Impact of Electronic Imaging on Clinician Behavior in the Urgent Care Setting

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Although it is intuitively valuable that more expedient delivery of radiographic images and reports to clinicians would improve patient care, it is important to document these outcomes to validate further advances in these areas. We evaluated the care of 215 patients seen at a walk-in clinic to determine what benefit digital imaging is to the patient. Cohorts consisted of all patients for whom specified radiology examinations were ordered during a 7-day period. The first cohort was recruited when analog films were used. The second cohort received examinations performed with computed radiography (CR) acquisition and computer display, which had been in use for 2 years. Patients were categorized as to the type of study they received, as well as whether a staff radiologist was immediately available to read the study. Clinical behavior was characterized by outcome measures of time to final diagnosis, time to final treatment, and need for follow-up. Our analysis demonstrated a reduction in time to final diagnosis that was better appreciated during the times when a staff radiologist was not immediately available. It also suggested that greater time reductions were seen for patients who received extremity examinations than those who received chest, sinus, or rib films. These data suggest that digital imaging is a useful tool to improve clinical outcome of patients seen in the acute care setting.

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IN THE CURRENT ERA of digital imaging, with the widespread use of computed radiography (CR) and picture archiving and communication systems (PACS), it is assumed that these advances have correlated to an improvement in the delivery of patient care. Many authors have examined this question focusing on time savings in regard to patient, film, and report flow times.¹⁻³ The results of these investigations have varied with the state of technology, the clinical setting, and the users' experience. Others have looked at the manner in which clinicians use a PACS.^{4,5} However, research focusing on the effects of digital technology on clinical behavior is limited.⁶ We are currently at a point in time where the technology has been refined and well established in clinical practice.⁷⁻¹⁰ As

radiology departments around the country are replacing conventional film/screen radiography units with CR and PACS, little evidence exists that these investments truly benefit the patient. Our aim, then, was to answer that question.

MATERIALS AND METHODS

Selection of Patients

We conducted a case-control study of 233 patients seen in the Urgent Care Center (UCC) at the Mayo Clinic who received either extremity, chest, rib, or sinus x-rays. Extremity films (EXT) were defined as films of the shoulders or any distal upper EXT, as well as the hips and any distal lower EXT. The patient population was enrolled prospectively for another study, which is described in detail elsewhere.¹ Patients were recruited in two cohorts. The first group contained all patients seen from Saturday, May 13, 1995 to Friday, May 19, 1995. The second group contained all patients seen from Saturday, May 17, 1997 to Saturday, May 24, 1997. While the initial study did collect information on the time of certain events, the nature and resolution of clinical problems were not collected. Medical records were reviewed in 1998 to identify/collect this information.

Two hundred thirty-three patients were enrolled, of whom 215 qualified for our study. Eighteen patients were excluded as they had received radiologic examinations not included in the selection criteria (Table 1). Two of the 215 patients received two examinations. For the purposes of this study each examination is considered separately for a total of 217 examinations.

Patients were classified into one of eight groups. The groups were designated by three factors: (1) date patient was seen (1995 or 1997), (2) time patient was seen (weekdays or evenings and weekends), and (3) type of study ordered (EXT or chest x-rays). The chest x-ray classification (CXR) included patients who received chest x-rays, rib films, or sinus films. The UCC began using CR/PACS in the spring of 1995 but a screen/film system was used during the first trial period. Thus, the first factor separated patients who were imaged digitally from those who were imaged conventionally. The second factor separated those patients whose examinations were initially reviewed by a staff radiologist on site from those whose studies were initially reviewed by a radiology resident at a remote location. The final factor attempted to divide those patients with a chief complaint of trauma from those with other chief complaints. Although the CXR division in this latter category included some trauma, it was primarily inflammatory processes. Table 2 describes the number of patients in each category, as well as the health care provider who saw each patient.

Demographics

The patient age and sex distributions are described for each category in Table 3. The patient population seen during the weekdays was not statistically different from those patients seen in the evenings and on weekends. However, there was a trend

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Table 1. Excluded Patients

Date	Skull	Facial Orbits	Cervical Spine	Lumbar Spine	Abdomen	Pelvis	Totals
1995	1	1	2	1	4	1	10
1997	0	0	3	1	4	0	8

toward younger patients (mean, 33.0 v 38.7 years) seen during evening and weekend shifts than during the weekdays. Overall, there were no statistical differences in age or sex between those patients seen in 1995 and those seen in 1997. One hundred eight patients were enrolled in 1995 at mean age of 37.3, as compared with 109 patients in 1997 at a mean age of 35.8. The only statistical difference with regard to age was in those patients receiving EXTs versus CXRs. The average age of females receiving EXTs was 32.5, as opposed to 42.3 for those in the CXR group. There was no statistical difference in the ages of males within this group. Accounting all patients, there was a statistical difference in the EXT group versus the CXR, with average ages of 33.9 and 41.4 years, respectively.

Equipment

Film images were obtained for the 1995 cohort using conventional screen/film technique appropriate for the body part imaged. During regular hours, films were carried to the staff radiologist located immediately adjacent. The radiologist would dictate directly to a transcriptionist, and the typed report would be pasted on the examination jacket containing the films. Films would be carried to the UCC approximately every 30 minutes. On evenings and weekends, the film was transported to the nearby hospital where a resident would interpret the films, paste the interpretation on the jacket, and send the examination back. In some cases clinicians did walk to the radiology department to view images prior to them being sent to the hospital for interpretation.

The digital images were obtained for the 1997 cohort using a Fuji FCR-9000 (Fuji USA, Stamford CT) CR system, except for CXRs, which were obtained with a Fuji FCR-9501 (Fuji USA) dedicated chest CR unit. Images were then transferred to the PACS (formerly Loral, now General Electric Medical Systems, Milwaukee, WI), where quality assurance and interpretation were performed. Images were immediately available on a PACS

Table 2. Patient Classifications

	Group				Totals
	CIM	UCC	Peds	FM	
EW95EXT	2	0	1	26	29
EW97EXT	7	2	0	13	22
EW95CXR	8	0	2	9	19
EW97CXR	4	1	3	4	12
WKDY95EXT	3	0	0	42	45
WKDY97EXT	9	14	0	21	44
WKDY95CXR	5	0	0	10	15
WKDY97CXR	22	3	0	6	31
Totals	60	20	6	131	217

Abbreviations: CIM, community internal medicine staff/residents; UCC, urgent care providers (nurse practitioner/physicians assistant), Peds, pediatric staff; FM, family medicine staff/residents.

workstation in the UCC. Mayo practices direct dictation, and therefore, the report was available electronically as soon as interpretation was performed.

Evaluation of Clinical Behavior

Clinical histories were retrieved for each of the 217 radiologic examinations. A single reviewer examined the clinical notes. Several data points were extracted from each history (Table 4). Clinical behavior was then characterized by three different measures. The first measure was time to final diagnosis (TFD). Although registration time was available for all patients, complete patient and film flow times were not recorded for each patient. Therefore, we categorized time to final diagnosis as (A) final diagnosis made during initial visit, (B) final diagnosis made after the patient left the UCC but within the same day, or (C) final diagnosis made the after the day of the initial visit. The second measure was time to final treatment (TFT). This was categorized in the same way. Finally, using a similar system, we categorized any follow-up (F/U) visits the patient required related to the complaint for which the examination was ordered. F/Us were categorized as (A) no F/U, (B) F/U the same day as the initial visit, or (C) F/U after the day of the initial visit.

Two additional data points were evaluated. First, if final diagnosis was not made during the initial visit, we noted whether the radiologic examination was used to make the final diagnosis (Rad/assist). This was classified as yes, no, or no available data. Finally, we compared the ratio of patients who experienced any delay (Del) in either final diagnosis or final treatment beyond the initial visit in each group to the ratio of patients without a delay.

Statistical Analysis

Five sets of tables were analyzed for each of the five measures described in the previous section. The initial assessment compared all patients seen in 1995 to all patients seen in 1997. The following four comparisons matched exams from 1995 to 1997 limiting to (1) examinations on evenings or weekends, (2) examinations during the weekdays, (3) extremity examinations, or (4) CXRs (including sinus and rib examinations). Ordered contingency tables¹¹ were used to evaluate those categories with more than two variables (ie, TFD, TFT, and F/U). A chi-square test was used to evaluate the ratios of patients who experienced any delay in either final diagnosis or final treatment. The use of the radiologic exam to make the final diagnosis was also assessed by the chi-square test.

Due to changes in the style of practice of the ordering physicians within the UCC from 1995 to 1997, all statistical analyses were performed as described for three sets of patients. Analysis of all sets was performed before knowledge of results of any one set. The first set contained all patients. The second set included only those patients seen by family medicine staff physicians (FM Staff). The third set was further limited to those family medicine staff who saw a total of greater than 10 patients and saw some patients during each of the collection periods (Select FM). For all analyses a P value ≤.05 was assumed to represent statistical significance unless otherwise noted.

RESULTS

Ordered contingency tables demonstrated a statistically significant decrease in time to final diagno-

Table 3. Patient Age and Sex Distributions

	Weekdays	Evenings/ Weekends	Extremity	Chest	1995	1997	Total
Males							
No.	65	34	68	31	50	49	99
Mean age (95% CI)	39.4 (33.9-45.0)	31.7 (23.5-39.9)	35.3 (30.1-40.6)	39.9 (30.5-49.3)	33.7 (27.2-40.0)	40.0 (33.3-46.6)	36.8 (32.2-41.4)
Median age	40	24	33.5	41	31	42	38
P value	0.111		0.359		0.173		
Females							
No.	70	48	72	46	58	60	118
Mean age (95% CI)	38.0 (32.0-44.1)	33.9 (27.8-40.0)	32.5 (27.1-37.9)	42.3 (35.2-49.5)	40.5 (34.1-46.8)	32.3 (26.4-38.3)	36.4 (32.0-40.7)
Median age	32.5	32	26	39.5	37.5	27	32
P value	0.352		0.029		0.064		0.895
Total							
No.	135	82	140	77	108	109	
Mean age (95% CI)	38.7 (34.6-42.8)	33.0 (28.1-37.8)	33.9 (30.2-37.6)	41.4 (35.8-46.9)	37.3 (32.8-41.8)	35.8 (31.3-40.2)	
Median age	38	31.5	29	40	34.5	33	
P value	0.079		0.024		0.626		

Abbreviation: CI, confidence interval.

sis with the use of CR and PACS when compared with conventional screen/film methods. This difference was elucidated in the population of patients seen by family medicine staff physicians (Table 5). A significant decrease was also noted in this group when comparing all delays (Del). This difference was not appreciated during the weekday operating hours, but a significant decrease in TFD was found during the evening/weekend period. However, we were unable to demonstrate a that the radiologic study contributed to making a delayed diagnosis if one was made.

We also demonstrated a significant decrease in the all delays category within the EXT group. Although not statistically significant, the remaining categories within that group (TFD, TFT, F/U) all suggested a trend toward reduction with the use of digital film technology.

No significant differences were found in analysis of the groups including all patients or only those

patients seen by the selected family medicine physicians.

DISCUSSION

This study demonstrates that digital imaging does improve patient care in the outpatient setting. However, more convincing data are still needed. This was a retrospective case-control study based on a previously enrolled patient population. Given these limitations, it was difficult to establish a good

Table 5. Statistical Analysis (P values) of Outcomes Measures

	95 v 97	Weekdays	Evenings/ Weekends	EXTs Films	CXR's
All patients					
TFD	0.807	0.157	0.293	0.535	0.312
TFT	0.383	0.839	0.247	0.880	0.122
F/U	0.445	0.643	0.452	0.886	0.358
Del	0.511	0.464	0.738	0.508	0.114
Rad/Assist	0.032	0.013	0.631	0.019	1.000
Select FM					
TFD	0.788	1.000	0.530	1.000	Not possible
TFT	0.111	0.335	0.374	0.204	Not possible
F/U	0.889	0.978	1.000	0.440	0.231
Del	0.274	0.335	1.000	0.289	Not possible
Rad/Assist	1.000	Not possible	1.000	1.000	Not possible
FM staff					
TFD	0.024	0.311	0.031	0.095	0.134
TFT	1.000	0.106	0.241	0.068	0.376
F/U	0.182	0.575	0.175	0.085	0.916
Del	0.007	0.118	0.076	0.032	0.134
Rad/Assist	0.526	0.444	1.000	0.509	Not possible

Table 4. Information Extracted

Registration time	Means to initial diagnosis
Department of requesting physician	Initial therapy
Presenting symptoms	Follow-up
Physical exam findings	Final diagnosis
Radiology report	Means to final diagnosis
Initial diagnosis	Final therapy
Use of radiologic exam for initial diagnosis	

model for clinical practice outside of an academic center.

The Family Medicine staff group provided the closest model to private practice, given that ours is a large academic medical center. When all patients were considered together, several confounding variables were introduced. Nurse practitioners and physician assistants saw a greater percentage of the patients in 1997 than in 1995. This is likely reflective of national trends. In addition, the family medicine practice within the UCC is quite different than the community internal medicine practice. The latter group employs interns and residents to initially see the patients. These physicians then "staff" the patients before employing a definitive plan. The nurse practitioners and physician assistants function in a similar fashion. This practice focuses on the academic approach to the patient, perhaps sacrificing efficiency. Given the increasing demands on private practice physicians to see more patients, it is important to model the study on a group such as the FM staff.

Although statistically significant on only one account, the results suggest a greater difference during the evening/weekend hours than during the weekday. This is expected as less time is saved during the period when a staff radiologist is available at the UCC site. However, many private clinics do not have this luxury, and the evening/weekend periods would better represent the daily function of such clinics. (In fact, we no longer staff this site with a radiologist.) It is also important to point out

that EXTs demonstrated a greater difference than CXRs. If the former do represent posttraumatic complaints and the latter more inflammatory processes, then this too would be expected. The importance of early diagnoses of traumatic injuries and greater consequences of missed diagnoses may have contributed to an increased level of suspicion for such diagnoses. However, the ability to reduce the time to such diagnoses, may be more beneficial than a reduction in time to inflammatory diagnoses.

It was also interesting that even in those groups that demonstrated significant time reductions, we were unable to demonstrate that the radiographic study was involved in this reduction. A prospective approach would be more helpful in answering this question.

Several analyses were unable to be performed due to the small number of patients in some groups. When all delays were considered, significance was found more often. This may suggest that many more comparisons would reach significance if a larger number of patients were enrolled.

CONCLUSION

Digital imaging and PACS improves patient care in an ambulatory clinic setting by reducing the TFD. The greatest difference is appreciated in the EXT subgroup and during time periods when a staff radiologist is not available at site where the radiograph is acquired. A prospective trial to provide greater evidence would still be helpful.

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