AJR FOCUS ON:

Interpretive Error in Radiology

Stephen Waite[1]
Jinel Scott
Brian Gale
Travis Fuchs
Srinivas Kolla
Deborah Reede

OBJECTIVE. Although imaging technology has advanced significantly since the work of Garland in 1949, interpretive error rates remain unchanged. In addition to patient harm, interpretive errors are a major cause of litigation and distress to radiologists. In this article, we discuss the mechanics involved in searching an image, categorize omission errors, and discuss factors influencing diagnostic accuracy. Potential individual- and system-based solutions to mitigate or eliminate errors are also discussed.

CONCLUSION. Radiologists use visual detection, pattern recognition, memory, and cognitive reasoning to synthesize final interpretations of radiologic studies. This synthesis is performed in an environment in which there are numerous extrinsic distractors, increasing workloads and fatigue. Given the ultimately human task of perception, some degree of error is likely inevitable even with experienced observers. However, an understanding of the causes of interpretive errors can help in the development of tools to mitigate errors and improve patient safety.

Error in diagnostic interpretation is an unfortunate and common occurrence exacerbated by the increasing demands placed on radiologists. In this article, we discuss how humans search scenes, the definition and cause of interpretative error, mitigating factors, and potential solutions.

Definition

When discussing error in diagnostic interpretation, it is important to distinguish between an error and observer variation. Radiology often involves decision-making without clear clinical presentations and imaging appearances that are not always diagnostic of a particular diagnosis. Therefore, the interpretation of a radiologic study is usually not a binary process (normal or abnormal) [1].

Interpretive error can be defined as an incorrect interpretation. However, because of the subjective nature of radiology, the definition of what is erroneous is established by expert opinion. In a true error, the discrepancy is substantially different from the consensus of one's peers [2].

Acceptable observer variation occurs when there is a legitimate difference of opinion about the correct interpretation [3, 4]. Somewhere between a clearcut error and the inevitable difference of opinion in interpretation is an arbitrary division defining the limit of professional acceptability [1].

Medical Error

In a 1999 report, the Institute of Medicine (IOM) estimated that 44,000–98,000 people die in U.S. hospitals each year as a result of preventable errors [5]. The IOM is considered to have underestimated the severity of the problem. More recent analysis based on subsequent studies calculated a mean rate of death from medical error of more than 251,000 patients per year, which suggests that medical error is the third most common cause of death in the United States after cancer and heart disease [6]. Radiologists' diagnostic interpretations have a tremendous impact on diagnostic error rates resulting from delayed or erroneous diagnosis [7].

Radiologic Interpretative Error

In 1949, Garland [8] found a 33.3% error rate in the interpretation of positive films based on group consensus opinion and an 8% intrareader variation (when a reader disagrees with him- or herself when rereading a study). This rate of error has remained virtually unchanged. In a mix of abnormal

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[1]All authors: Department of Radiology, SUNY Downstate Medical Center, 450 Clarkson Ave, Brooklyn, NY 11203. Address correspondence to S. Waite (stephen.waite@downstate.edu).

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and normal studies representative of a typical clinical practice, the error rate is approximately 4% [7, 9]. Because 1 billion radiographic examinations are performed worldwide annually, a 4% error rate translates into approximately 40 million interpretive errors per year [2].

Fortunately, most errors are minor or, if significant, are found and corrected quickly enough to avoid serious harm to the patient. However, many interpretation errors do result in harm to patients and can be a humbling and frustrating experience for radiologists [10].

Despite advances in imaging technology, there is no evidence of improvement in the perceptual abilities of the human eye and brain [11]. Given this human limitation, many of the solutions developed to decrease interpretive error are technology based.

Cause of Interpretive Error

Perceptual errors account for 60–80% of interpretive errors, with variation depending on the modality and specific scenario (e.g., outpatients vs emergency patients) [12, 13]. Because the first step in image interpretation is detection, an error in perception can prematurely end the diagnostic process and lead to missed diagnoses [14]. For an interpretive error to be considered a perceptual error, the finding should be sufficiently conspicuous and detectable in retrospect by interpreting radiologists or in the consensus of their peers [2]. Not all subtle and insubstantial findings subsequently found to represent a pathologic process are therefore considered perceptual errors [2].

The intrinsic characteristics of lesions influence their detectability or conspicuity and depend on the physical properties of the lesion and its surrounding structures. Contrast is a composite property of the lesion and its surroundings. The greater the difference between the two, the better the lesion visibility [15]. Small nodule size, low lesion attenuation, and ill-defined margins are low-conspicuity characteristics on chest radiography [16].

In addition to intrinsic lesion characteristics, there are a number of both intrinsic and extrinsic factors that can contribute to the likelihood of an interpretative error (Fig. 1).

Scene Processing

Knowledge of how humans analyze and process scenes is required to understand perceptual and interpretive error. When scanning the environment, the eyes make jerky movements called "saccades" interleaved with fixation periods [17]. Frequent saccades are made to capture detailed snapshots with the fovea (the central part of the retina), which has sufficient photoreceptor density to provide high-resolution vision [17]. Vision depends on information obtained during fixation pauses between saccades because no useful visual information is obtained while the eyes undergo saccades [18].

It is postulated that when analyzing a radiologic study, there is rapid identification of abnormalities using peripheral vision with subsequent scrutiny utilizing central vision [19]. Radiologists compare this "gist" impression with information contained in long-term memory that forms the viewer's cognitive schema (or expectations) of what information is in an image. This rapid response is shown when a radiologist identifies subtle abnormalities on mammography and chest radiography in only 250 ms [20–23].

A second systemic scan then occurs, allowing specific object recognition using central foveal vision [22]. Features are examined closely and are tested against the cognitive schema to determine whether a finding is suspicious. Decisions are made once image features sufficiently match the cognitive scheme of the viewer [23]. This pathway, lasting seconds to minutes, is capacity-limited and is the bottleneck of attention [19, 22].

Omission Errors

Eye-tracking technology has been used to classify omission or false-negative errors into three categories on the basis of fixation times on missed lesions: search, recognition, and decision-making.

Search Error

This type of error occurs when the observer never fixates on the lesion with high-resolution foveal vision precluding processing [24–26] (Figs. 2 and 3).

Recognition Error

A recognition error is a failure of the basic mechanism of object recognition; the radiologist fixates on the target for a duration shorter than the threshold dwell time considered sufficient to recognize lesion features [25]. The threshold for lesion detection depends on the imaging modality and ranges from 500 to 1000 ms [25, 27]. Both search and recognition errors are considered perceptual errors [28].

Decision-Making Error

Decision-making errors occur when a radiologist fixates on the lesion for an extended period of more than 1 second but either fails to recognize concerning features or actively dismisses them [23, 25].

Attention and Perception

Failure of attention is one source of error in radiology. Because humans cannot process everything in the visual field, attention is drawn to objects that have prominent intrinsic features. This is referred to as bottom-up processing. Color, motion, orientation, and size are among the attributes that guide visual search and are called "preattentive," meaning that they are perceived rapidly without any conscious effort [29, 30]. In top-down guidance, the searcher has a representation of a target in mind and directs attention to items that have those features. Learning, memory, attention, and expectation shape this perceptual process. [29]. Scene guidance is learned and is based on the understanding of a scene's contents and layout.

Differences in attentional processing explain the variations in search patterns between experts and novices. Expert radiologists know where to look for nodules, which limits inspection of many irrelevant areas [29]. Other regions may not be scrutinized because they lack concerning preattentive attributes.

Observers can fail to note even seemingly obvious findings that they are not actively paying attention to. To determine whether this phenomenon, termed "inattentional blindness," occurs in expert searchers, Drew et al. [31] created a pixelated gorilla (48 times the size of a 5-mm nodule) with a white outline and inserted it into consecutive CT images while radiologists performed a nodule detection task. Twenty of 24 (83%) radiologists failed to notice the gorilla even though 60% directly fixated on it [31]. Although radiologists outperformed naïve observers (0% detection rate), their 83% miss rate received significant media attention [32, 33]. Inattentional blindness has also been implicated in the failure of 60% of radiologists to notice a missing clavicle on a chest radiograph when denied relevant history. When given the indication that the chest radiograph was part of a metastatic survey, 83% of the observers found the abnormality [34].

Focused attention is considered a fundamental feature of the human brain. It is regarded as an inherent limitation of the human "search engine"; therefore, inattentional blindness cannot be entirely prevented [30].

Cognitive Biases

Cognitive biases are logic fallacies that are often triggered by a particular situation that can lead to error. These biases are largely the result of nonanalytic reflexive thinking and can affect diagnostic interpretation [24, 35–39] (Table 1 and Figs. 4–7).

Satisfaction of Search

Initially characterized as the discontinuation of a visual search once the searcher finds an abnormality and becomes "satisfied" with the "meaning" of an image, satisfaction of search (SOS) occurs when interpreting a number of different imaging modalities [40–43] (Fig. 8).

Since the original 1990 study showing the SOS phenomenon, radiologic imaging has become computer-based to allow greater flexibility in adjusting window and level settings to optimize search. Furthermore, readers are now more aware of the SOS phenomenon. A recent study by Berbaum et al. [44] using modern computed radiography of the chest noted no SOS effect. It is not certain whether there have been similar changes in this effect on other imaging modalities, and further research in this area is needed.

Prevalence Effect

The prevalence effect refers to the relationship between the prevalence of a particular abnormality and observer performance. For example, there may be an increase in false-positives readings on the chest radiographs of known smokers given their increased prevalence of nodules.

Reed et al. [45] found that as the prevalence expectation for nodules increased radiologists had an increase in the number of fixations per image and the overall analysis time increased. These results show a change in visual search in response to prevalence expectations. When Evans et al. [46] manipulated the prevalence levels of breast cancer on mammograms, omission errors increased in the low-prevalence scenario. In conditions of low prevalence, observers are more likely to reject ambiguous findings and terminate a search more quickly [29] (Fig. 7).

External Factors Contributing to Interpretive Error

Clinical History

The presence of clinical history may affect a radiologist's level of interpretive error. Conceptually, clinical information can improve accuracy during both perception and interpretation, focusing perception on an area of interest or changing the level of interpretive suspicion [47]. An argument against providing clinical information is that history could bias radiographic interpretation and cause readers to perceive abnormalities that are not present [47].

There have been a number of studies analyzing the effect of clinical history on interpretive accuracy with conflicting results depending on the particular experimental condition. Doubilet and Herman [48] and Berbaum et al. [49] found increased interpretative accuracy when radiologists were given relevant history. On the contrary, Good et al. [50] found that clinical history had no effect on the accuracy of chest radiograph interpretations. In an analysis of 16 articles comparing the accuracy of tests with and those without clinical information, Loy and Irwig [47] found that clinical information improves interpretive accuracy through improved sensitivity without a loss of specificity consistent with readers being alerted to additional imaging features rather than merely altering their level of suspicion. Leslie et al. [51] found that providing clinical history resulted in changes in 19% of CT reports with more than half being major.

Accurate clinical information also ensures that the appropriate study is performed, helps radiologists avoid spending time and effort searching for findings irrelevant in the clinical context, and facilitates optimal diagnostic workup [4, 37]. These factors alone outweigh any potential bias from knowledge of the clinical scenario [4]. Moreover, no proven deleterious effect has been documented by providing an accurate clinical history [47].

Fatigue and Error

Krupinski et al. [52, 53] found increased subjective fatigue and decreased accuracy on both conventional radiography and CT interpretation after a day of reading. Specific work shifts may exacerbate interpretive error rates. Although there is minimal research regarding the effects of after-hours work (usually defined as between 5 pm and 8 am) on interpretative accuracy, there is concern that circadian misalignments during these shifts can result in sleepiness and chronic fatigue and adversely affect performance [54].

Workload, Interpretative Speed, and Error

McDonald et al. [55] found that the average number of images requiring interpretation per minute has increased nearly sevenfold per radiologist from 1999 to 2010. There

TABLE 1: Cognitive Biases Relevant to Radiology and Corrective Strategies

Cognitive Bias	Description	Corrective Strategies
Anchoring	Failing to adjust initial impression in light of contrary information. Associated with confirmation bias in which clinicians modify interpretation of subsequent information to suit initial predictions to support their hypothesis (Fig. 4).	Seek to disprove initial diagnosis rather than to confirm it. Avoid early guesses and reconsider diagnosis with worsening symptoms.
Framing	Radiologists are influenced by the way a problem is worded or framed. The diagnostic possibilities are mentally restricted by the referral situation (Figs. 4 and 5).	Initially read study objectively without reviewing clinical history. Remember that clinicians may have biases and that even a strongly held clinical interpretation may be incorrect.
Availability	The tendency to consider some diagnoses to be more likely if they readily come to mind. This bias may be especially frequent after a known diagnostic miss (Fig. 6).	Be aware of the tendency to overestimate the frequency of previously missed or memorable cases. Objective information of the true base rate of disease should be used when possible.
Alliterative	Results from the influence radiologists have on each other. Previous interpretations (even from the same reader) influence the interpretation of the current examination (Figs. 7 and 8).	Attempt to increase diagnostic possibilities to break tendency to simply repeat what was previously reported. When possible, read old reports after new interpretation.

Note—These errors occur secondary to mental shortcuts inherent in the heuristic intuitive method of diagnosis. Because these biases are unconscious, they are notoriously difficult to recognize and avoid; however, awareness may decrease susceptibility.

is a concern that this drastic increase in imaging content can increase error secondary to radiologists' fatigue and stress because they may take fewer breaks to keep up with the increased workload [52, 55, 56].

Rapid film interpretation speed can also be a source of error. According to Oestmann et al. [19], the accuracy in lung cancer detection decreases significantly with viewing times of less than 4 seconds. Sokolovskaya et al. [57] reported that when radiologists were asked to interpret studies at twice their baseline speed, the number of major misses increased from 10% to 26.6%. Because reimbursement in many practices is based on productivity, there is a strong financial incentive to read as many studies—without breaks—as possible. A sustained artificially high interpretative rate can result in additional interpretive errors from both general and oculomotor fatigue.

Distractions and Error

Radiologists spend a significant amount of time toggling between medical tasks such as examination interpretation, consulting with referring physicians, and nonmedical functions such as answering telephone calls and returning pages [58]. Multitasking has the potential to introduce errors [59]. Correlating the number of telephone calls received by an overnight on-call resident with resident–attending discordant interpretations, Balint et al. [58] found that in the 1 hour preceding a discordant preliminary report, a single additional telephone call above the baseline increased the odds of a major discrepancy by 12% (Fig. 9).

Role of Specialization

The interplay of the particular imaging modality and the specialty of the interpreter is an additional factor to consider when developing mechanisms to reduce error rates. Several studies show that subspecialists have improved accuracy in their relative fields of expertise compared with general radiologists [60–62].

Potential Solutions

Many of the solutions proposed to reduce interpretative error are technology-based because computers are not subject to human limitations. Other solutions attempt to optimize conditions to facilitate interpretative accuracy. Because diagnostic errors have differing causes, proposed solutions will have different efficacies depending on the particular situation and interpreter.

Nontechnologic Solutions

Structured Reports

Structured reporting was developed to enhance communication with referring physicians and improve interpretative efficiency. A well-constructed structured report template can serve as a checklist that facilitates systematic inspection of relevant anatomy and potentially decreases inattention-related errors [63].

Optimization Ergonomics

Optimal lighting and reduction of physical stressors by optimizing the ergonomics of PACS stations can improve the reading experience and can potentially decrease interpretation errors [64].

Rohatgi et al. [54] describe strategies for radiologists to minimize associated adverse health effects when reading after hours. Suggestions included naps, appropriate light exposure, social interaction, and caffeine [54]. Additional radiology-specific research is needed to understand the role of after-hours coverage on interpretive error and attrition.

Interruption Reduction

Not all interruptions are harmful. Therefore, when designing methods to minimize them, it is important to remember that the goal is not to eliminate all interruptions but to eliminate those that are uninformative and that occur during error-prone scenarios such as during active imaging interpretation [59]. Interruptions may be avoided by providing radiologists access to clinical data at the PACS workstation and portals for referring physicians [59]. Clinical assistants and caller ID systems can further ensure that radiologists attend to distractions that warrant immediate attention.

Double Reading

A long-recognized method to reduce error in interpretation is to have "films interpreted independently by two readers" [8]. Double reading is not practiced consistently in the United States because it is time-consuming and the second read is not reimbursed [65]. Because of the time commitment and lack of financial compensation, double reading should be reserved for complex cases in which a second opinion will provide a substantial benefit. Furthermore, the process must be rapid, and mechanisms to reconcile discrepancies between readers should be clearly defined [66].

Peer Review and Quality Improvement

The traditional punitive approach to quality improvement is to treat all interpretive errors as unique events attributable to individual radiologists. Unfortunately, this model captures only a small fraction of errors and does not result in substantial improvement in overall performance [67]. In an excellent review, Larson et al. [68] outline a modern nonpunitive approach to performance improvement with the expectation that this approach will enable a shift in culture from self-protection to shared responsibility. In this model clinicians may readily disclose even personal mistakes and view feedback as a learning experience [68].

Rosenkrantz and Bansal [13] showed that analysis of report addenda may serve as an additional easily searchable source of error characterization, although it is limited by the fact that these errors were detected and corrected.

Technologic Solutions

Oculomotor dynamics and visual search characteristics can be quantitated and analyzed using eye-tracking technology. Once technologies such as perceptual feedback, attentional guidance, and search pattern analysis become more clinically practical, they can play a prominent role in error reduction. Computer-aided diagnosis and methods of improving lesion conspicuity are other currently available technologic solutions.

Perceptual Feedback

Eye-tracking technology has shown that the average dwell time (i.e., the total fixation time) on false-negative nodules is almost as long as the average dwell time for nodules reported as positive. This suggests that an active decision was made to call the region negative [69, 70]. This understanding led to the development of a perceptual-based method of enhancing nodule recognition in which areas of interest receiving dwell times more than a specified temporal threshold (e.g., > 1 second) are circled, and radiologists are permitted a second look [71]. A 14–16% increase in true-positive nodule detection is seen in readers who received this feedback with no change in specificity [71–73].

Attentional Guidance

Because humans are highly sensitive to other peoples' eye movements, there is interest in determining whether presenting the eye movement patterns of one observer to a subsequent observer improves performance in a range of visual search and problem-solving tasks [74]. Litchfield et al. [74] found that novice radiologists improved performance after watching the search patterns of both experts and novices when they searched for nodules. Subsequent experiments showed that viewing unrelated eye movement patterns did not lead to performance improvement. Therefore, better performance was secondary to guiding the observer toward task-relevant areas. Expert radiologists, however, did not consistently show improvement on nodule search tasks after eye movement previews suggesting that this guidance may be most useful during the early stages of learning before the development of an effective visual search [74].

Search Strategies

Compared with experts, novices have more fixations, saccades, and greater coverage of images despite worse accuracy. Also, a recent study of radiologists at different levels of training showed that improvements in search did not parallel diagnostic accuracy [75]. Additional research can further elucidate optimal training methods and reveal clinically practical interpretation methods to reduce error rates.

Bone Subtraction Techniques

Overlying bones are a major contributor to anatomic noise on chest radiographs and are an important cause of missed lung nodules [76]. Several techniques (software- and hardware-based) have been proposed to suppress overlying bone structures, thereby increasing lesion conspicuity by reducing surrounding anatomic noise [76–78]. Digital removal of bone shows promise because no additional equipment is required and there is no additional radiation exposure. Several studies show a statistically significant increase in observer sensitivity for pulmonary nodules and infections of up to 17% [76, 79, 80] (Fig. 10).

Computer-Assisted Detection

Computer-aided detection (CAD) refers to pattern recognition software that flags suspicious features on an image in an attempt to decrease false-negative readings [76, 81]. The radiologist reviews the examination and the CAD-marked areas of concern before issuing a final report [81] (Fig. 10). CAD systems do not mark all actionable findings; therefore, the absence of a CAD mark on a finding should not preclude evaluation. In addition, current CAD systems generate more false findings than true findings. The radiologist must determine whether a CAD mark warrants further evaluation [81]. The difficulty in discriminating between true- and false-positive marks is the biggest current challenge in CAD software. CAD is currently used and studied most widely in mammography but is also used in chest imaging and other modalities.

Chest imaging—CAD in chest imaging has improved significantly since its inception. The number of false-positive marks on chest radiographs has decreased from 15 per image in the 1970s to 1.3 per image in 2015 [76, 82].

There have been fewer studies assessing the utility of CAD for chest CT interpretation. White et al. [83] found a 1.9% increase in accuracy for readers using CAD on chest CT examinations.

CAD has been advanced as a “second reader” for acute clinical scenarios when the focus of attention may be on more critical findings and for high-demand readings such as lung cancer screening [83–85].

Mammography—There is a long history of CAD use in mammography with mixed results. Initial studies were promising and led to U.S. Food and Drug Administration approval in 1998. More recent studies, however, question its clinical utility. In 2007, Fenton et al. [86] found no improvement in sensitivity in facilities using CAD and a significant decrease in positive predictive value. Lehman et al. [87] in 2015 corroborated those findings and noted that diagnostic accuracy did not improve with CAD on any performance metric (sensitivity, specificity, or overall cancer detection rate). Therefore, CAD in mammography is associated with an increased rate of harms associated with screening including higher recall and biopsy rates and is of unclear clinical benefit [86].

Summary

Radiologists use visual detection, pattern recognition, memory, and cognitive reasoning to synthesize final interpretations of radiologic studies. This synthesis is performed in an environment in which there are numerous extrinsic distractors increasing workloads and fatigue. Given the ultimately human task of perception, some degree of error is likely inevitable even with experienced observers. However, an understanding of the causes of interpretive errors can help in the development of tools to mitigate errors and improve patient safety.

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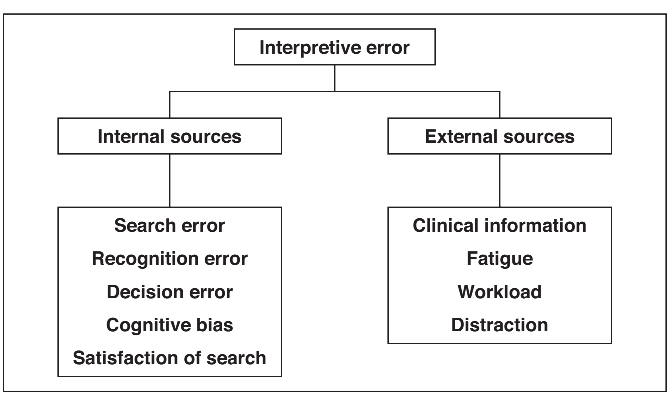


Fig. 1—Diagram shows diagnostic interpretive error and common mitigating factors: internal and external sources.

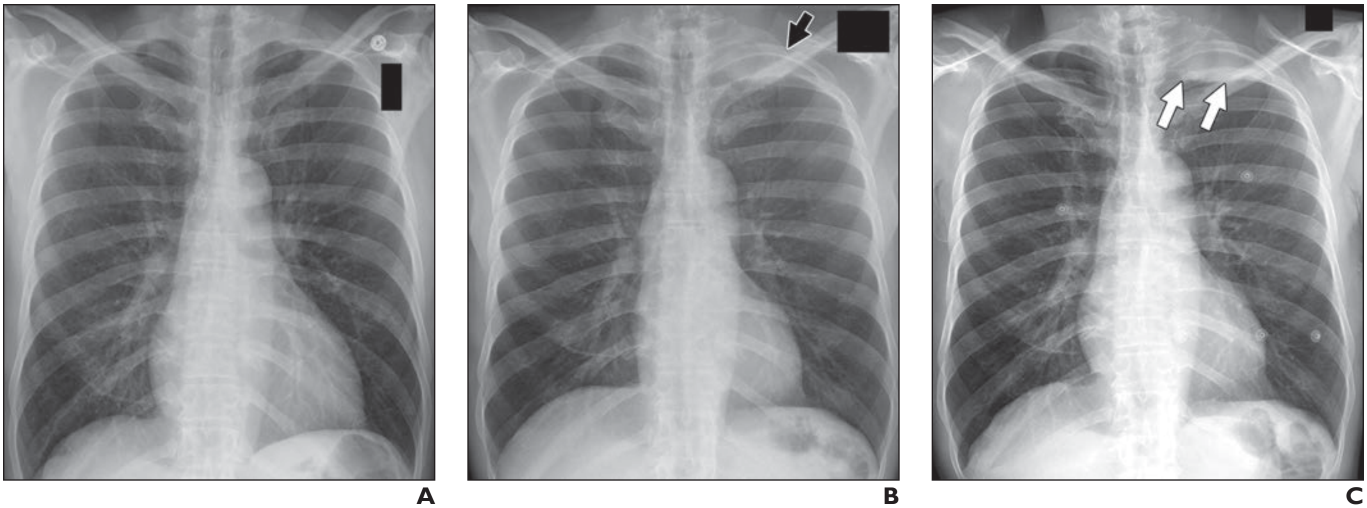


Fig. 2—70-year-old man with no significant medical history.
A, Search-related omission error. Routine chest radiograph was correctly interpreted as normal.
B, Search-related omission error. Patient presented 8 months later with complaints of left arm pain. Chest radiograph was interpreted as normal; however, left apical mass (*arrow*) was missed. Apices are common blind spot in interpretation, and radiologist reported not looking in this region.
C, Discrimination error. Patient presented 1 month after **B** with persistent symptoms. Chest radiograph interpreted as “unchanged left apical pleural-based opacity, likely pleural thickening.” However, opacity (*arrows*) is larger compared with size on prior examination (**B**), is markedly asymmetric, and has convex borders suggestive of malignancy. This is example of discrimination error rather than omission error because finding was noted but was incorrectly interpreted. Imaging performed 3 months later (not shown) showed further interval growth with bone destruction. Pathologic diagnosis was squamous cell carcinoma, Pancoast tumor.

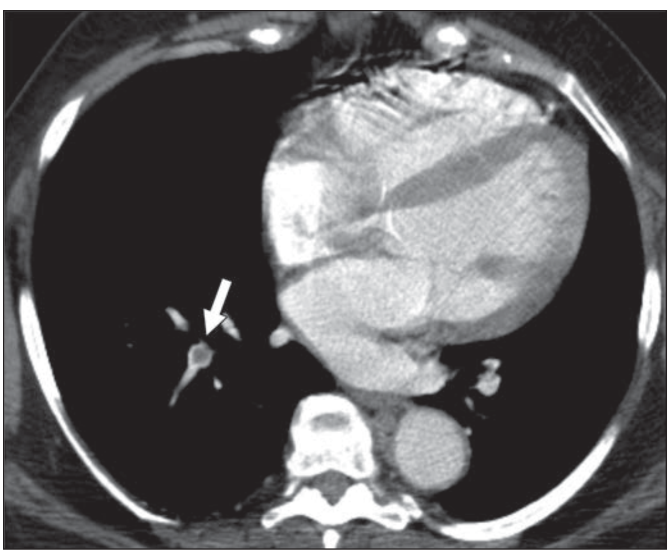


Fig. 3—Search error. Abdominal CT scan of 53-year-old man who presented with abdominal pain shows pulmonary embolus (*arrow*) in right lower lobe overlooked on interpretation. Abnormalities of lung bases are commonly missed on abdominal CT because they are not primary target of examination.

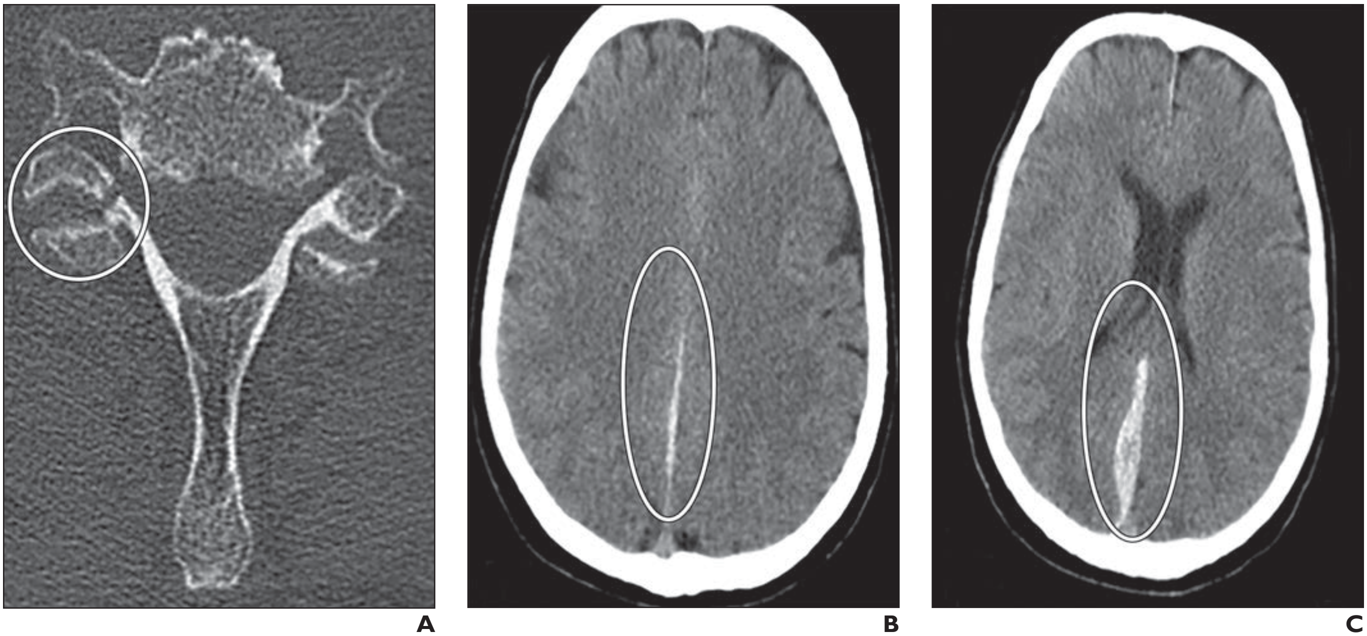


Fig. 4—Cognitive error due to anchoring and framing biases.
A–C, Axial CT images of cervical spine (**A**) and head (**B** and **C**) of trauma patient (72-year-old man). Emergency department provider insisted patient was asymptomatic (anchoring bias), which prompted interpreting radiologist to attribute fracture of right lamina (*circle*, **A**) to sequela of degenerative disease (framing bias). However, on reviewing head CT, which showed interhemispheric subdural hematoma (*ovals*, **B** and **C**), radiologist corrected his report to reflect that this fracture was acute fracture.

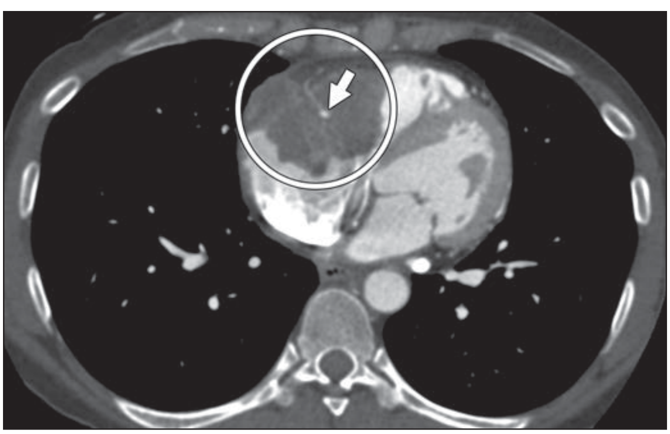
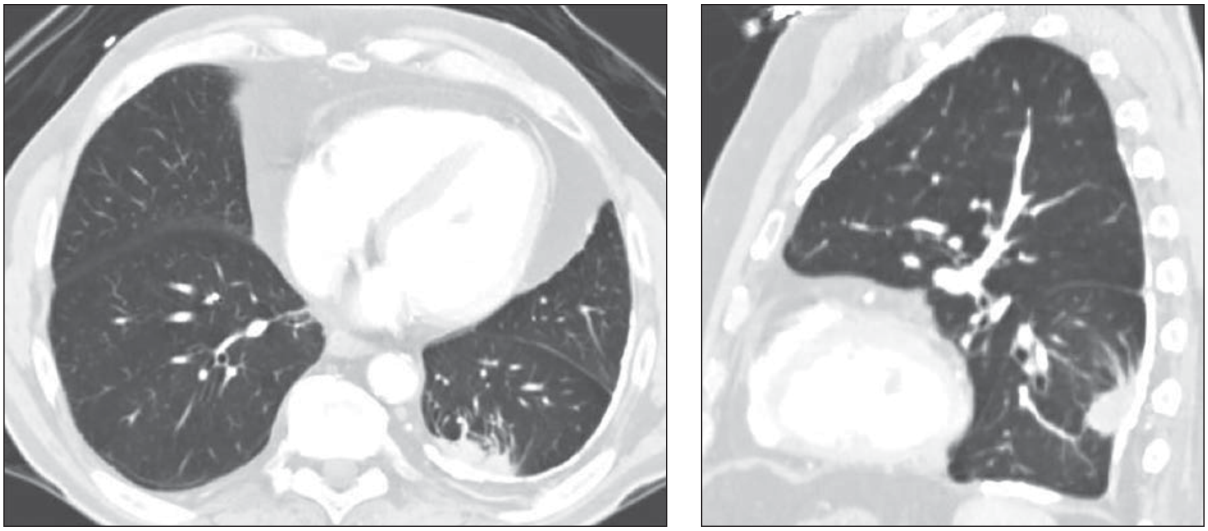
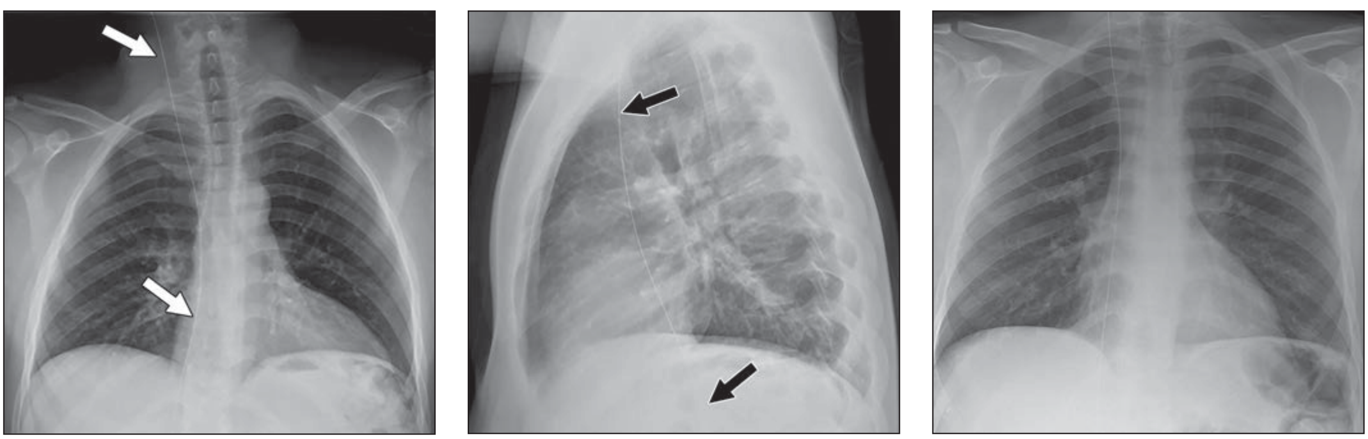


Fig. 5—Search error and framing bias. Clinicians reported high suspicion for pulmonary embolism (PE) in 40-year-old woman with history of cervical cancer and shortness of breath. CT scan was interpreted as negative for PE overlooking intracardiac metastasis (*circle*) crossing between right atrium and ventricle. Note right coronary artery in right atrioventricular groove (*arrow*). Framing bias may have played role in this case because radiologist framed their interpretation around concern for PE.



A B

Fig. 6—Availability bias.
A and **B**, Axial (**A**) and sagittal (**B**) CT images of 50-year-old man with history of nodule seen at left base on chest radiography (not shown). CT study was interpreted as showing left lower lobe subpleural nodule "concerning for neoplasm." However, this nodule shows classic characteristics of round atelectasis. Radiologist reported missing lung cancer day before this interpretation, predisposing her to diagnose lung cancer.



A B C

Fig. 7—Prevalence effect and alliterative error.
A and **B**, Posteroanterior (**A**) and lateral (**B**) chest radiographs of 20-year-old man who presented with cough, fever, and chest pain. Official interpretation was right-sided ventriculoperitoneal (VP) shunt (*arrows*).
C, Repeat posteroanterior chest radiograph obtained weeks after **A** and **B** was interpreted as "unchanged right-sided VP shunt." However, structure is too medial, lacks lumen, and is not in subcutaneous tissues (**A**) as would be expected with shunt. Findings are consistent with retained guidewire. Interventional radiologist retrieved guidewire, confirming diagnosis. In most cases, thin line overlying patient on frontal view is VP shunt and is therefore first consideration (low prevalence effect). Cognition needed to note correct nature of this finding may not be given in time-pressured environment. Interpretation of repeat chest radiograph deferred to opinion of prior reader (alliterative error).

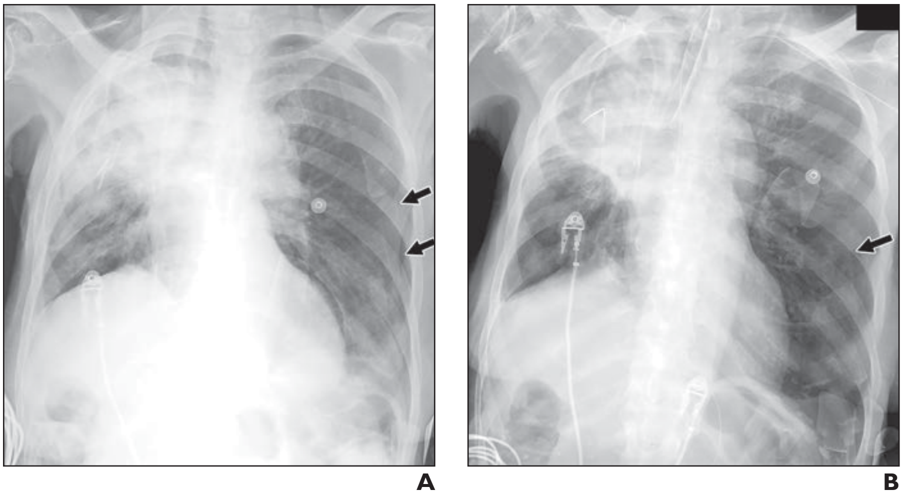


Fig. 8— Satisfaction of search (SOS) and alliterative error.
A, 78-year-old woman presented to emergency department with nonlocalized chest pain and history of lung cancer. Reading of initial radiograph was “bilateral perihilar and right midlung opacities, suggestive of underlying mass and hilar adenopathy.” Significant left-sided pneumothorax (*arrows*) was missed. On review, radiologists thought that pneumothorax would not have been missed without presence of distracting right-sided opacity; interpretive error in this case is consistent with SOS error.
B, Interpretation of portable postintubation radiograph obtained 3 hours after **A** also failed to note left-sided pneumothorax (*arrow*). Cognitive failure identified is alliterative error. In this case, dominant abnormality (right lung mass) was mentioned by prior radiologist; therefore, subsequent readers only looked for changes such as lines and tubes.

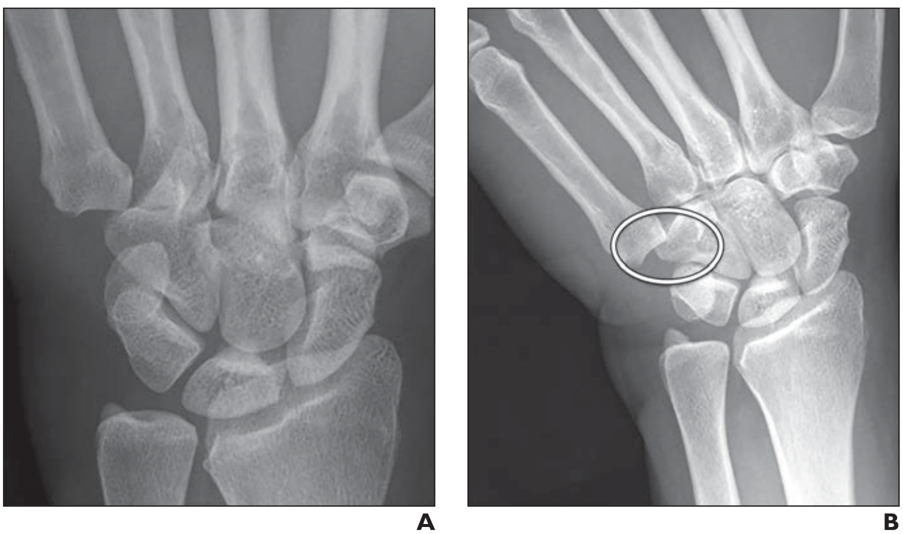


Fig. 9—Distraction error.
A and **B,** Posteroanterior (**A**) and oblique (**B**) radiographs of wrist and hand of 32-year-old man show subluxation of fifth carpometacarpal articulation (*oval*, **B**) missed on initial interpretation. Radiologist recalled being on telephone with clinician while interpreting this study.

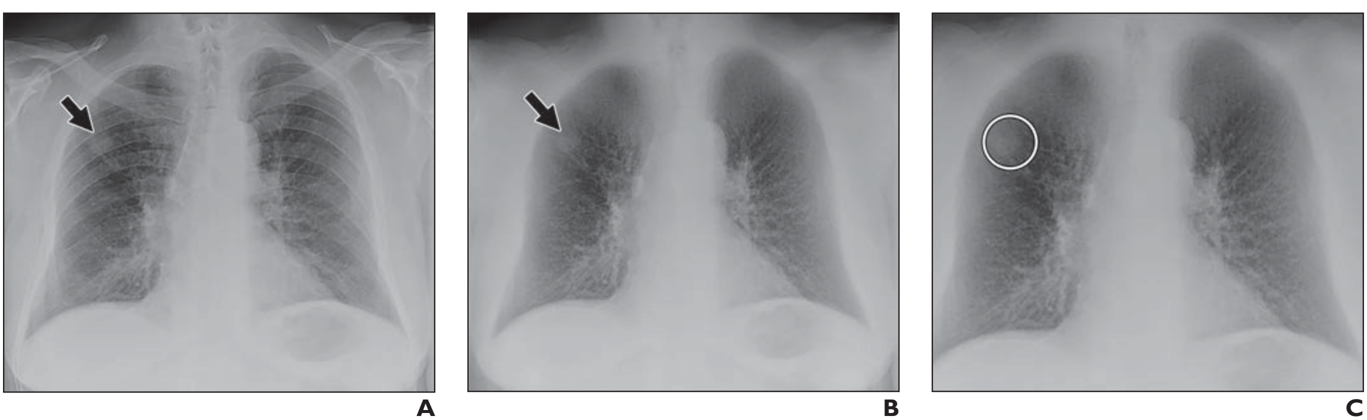


Fig. 10—50-year-old woman with no significant medical history. (Courtesy of Riverain Technologies, Miamisburg, OH)
A, Routine chest radiograph. Study was read as normal; however, there is low-conspicuity poorly marginated density (*arrow*) in right mid upper lung.
B, Bone suppression image. Lack of superimposed ribs on this image shows lesion (*arrow*) more clearly.
C, Combined computer-aided detection (CAD) and bone suppression image. CAD placed true-positive mark on nodule (*circle*) for radiologist to review. This nodule proved to be early-stage adenocarcinoma at pathology.

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