Computers in Radiology

Improving Report Turnaround Time: An Integrated Method Using Data from a Radiology Information System

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***OBJECTIVE. In the face of a changing health care system and increased competition, radiology departments need to become more efficient. One measurement of efficiency is promptness in producing a final report. Many large radiology centers have radiology information systems (RIS) that track work flow, collecting tremendous amounts of data. Most, however, lack an appropriate analytic mechanism. We have developed an integrated system that allows continual monitoring of radiology work flow and thus of opportunities to apply interventions. This system can form an important component of the quality management process in the radiology department.**

MATERIALS AND METHODS. In developing the system, we identified seven key steps in the work-flow process. When left to chance, these steps occur out of sequence and large delays occur. A scheme was devised to improve the sequencing of the work flow by using the data collected from the RIS, sorted by radiology division and patient type. Biweekly, the appropriate data file is transferred to each division for analysis, via the department's computer network. A one-step process follows, using desktop Macintosh computers and a custom program written in Microsoft Excel. Extracted data are quickly converted into a tailored division summary, and a report is automatically generated.

RESULTS. The result summary format is uniform throughout the department, allowing ease of review at divisional and departmental meetings. Problems can be immediately localized to a specific step in the work-flow process. Automation of much of the system allows continual, near-real-time review of work flow. Using this approach, we have seen a sustained reduction of average report turnaround time.

CONCLUSION. This system allows continual monitoring of work flow. It is largely automated and lends itself well to inclusion in the quality management program of any radiology department.

With major reforms under way in health care, it is likely that the future will bring increased competition among radiologic facilities. Even the largest facilities face the need for increased efficiency. Many large radiology centers have a radiology information system (RIS) that potentially can collect tremendous amounts of data for analysis of work flow through a department. Most often, however, this potential is unrealized, for want of an appropriate analytic mechanism.

A recent report [1] has described a system for using data from the RIS as an aid to clinical research. In our institution, we have developed a system that uses RIS data as a quality management tool. The system allows continual monitoring of all steps of work flow through the radiology department and distills a wealth of data into a final standardized report.

The Work-Flow Process

Development of the work-flow review system fell into two stages. First, we analyzed the existing process of work flow. Second, we created an automated system that would use RIS data to allow continual review of the process.

Analysis

We started with the aim of reducing report turnaround time, which we defined as the interval from the completion of a radiologic study or procedure to the printing of the final report. Although later we would apply the system to other divisions in the department, we focused initially on a single

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subgroup of patients within a single division: plain-film musculoskeletal examinations performed on inpatients.

We began by creating a flowchart of this work process (Fig. 1). Each case passes through seven discrete steps. Importantly, each step is generally dependent on the preceding step and cannot be done until the prior step is completed. There are exceptions to this. Occasionally faculty dictate cases themselves or sign off cases before the resident signs off. Occasionally, cases are dictated without waiting for the clerical staff to display the films on an alternator. In general, however, a case passes through each of these steps sequentially.

The sequential dependence of this series of steps immediately raised the question of how our work habits fit the sequential work flow. To analyze this, we obtained representative data from the RIS for this population of patients. For each of the seven steps, we plotted a 24-hr profile (Fig. 2A). This plot graphically shows the lack of coherence then extant between sequential steps of the work-flow process. For example, faculty report approval bears no constant relationship to resident approval. Frequently faculty members would sit down to approve reports just before the resident did; if the faculty member next logged in for a report approval session the following day, a delay of 24 hr would result.

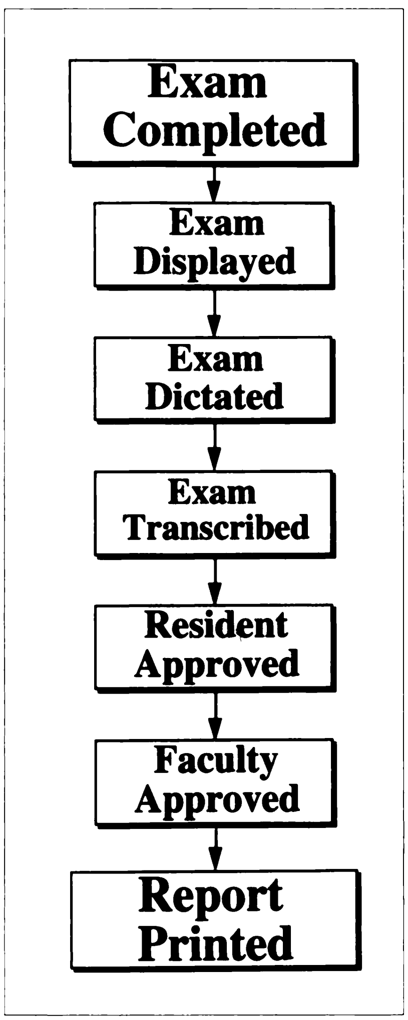


Fig. 1.—In attempting to reduce report turnaround time, we considered interval between completion of examination and printing of final report. Flow chart shows five steps that lie between these end points and six discrete intervals that these steps create in turnaround time. Subsequent analysis concentrated on these six intervals.

Analyzing these data over several days revealed other institutionalized delays. For example, the steps of the work-flow process that were formally scheduled—film hanging, dictation, and printing—were each scheduled only once daily. When combined with the nonscheduled steps, delays of several days could, and did, occur.

It was clear, then, that the first stage in reducing report turnaround time must be to introduce a system to properly sequence the steps. Figure 2B shows an idealized situation, where each step is scheduled to finish in time to allow the next step to be performed without delay. For clarity, this figure shows only one cycle of the process. In reality, we saw the chance for increased efficiency if two cycles were occurring simultaneously, but out of phase.

With two cycles progressing simultaneously, keeping to this sequential scheme, we could guarantee that the maximum turnaround time for a case would be 32 hr. This scheme's operation, however, was entirely dependent on each step being completed in time for the next step to begin. This naturally raised the concept of what we named "work-flow targets."

Targets were the times, twice daily, when each step was scheduled to be completed. The targets are shown in Table 1; this table was posted in work areas within the department. Twice-daily printing was instituted, and these two print times, at

TABLE 1: Targets for Work-Flow Through Inpatient Bone Service

Task	Target		Comment
	Cycle A (AM reading)	Cycle B (PM reading)	
Exam completed	6:30AM	2:00PM	For example, an exam completed by 6:30 AM will be hung for the 8:30 AM reading
Exam displayed	8:30AM	4:00PM	Films should be hung by these times
Exam dictated	11:30AM	5:30PM	Films should be dictated by these times
Exam transcribed	3:00PM	7:30AM	Reports should be transcribed by these times
Approved by resident	5:00PM	11:00AM	Resident queue should be empty at both these times each day
Approved by faculty	6:00PM	11:30AM	Faculty queue should be empty at both these times each day (whether or not resident has approved reports)
Report printed	7:00PM	12:00noon	These print times are fixed and automatic. Our aim is to complete all steps prior to these targets twice daily

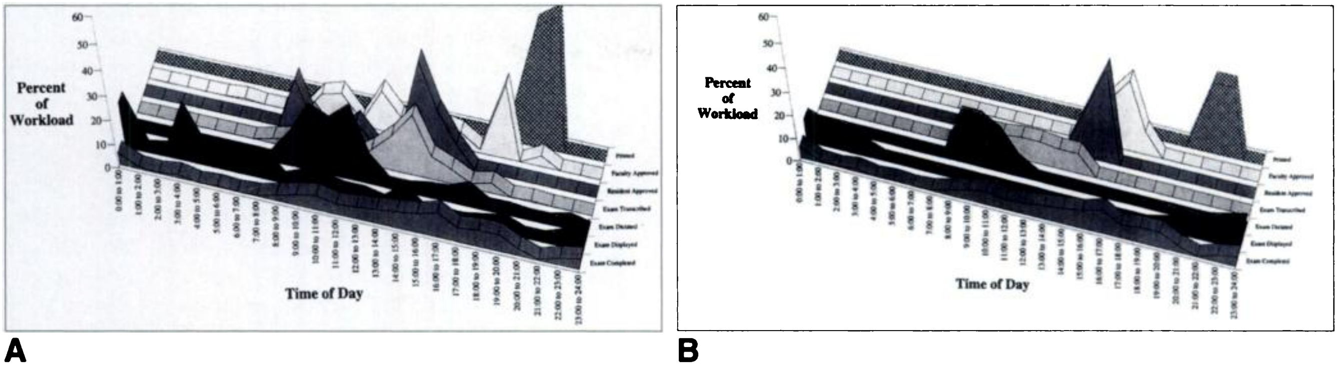


Fig. 2.—Graph shows data collected by radiology information system plotted to show time of day of each step in work-flow process.
***A*, Real data for inpatient bone service, collected from RIS during a 2-week period. Lack of sequential dependence of steps is shown.**
***B*, Fictitious data are plotted in a similar manner, to show "ideal" situation, where each step in work-flow process is timed to follow prior step. Sequential dependence is fully recognized. For clarity, only a single cycle of work flow is shown. In reality, a second cycle was timed to run out of phase with that shown, to include an afternoon dictation and a noon printing.**

noon and 7:00 PM, were the fixed endpoints of each of the work-flow cycles. Targets for each of the other steps in the process leading up to printing were scheduled twice daily to fit in with other work in the department, but to converge on the print times.

With this sequenced, targeted approach, we could guarantee a maximum turnaround time of 32 hr, and an average time of significantly less than that, but only provided each target was met. We therefore needed a mechanism for assessing adherence to this process. This mechanism should monitor each step individually and do so in as near to real time as possible.

Review System

The review system converts the huge volume of raw RIS data to a final report, and the process is summarized in Figure 3. Our radiology information system is the Images 3000 system (Smith, Dennis & Gaylord, Milpitas, CA). This collects data from all stages of the work-flow process throughout our department, storing them in a Turboimage data base on an HP3000 model 967 computer (Hewlett Packard, Mountain View, CA).

Computer terminals are present in the examination suites, reading rooms, file rooms, and other key locations. Time and date of completion of an examination are recorded by the radiographer, who bar-codes the case into the RIS. The time and date when the examination is displayed on the alternator for viewing are recorded by the film management clerks' bar-coding the case as "moved" to the appropriate reading room. Transcription, signing, and printing dates and times are automatically captured by the RIS. In our department, the dictation system is integrated with the RIS, allowing automatic capture of dictation time.

The data base containing this information is periodically subjected to "extraction." The "extract file" so created contains a number of data fields, including all the times and dates of each step in the work-flow process just described.

The extract file contains data for the entire department over an extended period. This file is then culled to a reduced file, limited to the appropriate time interval and group of patients. We decided to gear our work-flow review system to analysis of consecutive 2-week intervals. The analysis would be done 1 week after the end of each 2-week interval, to allow at least

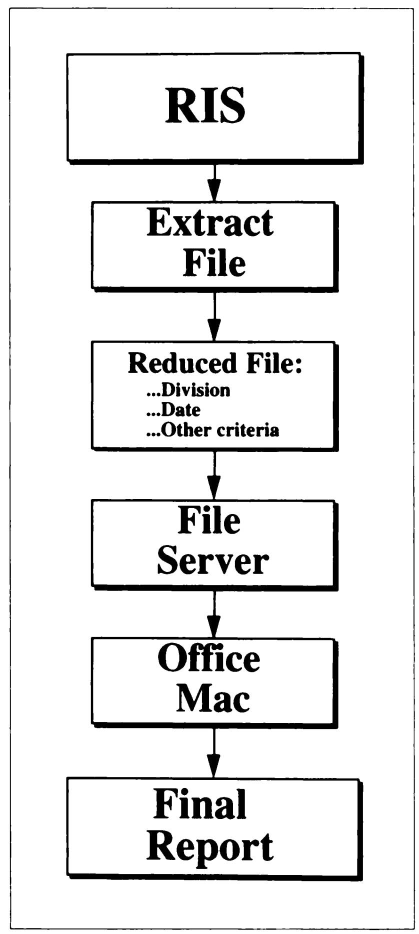


Fig. 3.—Flow chart shows review system created to monitor success or failure of various interventions in each division. This takes raw data from radiology information system and reduces it to a standardized report, tailored as appropriate for each division or service.

1 week for completion of each step in the work-flow process. Data were divided into radiology divisions (e.g., musculoskeletal, sonography, CT) and were then further subdivided. This subdivision was tailored for each division. For example, exam-

inations in the musculoskeletal division were further divided into inpatient and outpatient, whereas examinations in the sonography division were divided into obstetric and general.

Reduction of the extract file to tailored files for each division is currently initiated by a member of the computer services division of our department, although it is in the process of being automated.

These tailored data files are placed in a folder on the department's file server, for downloading over the network to the appropriate division. A radiologist in charge of quality management in each division then performs the final step in reducing the data to a usable form.

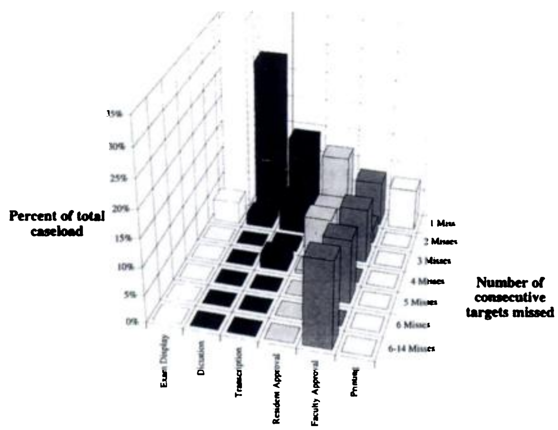
This final step is performed by a custom program written in the Excel programming language (Excel 4.0, Microsoft Corporation, Redmond, WA). The program runs on desktop Macintosh computers (Apple Computer, Inc., Cupertino, CA) found in each faculty member's office. The quality management radiologist or his or her secretary starts up this program and selects the appropriate data file, downloaded from the file server. Thereafter, the processing continues automatically until completion. When finished processing, the program automatically prints a report in a standardized format and records a summary of the data in a cumulative log.

The printed report that the program generates is standardized throughout the department (Fig. 4). In two pages, it presents three distinct summaries of the data. These data are represented both graphically, for ease of rapid, gestalt assessment, and numerically, for more precision.

The first page presents data on missed work-flow targets. The data listed in the table at the bottom of the page are presented graphically in the center of the page (Fig. 4A). Ideally, each step in the work-flow process would be completed by its target time. In this case, there would be no columns; the graph would be empty. If targets are missed, however, columns will appear in the appropriate step, represented along the horizontal axis. If targets are missed, it is better that only one or two consecutive targets be missed, rather than work flow stopping at a particular step while several targets (two per day) go by. This is represented by the axis of the graph that goes into the page, away from the reader. Columns in the distance represent fewer consecutive misses and are therefore more desirable than columns in the foreground. If a case is stopped at any one step in

From file IPBONE.9/13-9/26
Created: 4/8/94 3:47 PM
Printed: 5/11/94 2:34 PM

Inpatient Bone, 9/13/93 to 9/26/93



	Exam Display	Dictation	Transcription	Resident Approval	Faculty Approval	Printing	Totals
1 Miss	35%	28%	14%	12%	8%	8%	15%
2 Misses	4%	2%	6%	6%	3%		3%
3 Misses			1%	7%	10%		3%
4 Misses			2%	1%			1%
5 Misses					12%		2%
6 Misses							
6-14 Misses					16%		3%
Totals:	39%	30%	23%	25%	48%	8%	28%
Totals:	39/100	28/93	38/162	36/143	83/173	13/173	237/844

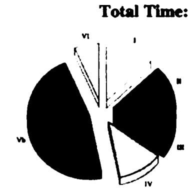
Consecutive missed targets as percentage of total caseload at each step

A

From file: IPBONE.9/13-9/26
Created: 4/8/94 3:47 PM
Printed: 5/11/94 2:35 PM

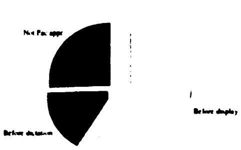
Average Times for Each Interval

I. Exam Completed to Exam Displayed:	9.9 hrs
II. Exam Displayed to Report Dictated:	10.0 hrs
III. Report Dictated to Report Transcribed:	7.3 hrs
IV. Report Transcribed to Resident Approval:	9.0 hrs
Va. Report Transcribed to Faculty Approval:	41.7 hrs
Vb. Resident Approval to Faculty Approval:	35.6 hrs
VI. Faculty Approval to Printing:	4.9 hrs
Total Time:	**82.6 hrs**



Work Flow Arrests

	Number	Percentage
Exam removed prior to being displayed:	4	4%
Removed after being displayed, before dictation:	1	1%
Dictated, but not typed:	0	0%
Not approved by resident:	0	0%
Not approved by faculty:	3	2%
Approved, but not printed:	0	0%
Total:	8	1%



B

Fig. 4.—The final report is a two-page document, created automatically on a radiologist's office computer. It graphically and quantitatively summarizes a period of activity in a particular division or service. This particular example shows a typical distribution of missed targets: in most divisions, faculty approval was slowest step, often with multiple consecutive missed targets.

the work-flow process for more than 1 week (14 targets), it is not represented in this graph, but instead is defined as a "work-flow arrest" and is included on the second page of the report.

At the top of the second page of the report (Fig. 4B), the average times for completion of each step are listed, together with the average total time (the turnaround time) for all studies. Faculty approval time is listed twice: once as time from resident approval, and once as time from transcription. The numbers for each step will not add up to equal the total turnaround time. This is because the program will use whatever data are available for calculating the time for each step, and complete data for each step may not be available for each case.

The relative contribution of each step to the total time is represented graphically in the pie graph below the average times. This allows rapid assessment of which steps are the slowest.

Finally, at the bottom of the second page, the work-flow arrests are listed. These are defined as cases in which the flow of work through the sequence of steps halts at one step for more than an arbitrary number of missed targets. We have adopted 14 consecutive missed targets (that is, 7 days) as our definition of a work-flow arrest. So, for example, if a case is removed from the radiology department before being hung on the alternator and not returned within 7 days, it will appear as a work-flow arrest in the row labeled, "Exam removed prior to being displayed." The absolute numbers of cases arrested at each step are listed, together with the percentage of the workload at that step. Totals are listed, and the figures are presented graphically at the bottom of the page.

The standardized format facilitates comparison between divisions and between different periods in the same division.

Results and Discussion

We have now introduced a version of this process into four of the divisions or subdivisions within the department. It must be emphasized that the monitoring system described will achieve no lasting change by itself. It can effect improvement only if it is combined with a vigorous process of identification and correction of specific problems within a division.

To this end, after obtaining baseline data for a particular division, members of our quality improvement team would meet with the members of the division. We would use a process known as Ishikawa cause-and-effect analysis [2] to determine the underlying causes for delays at particular steps. Some of the problems we found in this process were surprisingly easy to correct, for example, the need for an extra computer terminal or for increased clerical support in a specific area. The work-flow review system is designed to monitor the response to correction of these specific underlying problems.

An important feature of any work-flow review system is data accuracy. Data input occurs at many locations. Some are entirely automatic and transparent to the user—for example, transcription time and report approval. Elsewhere, data entry is manual—for example, the film hanging and examination completed times are entered by manual bar-coding. Both automatic and manual data input must be verified during establishment of the system, to ensure accuracy. Much of the development time of our data-review system was spent ensuring the validity of the data. The manual data entry, in particular, was designed to fit with the existing patterns of work, and high accuracy and compliance have been achieved.

TABLE 2: Results of Introduction of the Work-Flow Review System in Four Radiology Services

Division	Duration Followed (months)	Baseline Turnaround Time (hr)	Achieved Turnaround Time (hr)	Percentage Reduction in Turnaround Time
Inpatient bone	14	101	59	42
Sonography	7	95	34	64
Body CT	3	60	43	28
Neurologic CT	3	52	44	15

The divisions to which this process has been applied have been followed for various lengths of time, and representative results are summarized in Table 2. In each division where we have introduced this system, turnaround time has decreased. Each division, however, has its own unique problems, requiring different interventions. The rate of improvement therefore differs significantly from division to division.

The Hawthorne effect [3]—transient improvement purely due to the fact of monitoring a process—must be considered when interpreting these results. However, the division we have followed the longest—inpatient bone—shows no sign of backsliding after 14 months. This is because problems can be picked up swiftly as they occur and pinpointed to a specific step in the work-flow process, which allows rapid correction.

One key feature of the work-flow review system must be stressed. The system is designed to produce the final report, distilled from RIS data, on site where it is most needed: within the particular division involved. Monitoring of response to improvements takes place at this divisional level. Suggestions for further improvements then can be made by those most qualified to institute such changes—those working within the division itself. This avoids the pitfall of monitoring by an overseeing bureaucracy. Such an Orwellian approach very likely would engender resentment within the department and ultimately would be counterproductive.

Report turnaround time is not the only measure of efficiency of a radiology department. Other methods of communicating results may be more appropriate in certain circumstances. However, the written report will remain the mainstay of communicating findings to the clinician. The system we have outlined is part of an ongoing quality improvement process in our department. It continues to evolve, but the underlying process—continual feedback at the division level, with general overview at the departmental level—we believe is crucial to the maintenance of improvement. Ideally, the capabilities we have described would be included as standard features of radiology information systems in the future.

Efficiency is becoming the byword of the 1990s. Many radiology departments already have the information that would allow them to be more efficient. The system we have described would allow them to use it.

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