The Past and Future of Radiologic Error

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Although radiographs are extremely important in clinical medicine, their interpretation is susceptible to significant error: mistakes in detection and interpretation result in a false negative rate of 30-40%. This figure has not changed with nearly two generations of research.

What are some of the contributing factors? First, consider the complexity of the radiologic images with all the variable human anatomy and potential pathology. The radiograph is a two-dimensional projection of a three-dimensional structure, so that there are many superimposed structures to be sorted out. This superimposition is eliminated with cross-sectional imaging techniques, such as computed tomography (CT) and magnetic resonance imaging (MRI), but at great cost. Further, their interpretation is complicated by the large number of images which must be mentally assembled to cover the entire subject.

The term "conspicuity" was coined to represent the potential of a radiographic finding to be detected, as influenced by its size, contrast, and background complexity. These are complex functions of not only the pathology but also the radiological technique. Suffice it to say that there is great variability in the conspicuity of the abnormalities to be detected in clinical practice.

Another major topic to consider is the physiological limitations of the human eye; specifically, the limited extent of foveal coverage with reduced contrast detection and detail resolution by the rest of the retina. The way a radiograph is examined is a technique learned by practice, and differs among practitoners. This search pattern, described by researchers who track eye movement, consists of fixations and rapid movements, so that the fovea covers only a minority of the film surface. Scanning by eye does not provide the systematic coverage of a television raster. Large shadows in the lungs can be readily detected by peripheral vision, but any lesion of low conspicuity must be looked at directly, with foveal vision, in order to be detected. How this is achieved is based on clinical understanding of where obscure findings should be sought.

Studies of the cases missed in clinical radiology (mainly studies of lung cancer detection) reveal two main troublesome regions in the chest: the periphery, where small lesions lurk; and the hilar region, whose deformity by tumor is poorly recognized, or which hide lesions behind them. I have noted the upper medial portions of the lungs are a difficult region in which to distinguish overlapping bone and vessel shadows from possible tumors. Regions hidden by the heart, because of relative underexposure, have less contrast available, and so peripheral vision isn't good enough. These considerations should be reflected in a well-tailored personal search pattern.

It has long been recognized that the clinical history affects search patterns, a form of bias. This will affect the likelihood of detection of a finding. On the other hand, the clinical information implies the prior probabilities that facilitate interpretation of a finding. Those who have advocated interpreting radiographs while ignorant of the clinical history capture only half the picture, however. The other half follows a directed search for radiographic findings, based on the differential diagnosis (clinically) of the patient's history and other findings. I advocate interpreting all films both with and without the history, sometimes requiring some mental gymnastics by the radiologist.

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One of the problems in proper utilization of the clinical history is that the clinical information provided on a radiology request is usually missing or wrong. This is a consequence of individuals other than the knowledgeable physician filling out the request forms, as well as certain misuse of computerized databases. For example, the patient's admitting diagnosis may appear as the clinical diagnosis for days after the clinicians have dismissed it since it is readily and mechanically available. An unintended consequence of tighter standards for reimbursing radiologic examinations is that the justification must meet certain standards. For example, a study to "rule out" something is not reimbursable. The individuals who enter the justification into the radiology computer know what kind of history is acceptable, and dutifully put in something appropriate, but not necessarily true, and rarely the true reason that would guide the radiologist's interpretation, as discussed above.

Other socioeconomic trends have undesirable effects from the point of view of reducing radiologic error. Managed care's financial incentives are nearly all negative from this perspective. Managed care discourages specialization by physicians, discourages patients from seeing specialists, and also discourages patients from seeing physicians altogether. This reduces the clinical skill needed to use imaging intelligently. Among radiologists, there is similar pressure to practice general rather than specialized radiology, reducing expertise within the discipline as well.

To what extent does the threat of malpractice action help reduce error in radiology? That would be difficult to quantify. Certainly, a minimal level of care is encouraged, but the diligence with which a radiologist studies an individual case is not likely to be affected. On the other hand my impression of the knowledge of malpractice lawyers (?and juries) is that they may mistake error for incompetence (or malpractice) without justification. The well-documented facts of radiological error are not well recognized by either the public or physicians in general, and not acknowledged by lawyers in this field.

Of course, most radiologic findings are nonspecific. They do not correspond to specific diseases or, in many cases, even to well-defined gross pathology. Many diagnoses are indirect or inductive by nature. Sometimes a number of minor findings add up to a likely diagnosis. Radiologic diagnosis is usually pattern recognition.

THE ROLE OF TECHNOLOGY

Technological advances can be both a help and a hindrance in the effort to reduce error. An example of an historic development, automatic film processing, provided uniform development and reduced patients' radiation exposure, resulting in better quality and consistency. This would have a beneficial effect on error. Phototiming of exposure has been very useful to encourage uniform and good film quality. Unfortunately, the subject is often positioned poorly with respect to the phototimer cells, so that exposure is still incorrect.

High kilovoltage radiographic technique results in better penetration and wider latitude, so that exposure is not so critical. These tremendous advantages outweigh a greater insensitivity to the detection of calcium. Scatter-absorbing grids improve contrast and detail, at the cost of using more radiation. The better the clean-up of scatter, the more useful radiation is removed from the x-ray beam, requiring some increase in patient exposure to achieve adequate film-blackening.

Beam-equalizing methods help achieve more uniform film density, solving the problem of looking at the lungs and the mediastinum with one exposure. This can be done with a simple beam-shaping Pb-lucite filter or (better) with a complex scanning system that adjusts beam intensity depending on how much radiation gets through a particular region. The filter, providing an extra dose of radiation to the dense mediastinum, is very useful, unless the patient is not centered perfectly, in which case one of the lungs will be quite overexposed. A relatively inexpensive way to equalize radiation density has been to use high and low sensitivity intensifying screens and matching film emulsions. There is a risk of failing to recognize underexposure, however, because film density looks adequate with the more sensitive (faster) screen-film pair, andthe lack of any detail from the slower screen-film pair may be inapparent. Underexposure, of course, promotes missing smaller lesions in the lung periphery.

The ultimate in technology may be the application of computers to radiology. Computed tomography was the first major application. By removing superimposed shadows and enabling a true cross-section to be seen, CT has revolutionized imaging. The sensitivity of CT images for many findings is much greater than plain radiography in the chest; in the abdomen, CT can be legitimately said to be infinitely better for many findings (which were simply not distinguishable on plain films).

Computed radiography and direct digital radiography sacrifice a little in image quality as the cost of automation but their potential to streamline the imaging process is substantial. With the addition of an electronic medical imaging system for readout, they also increase productivity, which may not decrease error by itself, but makes it possible to study images more carefully.

Having digital images makes computer manipulation possible. For example, computerized edge enhancement is good in CT of the lungs, less useful in radiographic chest imaging. On the other hand, noise suppression or smoothing of images has limited application of which I am aware. Removal of calcium, using dual exposures (getting rid of the ribs on a chest film!) can be extremely useful in allowing detection of underlying lesions; selecting for calcium can separate bone defects from overlying air shadows. False color has been used in nuclear medicine and proposed for general radiology, but color translation of the gray scale is not useful in radiography because it doesn't sort out image overlap. Computer identification of suspect findings may eliminate some false negative readings, at the risk of increasing false positives from the radiologist. The human eye and brain are not about to be superseded, fortunately, at least in chest radiology.

It is appropriate here to mention some research results that create some doubt about the advantages of having a computer (or a partially-trained assistant) point out suspicious regions on the film, allowing the radiologist to make the final decision. In a complicated but well-controlled experiment, comparing films previously selected for false positive findings with the same films containing artificially introduced nodules, pointing out a possible lesion resulted in a less accurate assessment than if the radiologist interpreted the film from scratch, with no indication of the region of interest. A similar result had been found, although challenged, some years before. No simple mechanism can explain this result, and it remains to be seen how new technology will be affected.

PACS (picture archiving & communication systems) are the latest advance. Combining digital images (usually obtained digitally, de novo) with fast networks, cheap digital archives, sophisticated prefetching, and large, bright workstations with user-friendly software, will be nirvana. PACS provide new convenience and efficiency, but incorporate a risky dependence on cutting edge technology. We have annoying crashes of computers of all kinds now; when they support patient images, such crashes could be disastrous.

With regard to error, PACS make it easier to retrieve old images and compare them (it answers many questions and eliminates some errors, when the diagnosis becomes obvious with comparison films or images). PACS provides easier access to current images for clinicians, but potentially less contact with radiologists, which is bad for their joint function. However, radiologist notations on the films will be available to the clinicians remotely as soon as they are drawn on the images.

Methods of reading, reporting, and communicating findings will change: most radiologists use stack or cine viewing of CT/MR images when using a workstation in contrast to spreading out the images as on a viewbox. The temptation to make a great many more images when the expense of filming them is eliminated, has already been noted in some centers! Reformatting, reconstructions, MIPs (maximum or minimum intensity projections) are all useful for complex CT anatomy/pathology, although time-consuming. (It's another case of technology making it possible to do new things, but at a considerable cost in time.)

Machine voice recognition of dictation will speed reporting and make it possible to have the report available by the time the clinician sees the films. Of course, it will also pressure the radiologist to treat all films as "STAT" readings, which will lower the opportunity to reflect on the images longer; however, immediate availability of past plain film and CT images should more than compensate for this problem. A change in the way radiology is practised is at hand.

Finally, I am enthusiastic about the potential of portable messaging devices and wireless technology to improve communication between radiologist and clinician. I am thinking about not only the transfer of radiologic interpretations back to a responsible referring physician, but also the opportunity to query the clinician about more clinical historic details. Perhaps accurate clinical information will become available! On the whole, the changes to be wrought by the adoption of new technology should only improve care and reduce error, and can be embraced with enthusiasm.

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