

How to look at radiographs

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SUMMARY

Errors in radiology may result from poor radiographic technique, failures of perception, lack of knowledge and misjudgements. It is necessary to teach students how to interpret radiographs and teaching is likely to be most effective when it enables students to see more clearly what a radiologist does by making their thought processes more explicit.

Compared to the traditional directed search method for examining radiographs, there are advantages in teaching a hypothesis-driven search method in which students are encouraged to ask themselves simple questions about the radiograph based on what they may know about the patient or their initial observations of the radiograph. The answers to these questions may be used as a basis for forming hypotheses that influence the direction of further searches for information, and help build up an understanding of what and what features fit together and what diagnosis is most likely. This approach recognises the importance of using the clinical history when interpreting radiographs.

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What are the pitfalls?

In an ideal world, the results of diagnostic tests would always be true. Ideal diagnostic tests would always give a positive result in patients with the disease, and would always be negative in unaffected patients. Unfortunately, the practice of medicine is not perfect and false test results are encountered frequently. Radiology is not immune from this problem. Errors in radiology may result from poor radiographic technique, failures of perception, lack of knowledge and misjudgements. [1-4] Examples include:

- false negative results may occur when a lesion is not visualised because it is subtle or superimposed on complex anatomical features.
- false positive results may occur if a normal structure is misinterpreted as abnormal, a film fault occurs that mimics disease (figure 1) or if a measurement of a normal organ is outside the reference range.
- true positive, but misclassified results occur when a lesion is recognised but is interpreted incorrectly.

Avoiding errors in radiology depends on a variety of measures:

- false negative results may be minimised by making good quality radiographs, by including all the relevant anatomy and by looking carefully at the films.
- false positive results may be minimised by making good quality radiographs and knowing about all the common anatomical variations that occur between and within species.

Studies have shown that final-year medical and veterinary students tend to overinterpret normal radiographs. [5,6] This tendency probably reflects a lack of knowledge of radiographic anatomy, fear of missing an important abnormality, and an unrealistically high expectation that radiographs are abnormal. It is evident that it is necessary to help students learn how to look at radiographs. This involves training the brain, not improving vision. There is no need to have particularly good vision because ability to extract information from radiographs is not based on simple observation. The key point to recognise here is that there is no observation without interpretation. Even interpretation of the non-imaging clinical context in which the radiographs were made is crucial to understanding what they mean. Expert radiological ability principally requires skill in interpretation, but an expert may take for granted aspects of their technique that

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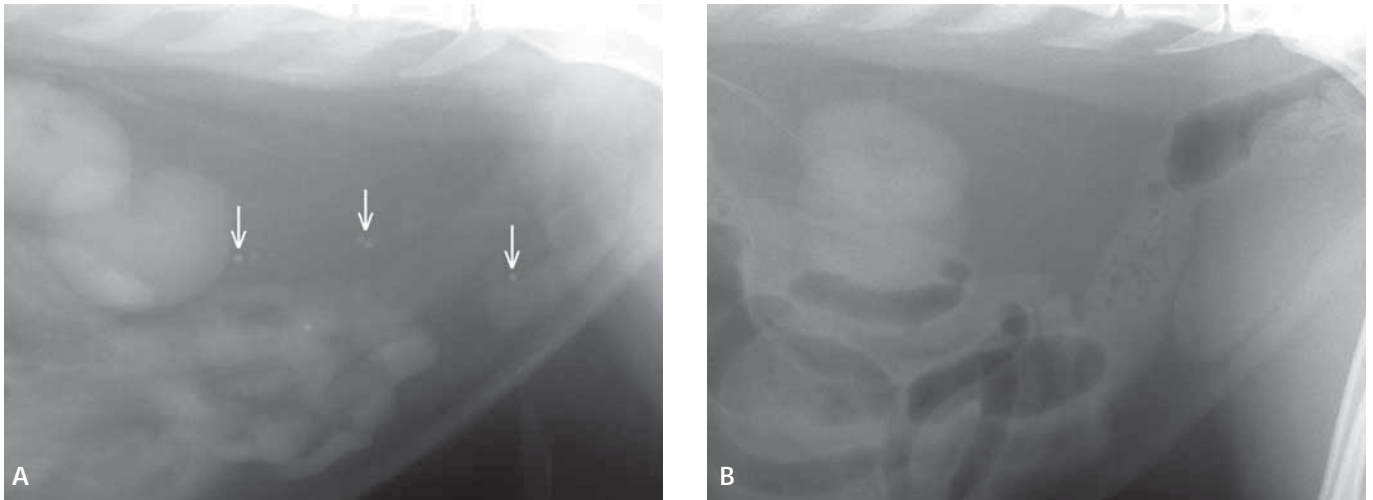


Figure 1. Example of poor radiographic technique contributing to a false positive diagnosis. A) Detail of a lateral abdominal radiograph of a cat with renal insufficiency was interpreted as showing multiple small calculi in the ureters and bladder (arrows). B) Repeat radiograph a few days later shows no signs of calculi, no crystals were found in the urine, and there were no signs of calculi or urinary obstruction on ultrasonography. The initial erroneous diagnosis was probably the result of artifacts caused by damaged screens, debris in the cassette or a processing fault.

a novice may not appreciate. Hence, one of the key aspects of teaching that will make it more effective is helping students to see more clearly what a radiologist does by making more explicit the thought processes used by experts. [7]

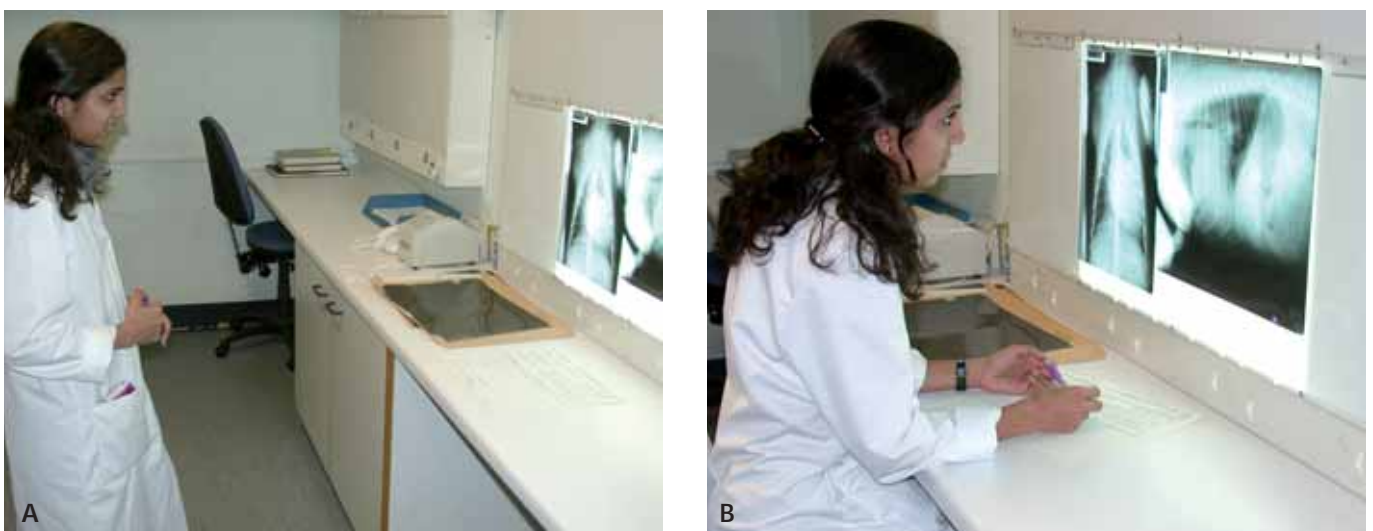
How do experts look at radiographs?

Even before looking at any radiographs of a patient, a radiologist will have engaged in non-image based interpretation, considering the answers to questions that help establish the context within which diagnostic imaging will occur. [7] For example, what do the patient's signs suggest? What do the laboratory results reveal? What kind of imaging will be most helpful? The answers to these questions help the radiologist to form an opinion about the probability that the radiographs will be abnormal. Once radiographs have been obtained, it is necessary to search them for signs of disease. Many radiologists scan the entire

radiograph with short excursions to examine in more detail regions that they suspect might be abnormal. [8] Radiologists routinely take steps to ensure optimal viewing conditions, such as blacking out bright parts of the viewbox. Many radiologists stand back from the viewbox to gain an overall impression of the radiograph before moving closer to examine it in more detail (figure 2).

Radiologists have generic visual abilities that enable them to quickly recognise anomalies in images that are either radiological or non-radiological in nature. [9] In radiologists, particularly high levels of neuronal activity occur in parts of the brain used to retrieve reference images from memory and for generation of mental representations, which are used to construct a three-dimensional mental version of the two-dimensional images. [9] The neural activity involved in the interpretation of images develops in response to training, usually over a period of several years.

Figure 2. Radiologists often stand back from the view box to gain an overall impression of the radiograph (A) before moving closer to examine it in more detail (B).



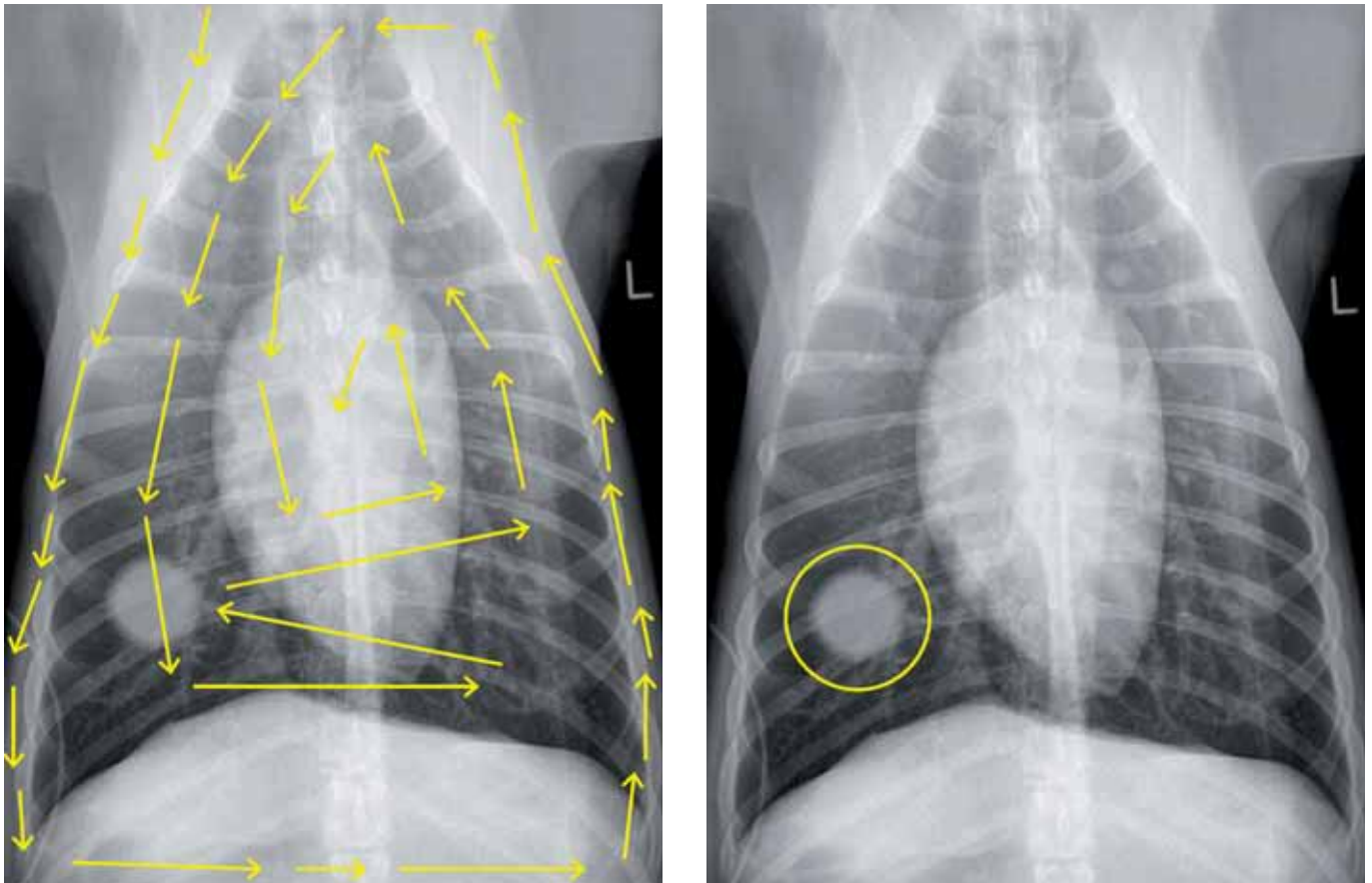


Figure 3. Simplified example of a directed search pattern in a dog with suspected pulmonary disease. A) Initial search in which the observer attempts to examine all the imaged anatomy by following a predetermined sequence unaffected by an obvious feature; B) subsequent examination of obvious feature.

When interpreting images, radiologists use non-image-based information to invoke a diagnostic schema that controls their radiographic interpretation by enabling possible interpretations to be weighed against the probability of disease. [9,10] Recognition of abnormalities involves observing image features and making decisions about the probability that the features represent a true positive finding with specific meaning. [11] It is thought that examining a radiograph involves making decisions about visual features at a rate of approximately one per second. [12] Integration of non-image-based information and observations of the radiographs result in a recognition of the radiographic features most likely to be related to the patient's condition.

How should radiographic interpretation be taught?

Once good quality radiographs have been made, they must be searched carefully for signs of disease. A principle that all radiologists will agree about is the need to always examine the entire radiograph. This need arises because we cannot always predict the position of lesions based on the clinical signs. Furthermore, some lesions may be suggested by the history, but others may be unexpected because many common diseases, such as trauma or neoplasia, have unpredictable patterns. The next question that arises is in what order should the various parts of the radiograph be examined? There are major differences of opinion between teachers of radiology about

how to search films for abnormalities. Opinions tend to fall in two categories:

- Look at structures according to a preconceived sequence. This is known as a directed search pattern.
- Form a hypothesis about the possible diagnosis from the patient's history or from the initial observation of the film, then use this to guide further examination of the radiograph. This approach is known as a hypothesis-driven search.

The principle of the directed search pattern may be summarised as follows:

- Examine the radiograph(s) in a predetermined sequence. For example, start with the periphery of the film and gradually move towards the middle, noting all structures along the way (figure 3). This sequence is usually based on personal preference; it does not rely on knowing the patient's history.
- If you immediately spot an obvious lesion, try to ignore it until you have completed your usual search sequence for all the anatomy depicted on the radiograph. Part of the rationale for a directed search pattern is that by avoiding concentrating on a central or obvious abnormality, the chances of missing a peripheral or unexpected lesion will be minimised.
- Examine the most obvious lesion last
- Collect up all signs and formulate a diagnosis

It is usual for undergraduates and radiology residents to be taught a directed search pattern [13] and this approach is

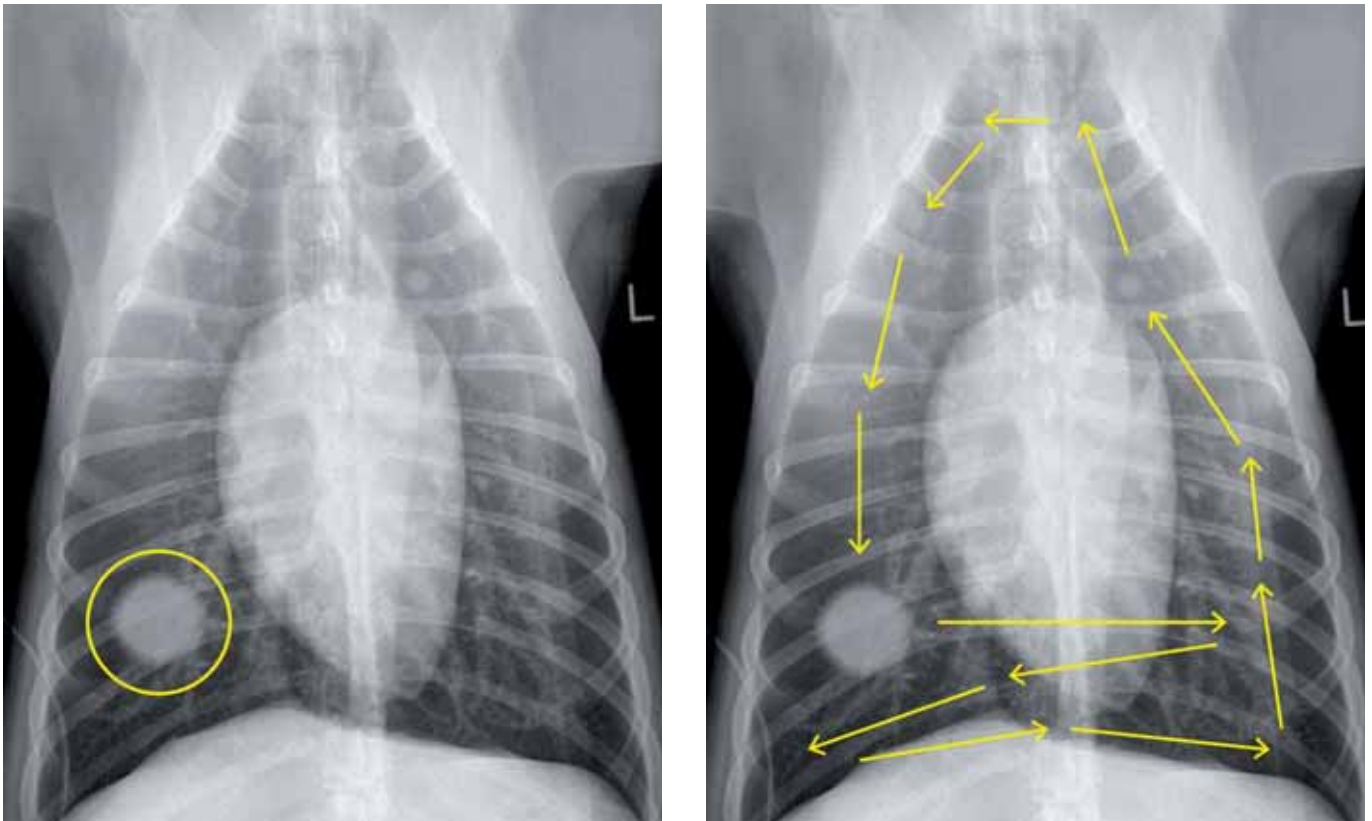


Figure 4. Simplified example of a hypothesis driven search in a dog with suspected pulmonary disease. A) Initial observation of obvious feature leads to the decision that it is probably a pulmonary mass; B) Need to assess if pulmonary mass is solitary or part of a multifocal process prompts subsequent search of the remaining lung for additional lesions. Additional pulmonary lesions are found. Further searches of the radiograph(s) will occur according to the updated interpretation of the possible significance of these findings.

described in various veterinary textbooks [14]; however, there is no convincing evidence that this approach is effective. For example, medical students taught a highly structured, step-wise approach to examining radiographs perform no better than uncoached students. [15]

There are various potential problems with use of a directed search pattern. Personally, I think it is unnatural and it seems doubtful that anyone could optimally examine the periphery of a radiograph while attempting to ignore an obvious feature. This suspicion is supported by the results of studies using vision tracking in which radiologists did not necessarily follow a directed search even when they thought they were doing so. [13] Furthermore, attempted use of a directed search pattern does not eliminate the tendency to miss an unexpected peripheral or subtle abnormality in a patient with an obvious abnormality, the error known as "satisfaction of search." [16] This error occurs because presence of an obvious abnormality inevitably captures visual attention and decreases the observer's vigilance for more subtle abnormalities. [17] A tendency to miss abnormalities can occur because of incomplete visual search, but simply fixating a feature on a radiograph does not necessarily mean it is recognised. [18] Missed nodules often receive prolonged visual attention, implying an active decision not to perceive a nodule. [19] It appears that the majority of false negative errors result from faulty decision-making rather than poor visual search. [12,18] Faulty decision-making can only be exacerbated by an approach to the radiograph that minimises use of the clinical history.

Over many years spent in the company of students learning to interpret radiographs, I have found that students who initially fail to observe certain radiographic abnormalities can often find them easily if prompted by an open-ended question about the patient or the likely clinical scenario. To take a very simple example, when discussing a radiograph of a dog with a partially collapsed left lung, asking a question about how the dog was positioned or restrained for radiography often prompts the student to think of the possibility that the dog was anaesthetised and, having thought of that possibility, they immediately observe the tip of the endotracheal tube that had previously eluded their gaze. The possibility that the dog has unilateral lung collapse because of lateral recumbency under anaesthesia is then added to the differential diagnosis, followed quickly by the notion that this possibility could be tested by repeating the radiographs after a few minutes of positive pressure ventilation. It seems obvious that studying radiographs in context – and knowing what questions to ask during the visual search – helps students to recognise relevant features, and to think of appropriate differential diagnoses and patient management.

Therefore, when teaching radiographic interpretation, my aims are to enable students to ask themselves simple questions about the radiograph based on what they may know about the patient or their initial observations of the radiograph, to use the answers to these questions as a basis for forming hypotheses that influence the direction of further searches for information, and to try to build up an understanding of what diagnosis is most likely based on the features that fit together. This approach



Figure 5. Radiographs exist alongside a larger clinical context that influences their use and their interpretation.

has been likened to a dialogue between the radiologist and the radiograph. [20]

The hypothesis-driven search may be summarised as follows:

- Form a hypothesis about possible diagnoses on the basis of history, experience or initial observation of film
- Use your hypothesis to prompt examination of specific parts of the film (figure 4)
- Think of possible links between abnormalities
- Remember to check remaining areas of film last

This approach recognises that radiographs exist alongside a larger clinical context (figure 5). With increasing experience, we become more familiar with the usual location and appearance of all the common veterinary conditions, which means we are more likely to check specific locations on the film, chosen because of our suspicions about that patient, rather than use a traditional “periphery first” directed search pattern. In cases in which no convincing abnormalities are found using a hypothesis-driven search, it then makes sense to revert to a more directed search pattern as a last resort before moving on to the next case.

The hypothesis driven search resembles the non-analytical reasoning processes used by experienced radiologists (and expert diagnosticians in other fields of medicine). [21,22] Introducing students at an earlier stage of their training to the methods used by most experts fosters consistency and may accelerate their development. There is evidence that the most capable students of radiology tend to use a hypothesis-driven search. In a study of 48 chiropractic students participating in a film reading examination, the students who gained the highest score were better able to identify key radiographic signs because they correlated the history with the radiographic findings and thought of possible diagnoses early in their examination of the films [23] (Table 1). Students who adopted a flexible search pattern had significantly higher scores than those using a directed search. [23]

Table 1. Successful strategies for radiographic interpretation [23]

- Use all available prompts
- Think of possible diagnoses early in examination of radiograph
- Try to find the relationship between multiple abnormalities
- Take your time

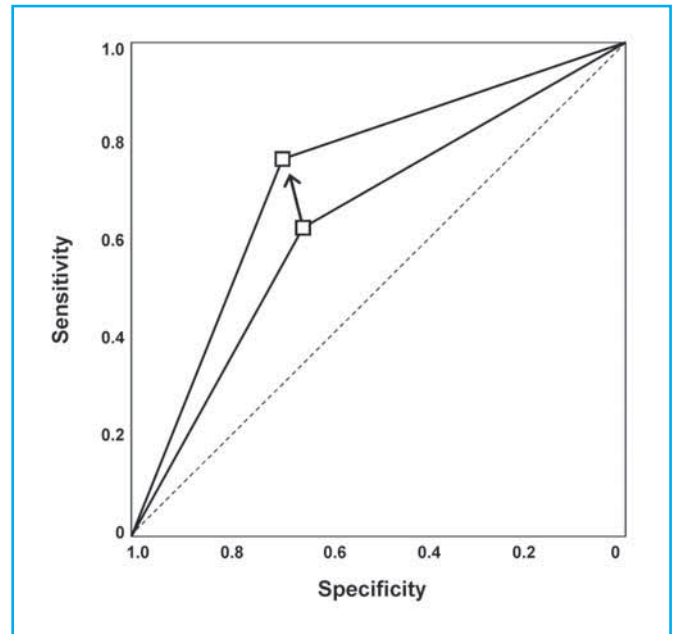


Figure 6. Plot of sensitivity versus specificity to illustrate the effect of clinical history (arrow) on diagnostic accuracy of radiography. Sensitivity and, to a lesser extent, specificity increase when a pertinent clinical history is available[25]. The area under the curve is a measure of overall diagnostic accuracy.

The role of clinical history

There are assessments that present candidates with radiographs without any accompanying patient information or history, but this is an artificial situation. In practice, I suggest that we should always know why we have made radiographs for the following reasons:

- Knowing the history helps to answer key questions, e.g.
 - Is the study adequate?
 - What is the prior probability (prevalence) of disease?
- It affects our level of vigilance
- It helps to interpret a negative result
- Accuracy is increased when the history is available

The accuracy of interpretation of a variety of diagnostic tests – including radiographs –increases when pertinent clinical information is available. [21,24,25] This occurs as a result of increased sensitivity and, to a lesser extent, increased specificity (figure 6). In other words, knowing the history makes it more likely that a radiologist will correctly observe an abnormality, and less likely that they will over interpret a normal feature of the films. Other studies have shown that prior information significantly increased radiologists’ confidence, facilitates new observations, and allows more specific diagnoses. When interpreting a new set of radiographs of a patient that has been examined repeatedly, viewing prior radiographs is more useful than reading the written report. [26,27]

Caveat

There will always be radiographic abnormalities that are difficult to recognise because they are inconspicuous. The conspicuity of a radiographic lesion is defined as a ratio between lesion contrast

and surround complexity. [28] Conspicuity correlates well with the probability of detecting faint nodular lesions in chest radiographs [28], and this concept helps us to understand why some abnormalities are liable to be missed even by experienced radiologists. All we can do is try to be vigilant.

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