-PACS period, results vary with the different imaging modalities.

KEY WORDS: PACS, dictation turnaround time, productivity

INTRODUCTION

Increased productivity has been cited as an important advantage of picture archive and communication system (PACS) implementation.[1–6] In the imaging department and throughout the hospital enterprise, this efficiency is accomplished mainly, but not exclusively, through the elimination of manually intensive tasks associated with the production of film and its subsequent distribution to radiologists and consulting clinicians. Studies of workflow show a significant decrease in the number of steps involved in the production and distribution of film within an imaging department following PACS implementation.[7,8] It follows that the time interval between the production of a medical image and dictation (i.e., dictation turnaround time) decreases in a filmless environment. The radiology information system (RIS), by monitoring the time of occurrence of each status change for every study, allows the measurement of the time interval between image production and dictation. This method has been previously used to evaluate the impact of electronic signatures on the delay between transcription and finalization of radiology reports.[9] If RIS implementation predates PACS, it

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Table 1a. Dictation turnaround time and productivity for chest radiographs

	Pre-PACS	Post-PACS	1 year post-PACS
Productivity (exams/FTE)	4,620	4,776	5,863
Dictation turnaround time[a] (days)	2.9 ± 2.8	2.3 ± 1.8[b]	1.6 ± 1.3[c,d]

ANOVA results ($F = 578.2$; $p < 0.001$).
[a]Mean ± SD.
[b]Pre-PACS vs. post-PACS, $p < 0.001$.
[c]Pre-PACS vs. 1 year post-PACS, $p < 0.001$.
[d]Post-PACS vs. 1 year post-PACS, $p < 0.001$.

is then possible to measure the impact of filmless operation on the delay between image production and dictation. Decreased dictation turnaround times reflect increased productivity only if the number of exams dictated per radiologist remains unchanged or increases. Thus, it is important to compare changes in the dictation turnaround times to changes in radiologist productivity, expressed as the number of studies dictated per full-time equivalent (FTE). The purpose of this study was to measure dictation turnaround time and productivity for several modalities, before and after implementation of PACS, in a university teaching hospital.

MATERIALS AND METHODS

A PACS was implemented in our institution in December 2002. An RIS had previously been implemented in April 2002. The RIS records the time of each status change for each exam entry (i.e., requested, performed, dictated, transcribed, report confirmed). The RIS database can be interrogated to obtain a file containing all examinations performed within a defined time period. For each exam entry, the data file contains the date and time of each status change. Residents participate in the reading of exams and a portion of the exams included in this studied were initially interpreted by them; however, exam status is changed to dictated only after review by a staff radiologist. Although radiologist worklists are available at the PACS workstations, workflow is still paper-based. Radiologists interpret studies as soon as they are supplied with requisition forms.

To measure the impact of PACS on dictation turnaround time, files were obtained from the RIS database containing exams performed during three 90-day periods. The periods selected corresponded to the 3 months of film-based operation immediately preceding PACS implementation, the first 3 months following PACS implementation, and the 3-month period at the start of 2004, 1 year after implementation. Three exam types were studied: chest radiographs, spine MRI, and abdominal CT. Dictation turnaround time (i.e., the time interval between the production of a medical image and dictation) was computed for each examination, for the three modalities and for each of the 3-month periods identified above. Dictation turnaround time refers to the interval between completion of an exam and the completion of the dictation by the radiologist. At this time, the study is ready to be transcribed by the transcriptionist. For each 3-month period and for each exam type, the number of exams performed was also recorded. Individual productivity was expressed as the number of studies interpreted per FTE radiologist. The FTE was determined by consulting the radiologists' work schedule for the periods studied.

For each 3-month period and for each exam type, the average interval delay was calculated (in days). The values of average interval delay obtained during the different pre- and post-PACS periods were compared using analysis of variance (ANOVA). This analysis was carried out for each exam type studied. The average dictation turnaround time was also calculated for each radiologist participating in the reading of the different exam types studied. The values of average interval delay obtained during the different pre- and post-PACS periods, for a given radiologist, were also compared using ANOVA. Finally, to assess the impact of residents on dictation turnaround time, distinct average interval delays were computed for those studies involving resident participation and those read only by staff radiologists.

RESULTS

The data from 19,888 examinations was compiled and analyzed during the three periods studied. The average number of FTE per period was 1, for each of the modalities studied; therefore, the number of studies per period and the productivity per FTE has the same value. Table 1a shows the results for dictation turnaround time and productivity with respect to chest radiographs. The average turnaround time decreased 20% ($p <$ 0.001) in the immediate post-PACS period and continued to decrease 1 year after implementation, with a diminution of 45% ($p < 0.001$) when

Table 1b. Dictation turnaround time per radiologist: Chest Radiographs

Radiologist	Pre-PACS mean turnaround time (days)	Post-PACS mean turnaround time (days)	1 Year Post-PACS mean turnaround time (days)
1A	3.7	2.6[a]	1.5[a]
1B	3.1	2.5[a]	1.7[a]
1C	3.4	2.0[a]	1.6[a]
1D	2.0	2.0[b]	1.2[a]
1E	2.0	1.8[b]	1.4[a]

[a]vs. pre-PACS, $p < 0.001$.
[b]vs. pre-PACS, ns.

Table 2a. Dictation turnaround time and productivity for abdominal CT

	Pre-PACS	Post-PACS	1 year Post-PACS
Productivity (exams/FTE)	691	955	1,364
Dictation turnaround time[a] (days)	2.3 ± 3.2	2.6 ± 2.9[b]	2.3 ± 2.8[c,d]

ANOVA results ($F = 3.9$; $p < 0.05$)
[a]Mean ± SD.
[b]Pre-PACS vs. post-PACS, ns.
[c]Pre-PACS vs. 1 year post-PACS, ns.
[d]Post-PACS vs. 1 year post-PACS, $p < 0.05$.

compared to the pre-PACS period. Productivity increased 3% and 27% during the same periods, when compared to pre-PACS values. Table 1b shows the mean dictation turnaround times for five radiologists accounting for 70–82% of all studies interpreted during each of the different periods studied. All five radiologists experienced a significant decrease in dictation turnaround time 1 year post-PACS implementation. In the immediate post-PACS period three of the five radiologists also showed a significant decrease in turnaround time, whereas the remaining two showed no significant change.

Table 2a shows the results for abdominal CT. Although a 13% increase was observed in dictation turnaround time in the immediate post-PACS period, this change was not significant. In the same interval, productivity increased 38%. One year after implementation, dictation turnaround time was identical to pre-PACS levels. By 2004, one of the CT scanners had been replaced by a 16-slice scanner leading to an important increase in the number of studies. Productivity in the 1-year post-PACS period almost doubled (98% increase) when compared to pre-PACS levels. Table 2b shows dictation turnaround times for four radiologists responsible for the interpretation of 88–94% of all studies. When compared to overall changes in turnaround times, individual results vary. Only one radiologist showed significant decrease in turnaround times in both the immediate post-PACS period and 1 year post-PACS. One radiologist actually experienced an increase in turnaround times both in the immediate post-PACS period and 1 year post-PACS.

Table 2b. Dictation turnaround time per radiologist: Abdominal CT

Radiologist	Pre-PACS mean turnaround time (days)	Post-PACS mean turnaround time (days)	1 year Post-PACS mean turnaround time (days)
2A	2.4	3.8[a]	3.6[a]
2B	2.3	1.7[b]	1.4[b]
2C	2.1	2.9[a]	1.9[c]
2D	2.2	2.4[c]	2.1[c]

[a]vs. pre-PACS, $p < 0.05$.
[b]vs. pre-PACS, $p < 0.001$.
[c]vs. pre-PACS, ns.

Table 3a. Dictation turnaround time and productivity for MRI of the spine

	Pre-PACS	Post-PACS	1 year Post-PACS
Productivity (exams/FTE)	517	485	617
Dictation turnaround time[a] (days)	2.8 ± 2.0	3.6 ± 2.7[b]	1.8 ± 1.5[c,d]

ANOVA results ($F = 110.6$; $p < 0.001$)
[a]Mean ± SD.
[b]Pre-PACS vs. post-PACS, $p < 0.001$.
[c]Pre-PACS vs. 1 year post-PACS, $p < 0.001$.
[d]Post-PACS vs. 1 year post-PACS, $p < 0.001$.

Table 3a shows the results for MRI of the spine. Dictation turnaround time increased 28% ($p < 0.001$) in the immediate post-PACS period when compared to the film-based period, but eventually decreased 36% ($p < 0.001$) 1 year post-PACS implementation. The number of studies interpreted per FTE decreased 6% in the immediate post-PACS period, but increased 19% 1 year later. Table 3b shows dictation turnaround times for three radiologists responsible for the interpretation of 80–98% of all studies. All three radiologists experienced an increase in turnaround time during the immediate post-PACS period. Although the overall increase was significant, when evaluated on an individual basis it was not. All three radiologists experienced a significant decrease in

Table 3b. Dictation turnaround time per radiologist: Spine MRI

Radiologist	Pre-PACS Mean Turnaround Time (days)	Post-PACS Mean Turnaround Time (days)	1 Year Post-PACS Mean Turnaround Time (days)
3A	3.2	3.5[a]	1.9[b]
3B	2.4	2.6[a]	1.3[b]
3C	2.8	2.9[a]	1.5[b]

[a]vs. pre-PACS, ns.
[b]vs. pre-PACS, $p < 0.001$.

turnaround time 1 year post-PACS when compared to the pre-PACS period.

Residents participated in the interpretation of 18.9% and 20.5% of chest radiographs in the pre-PACS and immediate post-PACS periods, respectively. Only 0.5% of chest radiographs were initially read by residents 1 year post-PACS. Mean dictation turnaround time was longer when studies were first read by residents as compared to studies read only by staff radiologists: 4.3 vs. 2.5 days, and 3.1 vs. 2.1 days, during the pre-PACS and immediate post-PACS periods, respectively. With regard to abdominal CT, residents participated in the interpretation of 40.2% during the pre-PACS period, 55.1% during the immediate post-PACS period, and 46.6% 1 year post-PACS implementation. Mean turnaround times were consistently shorter when initially read by residents: 2.0 vs. 2.4 days in the pre-PACS period, 2.3 vs. 2.9 days in the immediate post-PACS period, and 2.0 vs. 2.4 days 1 year post-PACS. Residents read less than 3% of spine MRI during the periods studied.

DISCUSSION

PACS can lead to increased productivity by improving efficiency at many levels. Previous studies showed that technologists' productivity can be improved through the elimination of tasks associated with film production and handling.[1–3] Most importantly, all the tasks and procedures associated with the film library are essentially eliminated, thus studies are available for interpretation and consultation more rapidly. Finally, it was also demonstrated that diagnostic workstations led to a decrease in interpretation times.[10,11] The empirical studies published to date involved time motion studies on a limited number of cases or surveys of perceived productivity gains. Although these studies have the advantage of being rigorous with respect to data collection and controlled conditions, extrapolating results to the enterprise level under real conditions is not always feasible. In our study, we attempted to obtain a broad picture of the impact of PACS implementation on an imaging department's activities. The RIS database allowed a comprehensive survey of dictation turnaround times for several modalities, over long periods of time, both before and after PACS deployment. This methodological approach has the advantage of reflecting the true impact of PACS at the operational level. Furthermore, the results obtained are validated by the large samples of data and the fact that all procedures, within the modality groups chosen, were studied. For other important factors, such as staffing and general distribution of work, being equal in the pre- and post-PACS periods, the changes in dictation turnaround time can be attributed, in large part, to PACS implementation. On the other hand, the limitation of this method is that specific factors such as image availability and increased efficiency at the workstation cannot be independently analyzed. Radiologists' work habits and assiduity were not controlled, but any changes in these factors in the post-PACS period can be attributed to new work methods made possible by PACS, as no changes in FTE occurred during the periods studied.

Our results confirm the improvements reported in the literature concerning reporting turnaround times.[4,12,13] This confirmation is demonstrated by significant decreases in dictation turnaround time, 1 year after PACS implementation, in two of the three modalities studied: chest radiography and MRI. The positive impact was seen in chest radiographs during the early post-PACS period and the gains were improved in the late post-PACS period. On the other hand, the early post-PACS period saw an increase in mean dictation turnaround time for MRI of the spine. This fact can probably be explained by the different approaches to the reading of images for chest radiographs and MRI. The workstation tools needed to be mastered to attain proficiency at interpreting chest radiographs are fairly limited and straightforward. It is therefore not surprising that radiologists adopting PACS would rapidly acquire these skills. When compared to chest radiographs, MRI studies represent more complex data sets, often composed of multiple series, with each series containing many images. Along with a lengthening of dictation turnaround time, a 5% decrease in productivity was also observed. Although dictation turnaround time slightly increased for abdominal CT in the immediate post-PACS period, this change was not significant; and the mean dictation turnaround time 1 year post-PACS was equal to the mean turnaround time before PACS implementation. The real impact of PACS on CT was the increased productivity: 38% immediately following implementation and 98% 1 year later. For chest radiographs and spine MRI, decreased mean dictation turnaround times were observed for each member of the group of radiologists reading the majority of examinations. The impact is thus distributed throughout the department. Individual values varied for abdominal CT, but three out of four radiologists showed either no significant change in turnaround time or a shortening of mean turnaround time 1 year after imple-mentation. Our data did not allow us to calculate individual productivity based on the number of studies interpreted on an hourly or daily basis; however, it follows that if the overall number of studies interpreted increases and the mean dictation time decreases or remains unchanged, then the amount of time spent interpreting an exam must decrease.

When mean dictation times were computed for studies interpreted with residents, the results vary according to the modality. For chest radiographs, mean dictation turnaround times were longer when residents participated in the reading process; on the other hand, the time intervals were shorter when residents participated in the reading of abdominal CT. The reasons for this difference are not clear and are likely related to the work habits of staff radiologists and the general organization of work. However, the mean dictation turnaround times for studies initially interpreted by residents followed the same trends as those reported for all examinations interpreted during the periods studied.

The mean dictation turnaround times reported in our study may appear unacceptably long to some observers, but this can be explained by several factors. First, the number of radiologists in the department is not optimal, given the workload. Second, the examinations audited for this study included those performed for both in- and outpatients alike. Inpatient examinations are usually read more rapidly, and the inclusion of outpatient procedures prolongs mean dictation turnaround time. Third, in some cases, the participation of residents in the reading process will also lengthen dictation turnaround time, as seen in our data for chest radiographs. Despite these factors, significant improvements in both turnaround times and productivity were observed.

As mentioned earlier, several factors are in play when measuring improved efficiency. By simply measuring the delay between the completion of an exam and the end of dictation, it is not possible to break down the gains according to the impact at the technologist's level, the film library level, or the radiologist's level. The impact of workflow modifications due to the elimination of the film library and the tasks of film distribution accomplished by the film library staff is expected to be felt early after PACS implementation. This effect is borne out by our results concerning chest radiographs. This early gain is, however, counterbalanced by a loss of productivity associated with acquiring new reading skills in a filmless environment with cross-sectional modalities. In our results, this impact was seen as latency in the improvement of dictation turnaround times that were attained only in the late post-PACS period. It is clear that this study only looks at a portion of the workflow, namely, the time interval between the completion of an exam and the end of dictation. But this is precisely where PACS exerts its impact. Obviously, the time interval between exam completion and availability of the report to the clinicians is a more important measure; however, the delay between the moment the report is available for transcription and the report is finally available depends on factors that are independent of PACS, such as the number of transcriptionists. Improved report turnaround times involve modifying the steps involved in transcription and report distribution, which were not addressed in this study.

In conclusion, PACS shortens dictation turnaround time and increases productivity. These impacts were observed for different modalities with the greatest impact seen in plain radiography. Auditing the RIS to track interval times between different exam status changes can be a useful tool to study the impact of introducing different technologies in the radiology workflow.

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