

# The Interpretation of Office Radiographs by Family Physicians

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*This study prospectively compared the interpretations of family practice residents and faculty with those of radiologists on 532 office radiographs using a uniform protocol. A total of 136 family practice residents (44 first-year, 40 second-year, 52 third-year) and 42 full-time and part-time faculty participated in the study along with 30 radiologists. The mix of radiographs evaluated was as follows: 44 percent chest, 20 percent lower extremity, 6 percent head, 4 percent lumbosacral spine, 3 percent cervical-thoracic spine, and 3 percent abdomen-pelvis. Interpretation concordance rates between family physicians and radiologists, by level of training, were as follows: first-year residents 83.0 percent, second-year residents 84.4 percent, third-year residents 86.0 percent, and faculty 88.6 percent. Concordance after the resident and faculty preceptor discussed the film and provided a collaborative interpretation was 92.1 percent. This finding compares with previously reported error rates of 10 to 40 percent between experienced radiologists. Only 10.3 percent of the discordant readings (0.8 percent of all radiographs) contained significant discordancies that may have affected patient management or outcome. Had the family physicians been given the option to refer an x-ray film to the radiologist, all x-ray films containing significant discordancies would have been referred.*

**R**adiology is an integral part of the office practice of family physicians. In a previous study the authors found that 87 percent of family physicians reported taking radiographs in their office,<sup>1</sup> and that they took a wide variety of radiographs: 90 percent of the practices surveyed took spine, abdomen, pelvis, extremity, and chest films. In that study it was also discovered that most family physicians (73 percent) believe that radiograph interpretation is a fundamental clinical skill of the family physician, that it is required for making timely management decisions regarding diagnosis and treatment, and that family physicians should be trained to read 90 percent of their own office films. These family physicians also believe that radiologists should be used as consultants in the same way that the family physician consults any other specialist, that is, when his or her own decision criteria indicate the need for referral.

If family physicians believe that they should obtain radiographs in their office, that they should read these films, and that they should have a set of referral criteria for utilizing the radiologist as a consultant, then it is appropriate to determine whether their interpretation skills in reading office radiographs are equivalent to the radiologists' skills and whether they can accurately identify those radiographs that need referral. These findings are necessary to ensure that high-quality patient care is maintained.

Most studies in the literature comparing the radiographic interpretation skills of nonradiologists with radiologists have compared skills in reading radiographs obtained from the emergency room setting rather than from the physician's office. These studies are summarized in Table 1, which indicates that the discordancy rates of the nonradiologists were all under 10 percent, with significant discordancy rates of 2.5 percent or less. Only one study (Mucci)<sup>3</sup> evaluated whether any of these significant discordancies would have been undiscovered had the nonradiologist had the option of not having all radiographs reread. He found that one half of the significant discordancies (1.2 percent of the total) would have been undiscovered had the emergency room physician not had the option of referring a film to a radiologist for an inter-

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TABLE 1. STUDIES COMPARING RADIOGRAPH INTERPRETATIONS BETWEEN RADIOLOGISTS AND NONRADIOLOGISTS

Author	Physician Group	Setting	Number of Radiographs	Discordance Rate (percent)	Percentage of Significant Misses
Fleischer, et al <sup>2</sup>	Pediatrician	Urban pediatric emergency room	564	8.9	1.2
Mucci <sup>3</sup>	Emergency physician	Urban emergency room	1000	4.4	2.3
Delacy, et al <sup>4</sup>	Emergency physician	Urban emergency room	531	7.0	2.5
	Radiologist	Urban emergency room	531	5.0	1.7
McLain and Kirkwood <sup>5</sup>	Family physicians	Rural emergency room	294	9.2	2.4
Strasser, et al <sup>6</sup>	Family practice residents	Urban residency training clinic	315 chest x-ray films only	23.5	—

pretation. Only one study (Delacy et al)<sup>4</sup> identified the discordancy rates that also existed between radiologists on the same set of radiographs. Only one study, Strasser et al,<sup>6</sup> compared family physicians' interpretations of office x-rays with those of radiologists as an incidental finding in a study that evaluated the effect of having on-site radiographic facilities on radiograph utilization rates in two residency training clinics. Strasser et al noted a disagreement on interpretation between the resident and the radiologist in 23.5 percent of patients from whom a chest radiograph was obtained. Residents noted more "abnormalities on the film that were not subsequently reported by radiologists," but no specific overreading rates were reported. The study by Strasser et al also did not compare interpretations by family physician faculty with those of the radiologist, nor did it evaluate the significance of any of the noted disagreements.

The present study investigated the interpretive skills of family physicians who read radiographs obtained in the office. Based on the interpretive accuracy of nonradiologists identified in the previously discussed studies, the investigators hypothesized that (1) family physicians and radiologists would agree on 90 percent or more of their radiographic interpretations, (2) less than one half of the discordant readings would contain significant discordancies, and (3) all of the radiographs with significant discordancies would be referred by the family physician to a radiologist for interpretation. As a result, none of the findings "missed" by the family physician would remain undiscovered.

## METHODS

This study assessed the skills of family practice residents and faculty physicians in interpreting radiographs taken

in the six residency training clinics of the University of Minnesota's Department of Family Practice and Community Health. Five of these six clinics are affiliated with community hospitals in Minneapolis and St. Paul, and the sixth is located in the University of Minnesota Hospitals and Clinics facility. All clinics have on-site radiographic facilities, either within the clinic or within the same building. After radiographs are taken, they are returned immediately to the clinic for interpretation by clinic physicians before they are read by a radiologist. It is standard practice in three of the six clinics to have all radiographs reread by a radiologist. In the other three clinics only certain types of films are referred. In all clinics, comprehensive family practice service is provided by family practice residents supervised on site by board-certified family physicians. These physicians are either full-time faculty members in the Department of Family Practice and Community Health or part-time faculty members who have clinical appointments in the department.

For 100 consecutive radiographs obtained in each clinic, starting February 1, 1987, the following data were collected: (1) the type of radiograph and chart number, (2) the graduate year of the resident interpreting the radiograph, (3) the resident's interpretation of the radiograph independent of faculty consultation, (4) the faculty preceptor's interpretation of the film independent of resident consultation, (5) a final collaborative interpretation after consultation between the resident and the faculty preceptor, and (6) a notation as to whether the radiograph would have been sent to a radiologist for a referral interpretation if the physician had the option of referring.

After the family physicians completed their interpretations, each film was sent to a radiologist, who was blinded from the family physicians' interpretations, for his or her reading. A copy of that report was then attached



to the resident and preceptor report form and given to the study coordinator at each of the six study sites (a faculty physician, one of the investigators). The coordinator at each site compared the interpretations and classified the family physicians' readings as either concordant or discordant with the radiologist. Following this initial review and classification, the interpretations were reviewed in the same manner by a second investigator for concordancy or discordancy. The two reviewers then conferred with each other on any radiographs where classification differences existed until agreement was reached.

Discordant readings were further evaluated following the protocol shown in Figure 1. Once a discordancy was identified, it was characterized as either an underreading error (abnormal finding omitted by the family physician that was identified by the radiologist) or an overreading error (findings stated by the family physician as abnormal and read as normal by the radiologist). The chart was then reviewed and the discordancy classified as significant (the discordancy identified could result in a potential change in management or change in patient outcome) or insignificant. Following this analysis, radiographs identified that had potentially significant discordant readings were taken to a second radiologist who read them without knowledge of either the family physician's or the radiologist's interpretations. If after the second radiologist's reading the interpretation of the family physician remained discordant with the radiologists', the patient was recalled for reevaluation, and the results of that reevaluation, including changes in management or outcome, were recorded. If the second radiologist's reading agreed with the family physician's interpretation, then the radiograph was reclassified as concordant.

Chi-squared and Cochran Q analyses were used to evaluate the significance of the study's findings. The Cochran Q is a nonparametric test that infers the statistical significance of differences in the frequency of specific observations. It was used in this study to assess the significance of the observed differences in the frequency of concordance between the different family physician interpretations (first-year resident, second-year resident, third-year resident, faculty, collaborative reading) and the radiologist.

## RESULTS

A total of 136 family practice residents participated in this study (44 first-year, 40 second-year, 52 third-year). Faculty participating included 12 full-time faculty and 30 clinical, part-time faculty. Interpretations by family physicians were recorded on 532 radiographs in this study. Both resident and faculty interpretations were recorded on 508. Faculty interpretations only (from their private

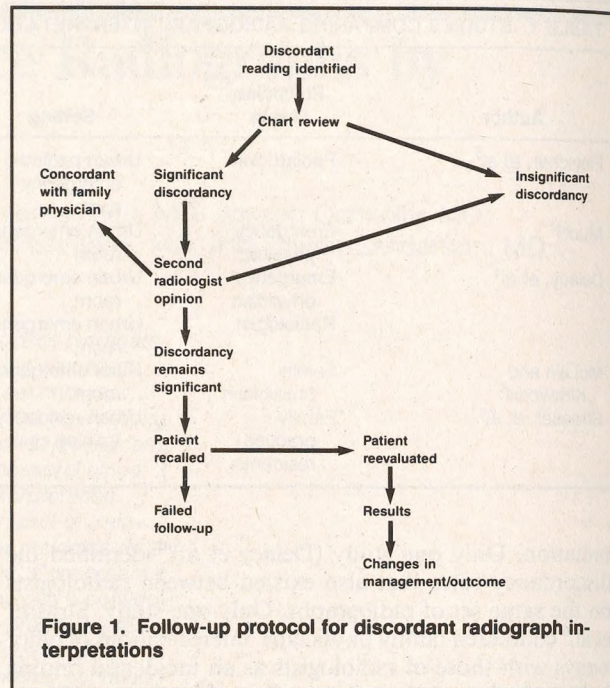


Figure 1. Follow-up protocol for discordant radiograph interpretations

clinic patients) were recorded on 24. Of the 508 radiographs with a complete set of resident, faculty, and collaborative interpretations, 53 (10.5 percent) were read by first-year residents, 171 (33.9 percent) by second-year residents, and 280 (55.6 percent) by third-year residents. Radiologist interpretations were obtained on all radiographs from one of 30 participating radiologists. Second radiologist readings were provided by a radiologist at a teaching hospital (St. Paul Ramsey Medical Center) who was not among the group providing the initial readings.

Concordancy rates on interpretation between the residents as a group and the radiologists were 85.2 percent. When concordancy rates were analyzed by resident year, it was found that first-year residents were concordant with the radiologist in 83.0 percent of cases, second-year residents in 84.4 percent, and third-year residents in 86.0 percent. These differences between residents are not statistically significant ( $\chi^2 = 0.4252$ ,  $P = .81$ ). Faculty interpretations were concordant with the radiologist in 88.6 percent of cases. This increase in concordance over residents' readings is significant (Cochran Q = 5.56,  $P = .02$ ). After residents and faculty discussed their independent findings and a collaborative interpretation was recorded, concordancy rates with the radiologist climbed to 92.1 percent. This increase in concordance over both the residents' and the preceptors' concordance rates is significant (Cochran Q = 21.12,  $P = .00$  for residents; Cochran Q = 14.73,  $P = .00$  for preceptors).



TABLE 2. RADIOLOGIST-FAMILY PHYSICIAN CONCORDANCE BY TYPE OF RADIOGRAPH

Radiograph Type	Family Physician Reading No. (%)	Concordant With Radiologist No. (%)	Discordant With Radiologist No. (%)	Errors	
				Underreading	Overreading
Chest					
Normal	138	131 (94.9)	7 (5.1)	7	—
Abnormal	86	69 (80.2)	17 (19.8)	—	17
Total	224 (44.1)	200 (89.3)	24 (10.7)		
Upper extremity					
Normal	69	66 (95.7)	3 (4.3)	3	—
Abnormal	32	29 (90.6)	3 (9.4)	—	3
Total	101 (19.9)	95 (94.1)	6 (5.9)		
Lower extremity					
Normal	70	66 (94.3)	4 (5.7)	4	—
Abnormal	32	31 (96.9)	1 (3.1)	—	1
Total	102 (20.1)	97 (95.1)	5 (4.9)		
Head					
Normal	17	16 (94.1)	1 (5.9)	1	—
Abnormal	13	12 (92.3)	1 (7.7)	—	1
Total	30 (5.9)	28 (93.3)	2 (6.7)		
Cervical thoracic spine					
Normal	10	10 (100)	— (—)	—	—
Abnormal	6	6 (100)	— (—)	—	—
Total	16 (3.1)	16 (100)			
Lumbosacral spine					
Normal	15	14 (93.3)	1 (6.7)	1	—
Abnormal	4	3 (75.0)	1 (25.0)	1	—
Total	19 (3.7)	17 (89.5)	2 (10.5)		
Abdomen, pelvis					
Normal	12	12 (100)	— (—)	—	—
Abnormal	4	3 (75.0)	1 (25.0)	—	—
Total	16 (3.1)	15 (93.8)	1 (6.2)	—	—
Totals	508	468 (92.1)	40 (7.9)	17 (43.6%)	22 (56.4%)

Table 2 displays the types of radiographs that were obtained and evaluated in this study. It also summarizes the concordance rates with respect to the radiologists' interpretations and the family physicians' collaborative interpretations by type of film. Most radiographs evaluated were either chest x-ray films (44.1 percent) or extremity films (40.0 percent). The film type involving the greatest interpretation discordancy was the category of chest radiographs, for which concordance rates were 89.3 percent. The main factor contributing to the increased discordance, as was apparent in the study of Strasser et al,<sup>6</sup> is apparent overreading by the family physicians. If the family physicians read the film as abnormal, the concordance rate was 80.2 percent.

When all discordant interpretations were evaluated, 43.6 percent were determined to represent an underreading error and the remaining 56.4 percent an overreading error. Clinically significant discordancies, however, occurred in only four cases, representing 10.3 percent of all discordant readings or 0.8 percent of all radiographs evaluated. Furthermore, each one of those radiographs with

a significant interpretation discordancy was included in that subset of films chosen for voluntary referral to a radiologist. Table 3 is an analysis of these four cases.

The voluntary referral rate to a radiologist by residents was 44.1 percent. When further evaluated by year of resident training, the following referral rates were found: first-year residents 49.1 percent, second-year residents 47.6 percent, and third-year residents 41.2 percent. Voluntary referral rates for faculty were not recorded. These differences in referral rates for the different graduate years of training are not statistically significant ( $\chi^2 = 2.34$ ,  $P = .31$ ).

## DISCUSSION

All three hypotheses set forth at the outset of this study were confirmed: the results show that family physicians (on collaborative interpretation) and radiologists agreed on at least 90 percent of radiograph interpretations (actual 92.1 percent), that less than one half of the discordant



TABLE 3. ANALYSIS OF RADIOGRAPHS WITH SIGNIFICANT INTERPRETATION DISCORDANCY BETWEEN FAMILY PHYSICIANS AND RADIOLOGISTS

Case	Radiograph Type	Features of Family Physician Error	Initial Treatment	Follow-up	Outcome	Selected for Referral
35-year-old woman	Chest	Overread pneumonia	Oral antibiotics	Patient recalled; returned for additional history and examination	Antibiotic continued for persistent cough and purulent sputum; patient recovered	Yes
96-year-old woman	Abdomen-chest	Underread mediastinal air	Admission advised. Family requested home trial on oral fluids only, by mouth, antacids and cimetadine. Advised to return if symptoms unrelieved in 2 hours	Returned to emergency room within 2 hours	Admitted. Gastrograffin swallow diagnosed perforated esophagus. Taken to surgery. Died post-operatively	Yes
9-year-old boy	Chest	Underread pneumonia	In spite of radiograph interpretation, clinical diagnosis was pneumonia; started on oral antibiotics	Routine 2-week follow-up	No changes in management; patient recovered	Yes
42-year-old man	Sinus	Underread sinusitis	Clinical diagnosis was sinusitis; treated with antibiotics and decongestants	Patient called, symptoms gone; no changes in management	Patient recovered	Yes

readings contained a significant discordancy (actual 10.3 percent), and that every film with a significant interpretation discordancy (0.8 percent of the radiograph total) would have been voluntarily referred to a radiologist for a second reading.

Several other important findings also emerged. One is the observation that there appears to be a continuum of increasing concordance related to level of physician training and experience, from an 83.0 percent concordance rate for first-year residents to an 88.6 percent concordance rate for faculty. That the differences between resident levels of training failed to reach statistical significance may relate more to the power of the study than to a true lack of significance. The continuum suggests that there seems to be a natural maturational process at work. It is also encouraging to note that this process continues beyond the conclusion of formal training. This pattern of increasing concordancy by level of experience is different from that observed for radiology residents. A previous study comparing interpretation errors between radiology residents found no constant pattern of increasing accuracy related to duration of training beyond the first year of residency.<sup>7</sup>

Although differences in concordance rates between residents failed to reach statistical significance, there was a significant difference in concordance rate between both the residents' and preceptors' interpretations and the collaborative interpretations. Two heads do appear to be better than one. This observation supports the position that all radiographs obtained by either residents or faculty should be viewed and interpreted collaboratively. Whether rereading by a colleague would increase concordance rates for seasoned practitioners in community practice is a question for further study.

When the discordant readings were further evaluated, several additional factors were noted. In this study total discordancies were more equally split between overreading (56.4 percent) and underreading (43.6 percent) problems than has been observed for discordancies between radiologists. This finding is similar to the data reported by McLain and Kirkwood<sup>5</sup> in which one half of their errors were identified as overreading and one half as underreading. Previous studies comparing radiologists' reading errors have found that overreading to underreading ratios were in the 20 percent overreading to 80 percent underreading range.<sup>7-9</sup>



Concern has previously been voiced that overreading errors may be the result of a "focused" interpretation of radiographs, leading the reader to unconsciously alter his or her criteria for what borderline findings shall be called abnormal, and subsequently overread the radiograph. Swenson et al,<sup>10</sup> in studying focused vs "free-search" interpretation, did discover that under focused conditions, the percentage of false-positive reports increased by 6 percent. He also found, however, that the focused condition increased the reporting of true abnormalities by 19 percent, decreasing the underreporting rate. Because they accumulate clinical data prior to viewing the radiograph, family physicians have been considered to be focused rather than free searchers in approaching the film. The combined effect, therefore, of slightly increasing the overreading rate, but decreasing the underreading rate, may have led to the more equal ratio between the types of errors observed in this study and in the McLain and Kirkwood study.<sup>5</sup>

Another question that may also be raised concerning the observed overreading by family physicians is whether these apparent errors are indeed true errors. What may appear to be overreading by the family physician, when compared with the radiologist, may actually represent underreading on the part of the radiologist. The clinical data obtained by the family physician may actually sharpen his or her diagnostic skills when interpreting subtle radiographic findings. For example, the family physician knows whether and where rales were heard in examining a child with cough and fever. A diagnosis of pneumonia on a chest film read by the radiologist as normal may indeed be more accurate. The same may be true for diagnosing subtle extremity fractures. Knowing exactly where the limb hurts and where it is swollen may aid the diagnosis of a nondisplaced fracture on the radiograph. The educational literature does indicate that providing more data to an individual prior to solving a problem increases his or her likelihood of selecting the correct answer.

Indeed, radiologists themselves often request clinical information to assist their interpretations. Current evidence from the radiology literature indicates that film interpretations are more accurate when radiologists have access to the patient's clinical history,<sup>11</sup> because it helps them to judge more accurately which ambiguous features of the film should or should not be reported.<sup>10</sup> The ideal interpretation setting for the radiologist, according to Berlin,<sup>12</sup> is to "study a radiograph for five to ten minutes, review the patient's medical history and physical and laboratory findings, consult the attending physician, and finally examine the patient before rendering his decision." Family physicians may reverse the order in this sequence of evaluation, starting with the patient's examination, but all the evaluative elements are there. It is probable, there-

fore, that the family physician's clinical setting actually places him or her in the ideal position to read the office radiograph.

Another important observation concerning the discordancies observed in this study is that very few (0.8 percent of all radiographs) involved disagreements that potentially could alter patient management or outcome. This rate is better than that observed from the emergency room studies reported, and it is better than the 1.7 percent "significant misses" between radiologists noted in the investigation of Delacy et al.<sup>4</sup> In fact, all error rates between nonradiologists and radiologists in the outpatient setting are significantly lower than previously reported error rates of 10 percent to 40 percent between experienced radiologists.<sup>7,8,13-16</sup>

Why the significant discordancy rates were so low in this study, compared with previous reported data, is unclear. Several possibilities may be considered, however. This study is the first to evaluate radiographs in the primary care office setting. That setting may be different in many respects from the hospital setting. The range of pathology to be found may be more limited. There may also be a greater number of films that are normal, without significant pathologic findings. Both of these factors would lower the degree of difficulty rating for interpretation. More radiographs may also be done to confirm clinical findings. The family physician therefore approaches the film with a high expectation of what will be found.

In addition to the low rate of significant misses found in this study, none of the radiographs with a significantly discordant interpretation would have escaped detection, as was noted in Mucci's investigation.<sup>3</sup> In that study significant discordancies, representing 1.2 percent of all radiographs evaluated, would have remained undiscovered had the emergency room physician had the option of referring only selected radiographs to a radiologist. In the present study, all radiographs with a significant discordancy were chosen by the family physician for a referral reading. No patient problem escaped detection.

When patient outcomes from the four significantly discordant x-ray films were evaluated, in only one case would the correct interpretation have affected management, perhaps by insistence on immediate admission (which was advised on a clinical basis) for further diagnostic study.

The voluntary referral rate of 44.1 percent for radiographs in this study is high when compared with referral rates previously identified for physicians whose practice is to send only selected radiographs to a radiologist for a referral reading. In the previously cited study of community practice,<sup>1</sup> 76 percent of those who refer only selected films referred 25 percent or less of their office radiographs, with 69 percent referring 10 percent or less. The higher referral rates observed in this study may relate to the educational nature of the clinics studied. The res-



idency training nature of the clinics may affect the referral rate in several ways: (1) As part of the learning process, residents may be appropriately requesting a radiologist's reading to support their own opinion if they are somewhat insecure. (2) Residents may also be requesting an interpretation to obtain evaluative feedback for educational purposes. (3) Because referral to a radiologist is a routine event in all clinics, as discussed in the Methods section, it has become part of the residents' practice style and may be creating a response bias in favor of referral.

Although differences between residents on referral by year of training failed to reach statistical significance, as did differences in interpretive accuracy, the pattern of decreasing referral rates from 49.1 percent in first-year residents to 41.2 percent in third-year residents again suggests a natural maturational process in perceived confidence with interpretive capability. Lack of statistical significance may again relate to the power of the study with inadequate numbers.

Potential methodologic weaknesses must also be considered when interpreting these results. If any of the interpreters were aware of the interpretations of others, their own interpretation may have been influenced. Care was taken, therefore, to ensure that each interpreter—the resident, the perceptor, the radiologist, the follow-up radiologist—was blinded from any other interpretations. Potential bias may also have existed with each reviewer who evaluated the concordance or discordance of the radiographic interpretations. A second evaluation by another reviewer, with subsequent discussion of differences, was done to minimize this bias possibility. Another concern involves the issue of how many interpreters need to agree before one can say that concordance has been reached. The definition of concordance was based on the agreement of two out of the three reviewers. The final problem relates to the question of who sets the "gold standard" with which interpretation accuracy can be judged. As long as error rates exist between radiologists, their readings are not absolute. Demonstrating error rates that are as good as or better than radiologists' rates is therefore the measure relied on to demonstrate competency.

In summary, the results of this study support the belief that family physicians can capably read radiographs obtained in their offices. In the outpatient setting, the family physicians' rate of missing significant problems (0.8 percent) is as good as or better than the previously recorded rate between radiologists (1.7 percent). Furthermore, the family physicians in this study were able to detect accurately those films that benefited from referral to a radiologist: all radiographs with significant discordancies (only four films) were selected for referral. No patient problem escaped detection. Patient care, therefore, was not com-

promised by having family physicians read all of the office radiographs and refer only those films that they felt needed a referral reading.

By defining the level of family physician competence in reading office radiographs, this study strengthens the position of those family physicians previously cited<sup>1</sup> who hold that office radiograph interpretation is a fundamental clinical skill of the family physician, that family physicians should be trained to read 90 percent of their office films, and that radiologists should be used as consultants on the basis of identified need, as other consultants are used. Because the results of this study were obtained in a residency practice setting, however, they may not be generalizable to community practice. Further study of the family physicians' interpretive accuracy in reading office radiographs is needed in that setting as well.

## References

1. Halvorsen JG, Kunian A: Radiology in family practice: Experience in community practice. *Fam Med* 1988; 20(2):112-117
2. Fleischer G, Ludwig S, McSorley M: Interpretation of pediatric x-ray films by emergency department pediatricians. *Ann Emerg Med* 1983; 12:57-62
3. Mucci B: The selective reporting of x-ray films from the accident and emergency department. *Injury* 1983; 14:343-344
4. Delacy G, Barker A, Harper J, et al: An assessment of the clinical effects of reporting accident and emergency radiographs. *Br J Radiol* 1980; 53:304-309
5. McLain P, Kirkwood CR: The quality of emergency room radiograph interpretations. *J Fam Pract* 1985; 20:443-448
6. Strasser RP, Bass MJ, Brennan M: The effect of an on-site radiology facility on radiologic utilization in family practice. *J Fam Pract* 1987; 24:619-623
7. Herman PG, Hessel SJ: Accuracy and its relationship to experience in the interpretation of chest radiographs. *Invest Radiol* 1975; 10: 62-67
8. Herman PG, Gerson DE, Hessel SJ, et al: Disagreements in chest roentgen interpretation. *Chest* 1975; 68:278-282
9. Rhea JT, Potsaid MS, DeLuca SA: Errors of interpretation as elicited by a quality of care audit of an emergency radiologic facility. *Radiology* 1979; 132:277-280
10. Swenson RG, Hessel SJ, Herman PG: Omissions in radiology: Faulty search or stringent reporting criteria? *Radiology* 1977; 123: 563-567
11. Schreiber MH: Clinical history as a factor in roentgenogram interpretation. *JAMA* 1963; 185:399-401
12. Berlin L: Does the "missed" radiographic diagnosis constitute malpractice? *Radiology* 1977; 123:523-526
13. Garland LH: On the scientific evaluation of diagnostic procedures. *Radiology* 1949; 52:309-327
14. Groth-Peterson E, Lovgreen A, Thillemann J: On the reliability of the reading of photofluorograms and the value of dual reading. *Acta Tuberc Scand* 1952; 26:13-37
15. Yerushalmy J: The statistical assessment of the variability in observer perception and description of roentgenographic pulmonary shadows. *Radiol Clin N Am* 1969; 7:381-392
16. Yerushalmy J, Harkness JT, Cope JH, et al: Role of dual reading in mass radiography. *Am Rev Tuberc* 1950; 61:443-464