

An Automated Results Notification System for PACS

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The purpose of this study was to determine if the interval between an examination being ordered by an Emergency Department physician and his or her review of the report and images could be shortened by notifying the physician that the results were available. This hypothesis was based on work done previously in the Medical Intensive Care Unit that showed that physicians would wait to review results for a time considerably longer than the time required for the radiologist to review the images and provide a preliminary report. The software developments operate properly and show that even simple integration of multiple information systems (PACS, RIS, speech recognition) can provide useful features. Early results indicate that the Emergency Department (ED) physicians prefer the notification system over the previous (travel to check on images and reports) methods. The hypothesized time reductions did occur, although it is not clear that the notification system accounted for all of them. A system for automated notification of radiology results availability has been shown to be possible and practical. To do this automated interaction of 3 systems with a low-level or no electronic integration was required. Although not fully successful for this study, early physician response has been positive, and requests to expand this service hospitalwide now are common.

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IN PREVIOUS STUDIES in the Medical Intensive Care Unit (MICU)^{1,2} we found that the time between a nonemergent radiographic examination being completed and the time it (or the report) was first reviewed by the referring physician did not change despite the introduction of a picture archiving and communication system

(PACS). As Reiner and Siegel³ have summarized, an expectation of PACS usage is improved productivity. It was shown that the PACS reduced the time between examination completion and results availability significantly. The question we had as a result of this reduction in time is why did it not shorten the interval before referring physician review? In fact, for a subset of examinations, it did shorten that time, but not for the majority of studies.

We developed several hypotheses to explain this result. The first was that of "habit" and was supported by the result that showed the time between examination completion and first review of the results did not change significantly after introduction of the PACS in the MICU. This hypothesis simply was that the physicians were used to looking for results after some length of time and continued to wait the same amount of time. Arguing against this was the fact that the time did not change even after training and posting of notices about the faster availability of results.

A second hypothesis was that the physicians had learned what the minimum time was to guarantee that when they did go to find the results, they would be available. Considering the time elapsed between examination completion and the dictation and transcription of the report, the major delay was the dictation and transcription steps and did not change with PACS implementation. We determined that this hypothesis would be very difficult to test; it would rely on questions about the behavior of the referring physicians using interviews or questionnaires. Although we did conduct a series of interviews, the reliability of memory-based answers to questions about waiting for results was questionable.

The third hypothesis, that the referring physicians simply did not know when results were available so they waited what they thought to be a sufficient time before checking, was one we believed to be testable. By notifying physicians that images and reports were available, we thought that they could reduce this waiting interval. A test of this hypothesis was designed into a series of research studies being conducted in conjunction with the Emergency Department (ED).

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MATERIALS AND METHODS

A first step was evaluation of possible methods of notification. We developed 3 possible techniques. Because the Emergency Department operates around a central station in which support activities are carried out, some form of annunciator board was one proposed method. Such boards are used, for example, in airports and railway stations to list arriving or departing flights or trains. However, for the annunciator to be visible to the ED physicians, it also would be visible to the patients and anyone accompanying them. This was believed to be a violation of patient confidentiality, so this idea was rejected.

The Emergency Department has its own electronic medical record (EMR) system developed locally (EMTrack). The ED is a "paperless" operation, at least for their own records and patient tracking. The status screen has a view that shows a listing of all the ED rooms, the names of the patients in them, and the names of the physician and nurse caring for the patients. There also are unused columns that the system displays, and it was thought initially that a notification of radiology results "ready" could use one of those columns. Unfortunately, the programmer who developed the system left the institution, so there was no support for development of new features. This eliminated this otherwise attractive alternative.

The third possibility was to use a paging system. The idea was to page the referring physician when the results were available. However, we also realized that an additional feature would be to send the report with the page. This is possible if the person being paged has an alphanumeric pager. We believed that this would save a step and potentially make the process even more efficient. Not all of the ED physicians had alphanumeric pagers, so a several of them were leased by the Department of Radiology for use by the ED physicians during this project.

The Department of Radiology has a reading room in the ED. The reading room is staffed by an attending radiologist and a resident in the evenings and at night. During the day, ED examinations are read in the musculoskeletal reading room of the main part of the Department. There are 2 main workstations in the ED reading room, a 4-monitor PathSpeed and a 4-monitor LiteBox as well as a 2-monitor Advantage Windows workstation (General Electric Medical Systems, Milwaukee, WI). There also is a single monitor ultrasound workstation (Kodak Health Imaging Systems, Dallas, TX). The PathSpeed workstation supports a function that allows a radiologist to type in a preliminary report. This report is replaced by the final report when the latter is signed. The full reports are handled by the IDXrad RIS (IDX Corporation, Burlington, VT). One of the authors developed a software tool that polled the "examination status" indicator associated with the ED studies on the PACS. When the status changed to "reported," the software captured the text of the typed-in report and paged the appropriate pager number, sending the report text.

Although initially tested and started with the typed-in report text, the Department of Radiology expanded implementation of a speech recognition system for reporting (TalkStation Radiology, TalkTechnology, Bensalem, PA) during the time of this study. Because reports were final as soon as they were dictated (in the mode in which the radiologists operated), the use of the

typed-in report decreased until it was essentially unused for ED cases.

The software was tested by first having the program page the research coordinators with the reports. Although the software was automated and worked, the testing process uncovered several problems. The pagers would accept only 128 characters of text, so anything longer than that was truncated. Although typed-in reports were shorter than this, the final reports frequently had more characters than this in the "impression" section. A strategy here was to send the message "report available" in these cases because we believed that a truncated report impression could convey incorrect information and pose a risk to the patient. A second difficulty was that, contrary to a common Departmental practice of dictating the impression first, some of the radiologists dictated the impression at the end of the report. A solution of this was to search the report text for the word "impression" and capture what followed as the message sent to the pager. This still occasionally resulted in messages that exceeded 128 characters. A third problem was that, although the ED EMTrack system was paperless, for requesting radiologic studies, paper request forms still were used. Because these were hand written, they were subject to the usual variability of handwriting, and a number of requests had illegible referring physician names. This meant that the radiology scheduler could not enter the actual name and (by convention) substituted the name of the ED attending physician in charge for that day. The problem was that the paging software needed the correct name to find the pager number so that it could be auto dialed. We did not want the ED attending physicians to be paged with reports from all patients, so the research coordinators developed a sticker for the request form explaining the importance of a legible name on the request and asking the ED physicians to print their names.

During the time that the software was being developed and tested, the research coordinators were collecting "baseline" data on the conventional PACS operation. That is, there was no notification automatically sent out to indicate that results were available. Typically, the radiologist either would call the ED physician with the results, or the ED physician would walk over to the ED reading room (at night) or call the radiologist him- or herself.

In addition to basic demographic information about the patient population seen in the ED, times of events were recorded. These times were:

- The time from patient registration in the ED until the imaging examination request was generated
- The time from the examination request until the technologist completed the examination
- The time from examination completion until report dictation
- The total radiology time (examination request to report dictation)
- The time from the examination request to the first encounter with the results
- The total ED time (patient registration to disposition)

The first 3 times in this list were considered "preradiology" time, technologist time, and radiologist time, respectively. The last 2 times were the ED components. These same times then were measured during the period in which the notification system was operational. Our hypothesis was that notification

Table 1. Comparison Times Between Baseline and Pager Notification Periods (Mean Values)

Time Measured	Baseline Mean	Baseline SD	Pager Mean	Pager SD
Registration to examination request	1:21 (1.37)	1:38 (1.64)	1:29 (1.50)	1:51 (1.87)
Examination request to examination completion	0:37 (0.62)	0:43 (0.73)	0:43 (0.72)	0:40 (0.68)
Examination completion to dictation	2:12 (2.21)	13:33 (13.56)	0:35 (0.59)	2:11 (2.19)
Total radiology time	3:16 (3.27)	14:36 (14.6)	1:20 (1.33)	2:22 (2.36)
Examination request to encounter results*	1:43 (1.72)	0:50 (0.84)	1:08 (1.14)	0:48 (0.81)
Total ED time*	6:49 (6.82)	6:22 (6.38)	5:32 (5.54)	4:21 (4.36)

NOTE. Times are hours:minutes (fractional hours).

*Significant (see discussion).

could help reduce the time between the examination request and the ED physician's first encounter with the results and might, as a result, reduce the total ED time for the patient.

We also used a short survey intended to determine the opinions of the ED physicians about the pager notification and reporting system. This questionnaire was given to the physicians as their shift in the ED was completed. It consisted of 3 questions so it was easy to complete.

RESULTS

During the baseline PACS period, a total of 356 examinations on 283 ED patients were evaluated for the above noted timings. For the pager notification period, the total was 429 examinations on 334 ED patients. Both periods were 2 calendar months in length. Trauma patients were not included, because these patients are managed by the Surgery service.

The mean ages of the patient populations in the 2 periods were not significantly different (baseline, 49 years; pager, 48.9 years). There was a difference in the gender distribution between the 2 periods, although this was thought not to have an impact on the study (baseline, 49% F, 51% M; pager, 57% F, 43% M).

The distribution of examinations for the 2 periods was not significantly different. Chest images were the most common in both the baseline and pager periods (53% and 52%, respectively). Next were studies of the appendicular skeleton (29% and 25%), spine and pelvis (9% and 11%), abdomen (4% and 7%), and skull (1% and 2%). The distribution of triage codes of the patients who had imaging studies also was not significantly different between periods.

Timing results had approximately skewed normal distributions with long "tails" towards increasing times. These were included in the tabulated results below but caused some anomalous results, particularly for the baseline examination to dictation times. This is discussed subsequently. Note

that a major confounding factor was the change from conventional transcribed dictation to speech recognition between the 2 periods.

Measured times are shown in Table 1 (mean times) and Table 2 (median times). The timing data also are shown graphically in Fig 1 (radiology times) and Fig 2 (ED times).

In addition to the timing data, the authors also computed the proportion of the patient's total stay in the ED that was attributable to radiology. The median fraction in the baseline period was 0.19 and in the pager period, 0.18. The mean fractions were considerably larger (0.68 and 0.41, respectively). The reason for this is discussed subsequently.

The authors also examined the manner in which the ED physicians obtained results for their patients on whom imaging studies were requested. Table 3 summarizes these results.

During the pager study period, we also were able to compare 2 subcategories of ED physicians; those to whom reports were sent via pager and those who did not receive such reports. The time between requesting the examination and first reviewing the results was compared for these 2 subcategories. These were not fixed groups because the option to request pager notification was

Table 2. Comparison Times Between Baseline and Pager Notification Periods (Median Values)

Time Measured	Baseline Median	Pager Median
Registration to examination request	1:05 (1.08)	1:16 (1.28)
Examination request to examination completion	0:30 (0.50)	0:33 (0.56)
Examination completion to dictation	0:17 (0.29)	0:17 (0.28)
Total radiology time	1:02 (1.03)	0:53 (0.88)
Examination request to encounter results	0:58 (0.97)	1:00 (1.02)
Total ED time	4:30 (4.50)	4:32 (4.54)

NOTE. Times are hours:minutes (fractional hours).

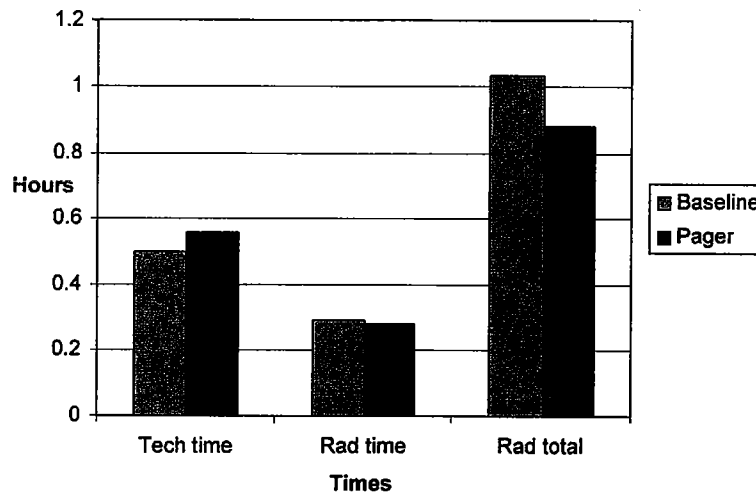


Fig 1. Radiology.

made on a per-examination basis. Although the mean and median times for the physicians when the pager report was sent were shorter than when the report was not sent, the differences were not significant (pager report sent, mean [median] times: 1.21 [1.02] hours; report not sent, mean [median] times: 1.24 [1.13] hours).

Of the 78 physicians who participated in the study, 16 returned the questionnaire, a return proportion of 20%. of the participating physicians, 41 (53%) stated that they did use the pager notification service. Asked if they wanted this as a regular

service, 13 (16.7% of total, 81% of survey respondents) said they did.

An important aspect of the results was the proportion of reports that were sent out to ED physician pagers. Unfortunately, as will be discussed subsequently, of 334 patients examined, only 43 had results sent to pagers, and, of these, only 23 included the report impression.

DISCUSSION

In reviewing the results presented in Table 1, the large standard deviation of the time from the ex-

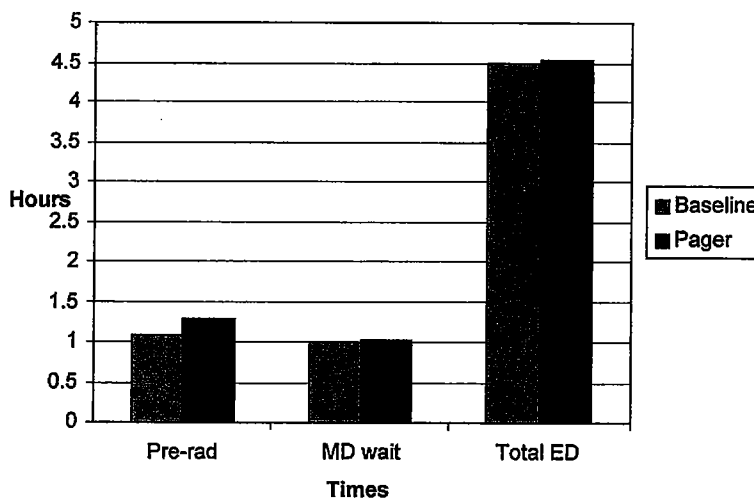


Fig 2. Emergency department.

Table 3. How Emergency Department Physicians Obtained Results

Information Type	Baseline		Pager	
	No.	Percent	No.	Percent
Image and report	62	22	28	8
Image only	59	21	112	34
Report only	29	10	71	21
No recorded exchange	133	47	123	37
Total	283		334	

amination completion to report dictation seen in the baseline data is readily apparent. This also affects the total radiology time standard deviation value. A study of the distribution of the data points showed a number of "outliers" with a maximum time between examination completion and report dictation of over 123 hours. An exploration of the cause of these outliers showed them to be a result of errors on the part of the radiologist. It should not be inferred from these lengthy times that the patient's treatment was delayed; for these cases, the results often were provided by the radiologist to the ED physician either in person or by telephone, but the report was not dictated immediately. The reason for this often was that there were additional studies to be interpreted arriving quickly, and dictating the delayed study subsequently was forgotten. A list of unreported studies is generated by the radiology information system (RIS) daily, so the radiologist would be asked to dictate the examination then. The longer-than-24-hour times are the result of the schedule of the radiologists covering the ED; the same radiologist did not always cover the ED for consecutive days, so he or she could miss the notification about the unreported case the first time.

Although the difference in mean time between examination completion and report dictation is large, it is not significant (2-tailed *t* test, assuming unequal variances). Note that the median times measured are nearly identical (0.29 and 0.28 hours for baseline and pager periods, respectively), and we find the median value a better measure of central tendency in these timing studies.⁴ Some of the reduced variance during the pager period also may have an explanation. The radiologists increasingly used the speech recognition system for report generation resulting in a reduction of missed dictation.

The results show that using the pager reporting

system did not significantly affect most times. Testing the differences in the mean times using the Student's *t* test (2-tailed, unequal sample sizes) did show 2 times that were significantly different. The first was a time we hypothesized would be shorter, the time between the examination request and the first encounter of the results by the ED physician. The mean times for the baseline and pager periods were 1.72 and 1.14 hours, respectively (significant; $P < .001$). The second time also was shorter; the total time spent by the patient in the ED decreased during the pager period (6.82 hours to 5.54 hours, respectively; significant, $P < .005$). Before we can ascribe these improvements to the pager reporting change, we would point out that this change would have to be based on a limited number of examinations. Aside from the pager notification, the change to speech recognition for reporting likely had a far greater overall effect (although this was not specifically studied) on these times. When the radiologists use the speech recognition system, the reports are available immediately after they are finished. Access to the RIS is available hospital-wide, so ED physicians have ready access to the reports. With conventional dictation, the minimum report turnaround time typically is an hour, but the mean is closer to 8 hours. Once the report turnaround time exceeds the average patient length of stay in the ED, the final radiology report is of little immediate clinical use. For this reason, much of the reporting of results is via telephone and in-person review.

Although 334 patients were examined during the study period and represent the total possible "universe" of examinations, of this total, 128 were ordered by physicians who had alphanumeric pagers. For the remainder, it was not possible to send the report to the pager because the pagers could not receive text messages. Of these 128 candidate examinations, 63 were scheduled correctly, that is, they included the ED physician's name so that the automatic paging software could determine whom to page. The remainder had requests either with no name (and the radiology schedulers automatically assign the request to one of the ED attending physicians for the day) or the name was illegible (with the same end result). Of these 63 examinations, 43 were dictated using speech recognition, so the report was available immediately. The other 20 were dictated conventionally, so no report text was available to send immediately. The 43 studies

that had reports available and could be linked to the correct referring physician, resulted in pager notification. However, of the 43 examinations, 23 resulted in the "impression" part of the report text being sent (the desired result). The remaining 20 either had no identifiable impression dictated, or the impression was too lengthy (> 128 characters). In this situation, the message, "report available" was sent instead. The end result of this unintentional "filtering" process is that only about 13% of the examinations done resulted in a pager notification, and only 6.9% included the report impression text. It is because the final proportion of studies resulting in pager notification is so small that it is difficult for us to claim that the reduced ED physician time and ED total patient stay time were the result of the notification process alone.

This result is an example of the importance of logistics in support of systems. The largest "filtering" step was the first, the fact that not all physicians who work in the ED carry alphanumeric pagers. A hospital change to such pagers has not taken place because of the higher cost of these pagers compared with the more abundant numeric-only models. We believe that automation of processes could reduce the effect of the other steps; for example, the illegible physician name problem could be solved through a paperless request process—the correct physician name and pager number are "known" to the ED's systems, but there is no interface from these to the RIS at present. Dayhoff⁵ has noted that the Veterans Affairs integrated, multimedia electronic medical record (VISTA) overcomes some of the logistical problems we describe in this project.

There was one area in which the pager notification process likely had some impact. In Table 3, we noted the various means through which it was documented that the ED physicians obtained the results on their patients who underwent imaging studies. The ED policy is that all imaging study results must be reviewed by the ED physician caring for a particular patient before that patient can be discharged from the ED (or admitted to the hospital). The proportion of examinations for which only the report of the results was reviewed by the ED physician approximately doubled (from 10% to 21%). During this time, the proportion of examinations for which both images and the report were reviewed declined (from 22% to 8%). The practice of reviewing the images without the report

(or without the radiologist in attendance) also increased (from 21% to 34%), a result similar to one noted in a study by DeSimone et al⁶ in the MICU and more recently described by Reiner and Siegel.⁷ In both periods, however, the largest single category was still the "indeterminate" one in which we could not determine with certainty how the ED physicians obtained the results (47% and 37% for baseline and pager periods, respectively). We strongly suspect that, in these cases, the ED physicians either called the radiologist for the results, or the reverse (which is the typical practice in the Department of Radiology). Without some form of automatically logging telephone calls, it was not possible to track all telephone reports. We asked the ED physicians how they got the results, but this usually was at the conclusion of their shift, so they may have forgotten how they obtained all the imaging reports.

CONCLUSION

Although some of the times measured (time to first encounter of results, total ED time) were shorter during the pager notification period, it is not likely that the changes were the result of the notification. The total number of reports that were sent out to pagers was thought to be too small (12.8% of all reports in the study period) to account for the changes. Other factors, the use of speech recognition in particular, are likely to have more impact but were not specifically studied.

Although the pager notification and reporting process were feasible from a technical point of view, the small proportion of reports actually sent is an illustration of how technological capability does not guarantee proper operation. Too many of the steps involved in the process, notably the physician generation of requests and the schedulers' entry of those requests into the RIS, were paper based and manual. Automation of these steps could improve both the speed and accuracy of the data entry process. Kaplan and Lundsgaarde⁸ have noted that system integration is of major importance in achieving overall system efficiency. The wider availability of alphanumeric pagers among the hospital physicians and having radiologists conform to a reporting standard with a clearly separated, and brief, impression also would help.

Despite the difficulties that this study encountered, the process was received favorably by the ED physicians. The questionnaire portion of the

project had a return proportion of about 20%. Of that group, about half used the pager service, and 80% of those returning questionnaires noted that they would like the service to continue.

It is likely that we will implement this process again when the steps can be more automated. Even though we ran a pilot study and corrected some problems, we believe that the whole study serves as a more realistic preliminary study and served to point out areas of difficulty not anticipated. The

study did show the potential for pager notification and reporting to be a factor in reducing ED physician time to obtain imaging results.

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