Chapter 35. Reducing Errors in the Interpretation of Plain Radiographs and Computed Tomography Scans

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Background

Misinterpretation of radiographic studies is a common source of medical error in both the inpatient and outpatient arenas.[1,2] Of particular concern is the significant number of misinterpretations of plain radiographs and cranial computed tomography (CT) scans in emergency departments (ED) or urgent care settings by non-radiologists.[3-6] The prevalence of this patient safety issue may result from the large volume of patients receiving these radiologic tests, which are often done outside normal working hours when radiologists are not available to provide an initial interpretation. This chapter focuses on practices to reduce non-radiologists' higher rates of misinterpretation of these commonly ordered studies.

Intuitively, it would seems that institutions could minimize the number of such mistakes by routinely having studies interpreted by the most accurate and experienced physicians, usually radiologists. The American College of Radiology (ACR) recommends that all imaging procedures culminate in a written, expert opinion from a radiologist or another licensed physician specifically trained in diagnostic radiology.[7,8] However, due to the associated costs, fewer than 20% of hospitals have full-time on-site coverage by a board-certified radiologist.[9] Instead, radiologists are generally available for 8 to 12 hours a day and may not provide an interpretation until the following morning, particularly when studies are performed after normal working hours.[9] For many routine examinations, it may be possible to delay interpretation without harm to patients. If results are needed urgently and a radiologist is unavailable, other physicians (eg, emergency physicians, hospitalists, neurologists) must take responsibility for the initial interpretation.

Patient safety may be enhanced by improving the diagnostic accuracy of these physicians or by implementing other systems to prevent initial misinterpretations from adversely affecting patient care. Several strategies reviewed here that may be effective in reducing these errors include educational courses to improve the diagnostic accuracy of non-radiologists, on-site coverage by radiology residents, and mandatory subsequent reinterpretation of studies by radiologists.

Another approach that deserves mention is to have the initial readings made by off-site radiologists or other specialists using a *teleradiology link*. Teleradiology has been effective in facilitating emergent neurosurgical consultation prior to the interhospital transfer of patients with head injury.[10-12] Teleradiology also allows rural physicians to obtain remote consults for selected patients,[13-16] which in one report led to treatment changes in 26% of cases.[17] Despite teleradiology's impact in these two specific settings, few studies have tested its accuracy and utility in more general circumstances.[18] Teleradiology of course requires the use of digitized rather than film-based radiographs. In two mixed case series, discrepancies of interpretation between digitized and original radiographs occurred in approximately 10% of cases,[13,14] with significant discrepancies in 1.5-5%.[19,20] For more subtle findings the sensitivity of on-screen images may be as low as 49%,[21] leading several investigators to conclude that teleradiology is inferior to film interpretation for difficult cases.[21-23] At present, it appears that image quality is the major reason behind the variable performance of teleradiology. Although the ACR has established detailed standards for equipment and image resolution,[24] radiology practices often utilize less expensive alternatives for viewing images, including personal computers.[23,25,26] The variation in practice, rapid evolution of technology, and lack of large prospective trials make it difficult to examine teleradiology from the standpoint of patient safety. Therefore, this chapter will not discuss teleradiology in detail; reviews can be found elsewhere.[27-30]

Interventions to improve the technical quality of imaging studies, such as ensuring proper patient positioning and film exposure, are certainly important but are also outside the scope of this chapter. Finally, although radiologists make mistakes in interpreting films,[31-37] this chapter focuses on practices to reduce the higher rate of misinterpretations made by non-radiologists.

Practice Descriptions

Training Courses

Training courses for non-radiologists are presumably common, but we could locate only 2 descriptions in the literature.[38,39] Both courses concerned interpretation of cranial CT scans, were conducted by radiologists, and targeted ED residents and faculty physicians. The training lasted 1-2 hours and consisted of a review of neuroanatomy and a small library of CT scans. Two continuous quality improvement initiatives were also recently described, in which radiologists provided regular feedback to ED physicians about their radiograph interpretations.[40,41]

Initial Interpretations by Radiology Residents

Initial interpretation of ED films by radiology residents follows no standardized practice. Their hours of coverage and the degree to which they interact with ED physicians vary widely.[42] It is also unclear to what extent emergency physicians rely on the resident interpretations when they are available.

Review of All Studies by Radiologists

Reinterpretation of all studies by a radiologist is already commonly used. When a radiologist finds that a study was initially misinterpreted, the medical error has already occurred. In this case, the safety practice concerns how the radiologist communicates the corrected interpretation to providers in order to minimize the risk of harm to patients. The method of communication varies among health care facilities and includes placing the interpretation in the patient's medical record, sending a report to the referring physician, or contacting the physician or patient directly for more urgent concerns (see also Subchapter 42.4).[7]

Prevalence and Severity of the Target Safety Problem

Many investigators have focused on the prevalence of <u>all</u> ED readings that are discordant with radiologists' subsequent interpretations (with the radiologists' interpretation assumed to be the "gold standard"). Against this standard, ED physicians and residents misinterpret 1-16% of plain radiographs[43-51] and approximately 35% of cranial CT scans.[52] However, many discordant readings involve subtle or incidental findings that are not clinically significant (ie, they do not affect patient management or outcome). From the standpoint of patient safety, it is the rate of clinically significant misinterpretations and related errors in management that are of concern.

Most ED studies show that important errors in interpretation occur in 1-3% of plain radiographs.[40,43,46-51] However, one pediatric study calculated a 6.8% rate of significant radiograph misinterpretation.[53] The most common error is failure to recognize an extremity fracture.[43,46,51,54] Lufkin and colleagues examined the readings of 16,410 consecutive radiographs and the effect of emergency physicians' confidence on the accuracy of their interpretations.[55] When ED physicians were confident in their interpretation, the rate of discordant readings was 1.2%. More importantly, the rate of clinically significant errors was only 0.1%.

Rates of misinterpretation are even higher for CT scans. In one study, ED residents and attending physicians overlooked new infarcts, mass lesions, and cerebral edema, as well as parenchymal, subarachnoid, and subdural hemorrhages.[52] The rate of clinically important errors was 20-25%, with failure to recognize a cerebral infarction the most common.[52] It is unclear how many patients had adverse outcomes as a result, but the authors estimated that less than 1% of patients were managed inappropriately by ED staff.[52] Other studies confirm that the radiographic accuracy of non-radiologists in detecting a major cerebral infarction is poor, with misinterpretation rates of 30-40%.[56-59] This may directly impact patient outcomes since management of suspected stroke, specifically determining eligibility for thrombolytic therapy, requires an immediate and accurate interpretation of the CT. In addition, intraobserver and interobserver reliability are fair to poor, with kappa (κ) values ranging from 0.41-0.20.[57,59]

Radiology residents have better accuracy in interpretation of cranial CT scans, though not as high as that of certified radiologists. As part of a departmental quality control program, Lal and colleagues found the rate of significant misinterpretations by radiology residents was 0.9%.[60] Roszler et al reported moderate or major errors in 2.1% of resident interpretations of post-traumatic head CT scans.[61] Wysoki and colleagues[62] found that major discrepancies between the interpretations of residents and staff radiologists occurred in 1.7% of neuroradiologic studies and that the rate was significantly higher when CT scans were abnormal rather than normal (12.2% vs. 1.5%). Residents missed 9% of intracranial hemorrhages and 17% of cranial or facial fractures.

Opportunities for Impact

The accepted standard of care, supported by the ACR, calls for routine review of all radiologic studies by a radiologist or other qualified physician in a timely fashion.[8] Given the available data on staffing patterns,[9] we estimate that on-site radiologists are available to interpret radiographs about half the time. Radiologists generally read any remaining studies the following day. In academic centers, the percentage of films initially interpreted by residents may range from 20% to 100%, and the availability of on-call residents is highly variable.[42] It is also unclear what proportion of academic and community hospitals provides radiographic training courses for non-radiologists.

Study Designs

Few studies specifically focus on methods to reduce clinically significant misinterpretations of radiographs and CT scans. No randomized trials have evaluated the effectiveness of the 3 patient safety practices identified above. Table 35.1 shows 4 prospective before-after studies (Level 2 design) of educational interventions and quality improvement initiatives.[38-41] Evidence for the other 2 strategies (initial interpretations by radiology residents and review of all studies by radiologists) is limited to descriptive studies reporting rates of discordant interpretations for various groups of physicians (see above).

Study Outcomes

Most studies reported the rate of clinically significant misinterpretations (Level 2 outcome).[38,40,41,53,55,63] However, the definition of "clinically significant" was subjective and varied among reports. One trial reported only the percentage of correct CT interpretations (Level 3), without describing the significance of specific errors.[39]

Evidence for Effectiveness of the Practices

Levitt and colleagues[38] found a significant improvement in cranial CT scan interpretations by ED physicians after a one-hour training course. However, there were several limitations of this study. The intervention was not tested before implementation, raising concerns regarding its reliability and reproducibility. Previously published research at the same institution showed a 38.7% misinterpretation rate of cranial CT scans by ED physicians.[39] Because physicians were aware of these results, they may have engaged in their own efforts that led to improvement in CT scan interpretation. The improvement might also be explained by significant changes in case-mix, which was not measured. A multicenter study by Perron et al[39] showed that a reproducible educational course significantly improved residents' ability to interpret CT scans. However, the study is limited by possible selection bias (participation in the course was voluntary; post-test data were obtained in only 61 of 83 subjects). Although subjects in the study by Perron were retested after a 3-month washout period, neither course has been shown to result in sustained improvement. Quality improvement programs such as those described by Espinosa and Preston[40,41] successfully reduced the rate of misinterpreted radiographs and number of callbacks, respectively. Through ongoing feedback and review of misinterpreted radiographs, Espinosa and colleagues lowered the rate of important errors from 3% to 0.3%, a relative risk reduction of 90%. The initiative described by Preston led to a 42.9% relative reduction in callbacks to the ED, although the absolute magnitude was less impressive (0.3% absolute risk reduction).

We found no studies that compared the readings of ED physicians with those of radiology residents in a real-world environment. Only one investigation compared their diagnostic skill in an experimental situation.[18] Eng and colleagues exposed 4 groups of physicians (ED attendings, ED residents, radiology attendings, and radiology residents) to a series of 120 radiographs and calculated their receiver operating characteristic (ROC) curves. The radiographs were selected for their difficulty, and ED physicians had previously misinterpreted many of them. The area under the ROC curve was 0.15 higher for radiology faculty than for ED attendings (95% CI: 0.10-0.20) and 0.07 higher for all faculty than all residents (95% CI: 0.02-0.12). Compared with ED faculty, radiology residents had an additional area under the ROC curve of 0.08 (95% CI: 0.02-0.14).

Potential for Harm

There is a potential for both radiologists[51] and non-radiologists[64] to overread films (ie, falsely identify non-existent findings), which may result in unnecessary diagnostic testing or treatment. Since the vast majority of this literature considers the radiologist's reading to be the gold standard, the proportion of discrepancies in interpretation that are due to false-positive readings by radiologists is unclear.

Costs and Implementation

Only one study reported the costs of false-positive readings by ED physicians, which averaged $85 per false-positive radiograph.[64] Given the paucity of research, it is not possible to estimate the costs of implementing universal review of emergency films by an on-site radiologist. Finally, no studies have measured the costs of misreads to the patient and health care system (eg, transportation, return visits, repeat or unnecessary studies, unnecessary medications) which could potentially offset staffing costs. The marginal costs of after-hours staffing alone may be prohibitive, especially for low-volume sites. No information is available to estimate the cost of establishing a high-quality teleradiology program, or of educational programs for ED physicians or trainees.

Comment

The rates of misinterpreted radiographs and CT scans are high in many studies. Of particular concern is the 20-25% rate of clinically significant errors in reading cranial CT scans, even among experienced emergency physicians and neurologists. Although plain films are correctly interpreted more than 90% of the time, even "low" error rates of 1% or less are important given the sheer number of films.

The relative roles of ED physicians, radiology residents, certified radiologists, and other physicians will depend on their accuracy and their cost. The literature is notable for the relative dearth of studies of interventions to reduce radiologic misinterpretation by non-radiologists, even though dozens of studies have documented the problem. Where radiographs must be interpreted by non-radiologists, there is limited evidence that brief educational interventions and continuous quality improvement programs improve diagnostic accuracy. (Chapter 54 reviews general issues surrounding changing practice behavior through education.) It is possible that radiologists' routine review of plain radiographs may not be cost-effective when the non-radiologist clinician has a high level of confidence in the initial interpretation, but this has not been rigorously established. Coverage by radiology residents may add back-up accuracy to the reading of an ED attending, but Eng's study was biased toward a difficult set of radiographs that had previously been misinterpreted by emergency physicians.[18] The added value of a radiology resident's interpretation may be much lower in actual practice.

One avenue of research that could yield effective safety practices is human resource management. Essentially, staffing could be optimized such that specific tests could be triaged to the individual with the highest diagnostic accuracy. This kind of intervention would require assessment of both potential coverage gaps and the skill mix of the available labor force. A formal protocol might be developed and tested to identify coverage vulnerabilities and develop realistic coverage options based on measured performance of the available personnel at a particular site. While the value of this strategy is entirely speculative, it draws on general management science and could be explored more explicitly in health care.

Table 35.1. Educational interventions for non-radiologists*

Study	Study Setting	Intervention	Study Design, Outcomes	Results†
Levitt, 1997[38]	14 ED physicians at a level 2 trauma center in California	One-hour course on cranial CT interpretation	Level 2, Level 2	Clinically significant misinterpretations decreased from 23.6% to 4.0% (ARR 19.6%, RRR 83%)
Espinosa, 2000[41]	ED physicians at an academic hospital in New Jersey, 1993-99	Training on plain radiograph interpretation and ongoing feedback from radiologists about their errors	Level 2, Level 2	Clinically significant false negative interpretations: from 3% to 0.3% (ARR 2.7%, RRR 90%)
Preston, 1998[40]	ED physicians and radiologists at a 150-bed community hospital in Louisiana, 1990-95	Continuous quality improvement initiative with regular review of film discrepancies	Level 2, Level 2	Patient callbacks to ED for clinically significant misinterpretation: from 0.7% to 0.4% (ARR 0.3%, RRR 42.9%)
Perron, 1998[39]	83 ED residents at 5 academic centers in the southeast US, 1997-98	Two-hour course on neuroanatomy and cranial CT interpretation	Level 2, Level 3	Correct interpretation of a series of 12 CT scans: baseline 60%; 3 months after the course, 78% ($p<0.001$ for difference)

* ARR indicates absolute risk reduction; ED, emergency deparment; and RRR, relative risk reduction.
† Results reported as change from baseline to after intervention.

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