Defining Quality in Radiology
C. Craig Blackmore, MD, MPH

The introduction of pay for performance in medicine represents an opportunity for radiologists to define quality in radiology. Radiology quality can be defined on the basis of the production model that currently drives reimbursement, codifying the role of radiologists as being limited to the production of timely and accurate radiology reports produced in conditions of maximum patient safety and communicated in a timely manner. Alternately, quality in radiology can also encompass the professional role of radiologists as diagnostic imaging specialists responsible for the appropriate use, selection, interpretation, and application of imaging. Although potentially challenging to implement, the professional model for radiology quality is a comprehensive assessment of the ways in which radiologists add value to patient care. This essay is a discussion of the definition of radiology quality and the implications of that definition.

Key Words: Quality, errors, pay for performance, evidence-based imaging

INTRODUCTION

Since the publication of the Institute of Medicine’s 1999 report To Err Is Human: Building a Safer Health System [1], there has been increased interest in quality in medicine. The report’s authors estimated that there may be as many as 100,000 preventable deaths each year at medical centers in the United States. Preventable deaths are caused by errors of omission, commission, communication, and other sources. This report highlighted the potential benefit to health care in the United States from improvements in the quality of care [1,2].

Coincident with increased awareness of a quality deficit is the continued rise in health care costs. As of 2003, the United States was spending 15.2% of its gross domestic product on health care [3]. This is by far the highest of all developed nations in the world, at least 50% higher than the number two country, Switzerland, and nearly double the average among developed countries of 8.3% [3]. Despite these expenditures, however, the World Health Organization in 2006 reported that the United States lags behind most other developed nations in the important health outcomes of life expectancy and infant mortality and, as of 2000, had only the 37th best health care in the world [3]. It is not unexpected that payers repeatedly question the value and the quality of the health care being provided in this country. Coincident with these rising health care costs is an escalation in growth in imaging procedures. Imaging procedure volume is expected to nearly double in the decade from 1998 to 2008.

One response to the inadequate quality and the high expense of US medical care has been the establishment of pay-for-performance programs. These programs feature lower payments to lower quality providers and presumably increased payments to providers that can demonstrate higher quality. The goal of such programs is to lower cost but also, importantly, to force improvement in provider quality.

Pay-for-performance programs require quality metrics to function. In response to a proposed 4.9% cut in professional fee components from the Centers for Medicare and Medicaid Services, the American Medical Association negotiated an agreement whereby the planned cut would be canceled, and in response, the American Medical Association would produce 140 quality metrics during calendar year 2006, which could be implemented as part of pay-for-performance schemes [4].

In radiology, the above-mentioned factors have led to increased interest in the development of radiology quality metrics. The ACR now has a metrics committee charged with developing radiology quality metrics [4]. An additional independent group, the Radiology Quality Summit, convened for the first time in September of 2005 in Sun Valley, Idaho, with a manifesto emphasizing developing methods of measuring and improving radiology quality [5].

The implications of the development of radiology quality metrics, however, go beyond pay-for-performance and current reimbursement schemes. As organized radiology moves toward defining radiology quality, in effect, radiology is defining for itself the role and responsibilities of radiologists. By defining quality radiology, the ACR and others are defining, on some level,
the standards that must be met to function as a radiologist. In the past, quality has primarily been defined through credentialing. Certification from the American Board of Radiology, possibly supplemented by a certificate of added qualification, was the basic quality standard in radiology. The development of these new quality metrics will supplement and in some ways supplant credentialing as the measure of radiologists’ qualifications.

On an even broader level, proposed quality metrics will define roles that radiologists should function in and therefore will define the profession of radiology for future generations. As turf battles continue in radiology, the quality metrics defined by radiology can be used to argue either for or against different providers’ providing imaging services. Nonradiologists could evaluate themselves under ACR or other radiology metrics and argue that they practice quality radiology. Thus, if radiologists are to argue that they provide superior quality radiology, they must ensure that quality metrics encompass the breadth of activities that differentiate true quality as it relates to patient care.

In current discussions of radiology quality metrics, two broad frameworks have evolved. These can be labeled the radiologist “production” approach and the radiologist “professional” approach. The objectives of this essay are to describe and contrast these differing perspectives on radiology quality and to define quality metrics under the different models. I also seek to explain why radiology as a profession needs to be proactive in defining quality.

### RADiOLOGIST PRODUCTION MODEL

In the radiologist production model, radiologists are an integral part of a production process whereby images are produced and interpreted, and results are communicated. Patients arrive for imaging, and radiologists carry the responsibility for supervising the technical aspects of the imaging, the accurate interpretation of the imaging studies, the generation of reports of the examinations and findings, and the communication of the results to referring clinicians. Radiologists are responsible for the safety of patients while they are in radiology departments, as well as the satisfaction of patients, their family members, and their providers, with the whole imaging experience. The final product of this process is the radiology report. Quality markers are easily defined from the technical aspects of imaging and from the production of the report, and include radiation dose, the number of repeat images required, patient satisfaction, the ease of scheduling, the accuracy of interpretation, and the promptness and clarity of communicated reports (Table 1).

<table>
<thead>
<tr>
<th>Step in Production Chain</th>
<th>Elements</th>
<th>Sample Metrics</th>
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<tbody>
<tr>
<td>Patient access</td>
<td>Time and ease of scheduling an appointment</td>
<td>First and third available appointments</td>
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<td></td>
<td>Communication between referring provider and radiology department</td>
<td>Billable indications provided with imaging orders</td>
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<tr>
<td>Preimaging planning</td>
<td>Communication with patients</td>
<td>Compliance with preimaging instructions (NPO, bowel preparation, hold medications, etc)</td>
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<tr>
<td>Patient imaging</td>
<td>Patient experience before imaging</td>
<td>Wait times</td>
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<td>Safety</td>
<td>Hand washing</td>
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<td></td>
<td>Radiation dose</td>
<td>Repeat rates, CT dose estimates, ACR technical standards</td>
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<td>Protocol selection</td>
<td>Imaging callbacks, inadequate studies</td>
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<td>Contrast administration safety</td>
<td>Contrast reaction, nephropathy, extravasation</td>
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<td>Interpretation</td>
<td>Expert interpretation</td>
<td>Accuracy, peer double reads, imager credentialing</td>
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<tr>
<td>Report generation</td>
<td>Timeliness of report</td>
<td>Time from imaging to report finalization</td>
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<td>Clarity of report</td>
<td>Use of structured reports, referring provider satisfaction with report</td>
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<td>Communication of important, unexpected findings</td>
<td>Documentation of communication</td>
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Note: CT = computed tomography; NPO = nothing by mouth.
turing chain, a radiologist may serve in a managerial role and also in a technical role as an interpreter of images. Because of the parallels to manufacturing, many of the same approaches to quality, such as total quality management [6] and Six Sigma [7], may be appropriate.

The radiologist production model is clearly important and encompasses much of the daily activity of practicing radiologists. Important and obvious metrics can be derived from this process, measured, and potentially used as targets for quality improvement and error avoidance. Many common practice management metrics, including report turnaround times, scheduling delays, repeat imaging rates, and the use of film markers, are easily translated into quality metrics under the production model. In addition, patient satisfaction can be measured and is one reflection of quality, as is the safety of patients and the appropriate minimization of radiation dose. The accuracy of interpretation (or at least interobserver agreement) is also measurable to some extent using approaches such as the ACR’s RADPEER® system and is an important component of the radiologist production model.

Although it is important, the radiologist production model is limited. The intrinsic assumption of the production model is that the final product is a timely and accurate radiology report produced in conditions of maximum patient safety and communicated to a patient’s health care provider. The radiologist production model suggests that if the function of a radiologist is to produce an accurate report, then the use of radiologists has no advantage over other approaches that can produce reports of similar accuracy, safety, and timeliness. The report itself becomes a commodity, and the radiologist’s role in patient care is limited to producing this fungible output. By focusing on the report as the output of diagnostic imaging practice, a radiologist’s value is defined as purely in terms of being part of the production chain. By extension, radiologists, though skilled, are labor and replaceable with less expensive labor either through nonphysician providers and outsourcing or through the further development of computer-assisted diagnostic software.

It is also important to note that current reimbursement is based solely on this production model. Radiologists are paid on the basis of the number and complexity of imaging studies they interpret, but they are paid only upon the production of the final product, which is the radiology report.

**RADIOLOGIST PROFESSIONAL MODEL**

By contrast, the radiologist professional model uses a broader definition of the role of radiologists and therefore how quality in radiology should be measured. Under the radiologist professional model, radiologists are physicians who are experts on the use of imaging for diagnosis, specialists in imaging acquisition and interpretation, and consultants on the application of imaging information to clinical care. Accordingly, radiologists have an explicit role in using imaging to improve the health of patients. This includes the functions of radiologists under the production model but also incorporates sharing responsibility for determining which subjects should be imaged, what imaging modalities and approaches should be used, how imaging studies should be interpreted, and how imaging study results should change patient care. A radiologist professional cannot practice in isolation, and effectiveness in the radiologist professional model requires interaction with the other medical providers sharing responsibility for a patient’s care.

The radiologist professional model as a concept is not likely to spark controversy among radiologists. No doubt many of us see ourselves as working in this model. However, the new focus on quality metrics means that radiologists and other physicians will now be evaluated on the various aspects of quality. For radiologist professionals, this means that they must now take responsibility for and be held accountable for which patients are imaged, how they are imaged, and even how the information is used in patient care. If radiologists are to function as physicians and professionals and bear partial responsibility for all of these functions, then quality in radiology should also include the measurement of these roles (Table 2).

**Who Should Be Imaged?**

With training in imaging physics and in-depth understanding of imaging, radiologists should be uniquely suited to influence decision making as to which patients undergo imaging. Radiologists should be involved in the development of evidenced-based guidelines on local and national levels, advising clinicians on the ideal use of imaging. Radiologists should also be involved in the research that underlies such guidelines, including the development, validation, and implementation of the clinical prediction rules to determine which subjects need imaging [8]. Clearly, radiologists are involved in such processes, although the lead role in the development of clinical prediction rules for imaging has often come from outside radiology [9-12].

Under the production model, a radiologist is a participant in a manufacturing chain, a passive role whereby studies are ordered by referring physicians and performed by the radiologist without questioning. The radiologist professional model implies a more active role influencing the process of image ordering. This may occur on the local level through medical-centered committees, case conferences, personal relationships with referring clinicians, and hospital administration, and it may occur on the national level through payers, organized medicine, and government. Unfortunately, despite the depth of
knowledge in imaging that radiologists possess, influencing the selection of subjects for imaging has not always been a role in which radiologists are recognized, and certainly not one for which they are compensated.

The radiologist professional model demands that the determination of the quality of radiology practice include assessments of whether inappropriate patients are imaged. When there is strong evidence supporting the determination of appropriate imaging, inappropriate imaging can be directly measured and used as a quality marker. For example, in emergency radiology there are internationally validated clinical prediction rules for trauma to the ankle [10], knee [13], head [12,14], and cervical spine [9,11], all of which can be used to determine which subjects do not need imaging, on the basis of simple clinical criteria. It is relatively easy to perform simple chart audits in such patients to ensure that these clinical criteria for appropriate imaging are met in subjects who are imaged. A simple quality metric can be derived consisting of the number of patients in whom an indication is documented as the numerator and the total number of patients imaged for a given clinical scenario as the denominator. For example, the New Orleans Criteria are an internationally validated clinical prediction rule to determine which subjects with minor head trauma require imaging [12]. This clinical prediction rule is much more detailed and exclusive than the lengthy list of indications that will currently lead to reimbursement. Adherence to the New Orleans Criteria can serve as a quality metric for the performance of imaging on only indicated patients in emergency departments.

Ideally, all imaging would be based on strong evidence. Unfortunately, however, the evidence basis for much of radiology practice is limited [15,16]. The book Evidence-Based Imaging [15], as well as the US Public Health Service Task Force on Preventive Services and the Cochrane Collaboration, serve as important repositories for the evidence supporting imaging. Barring strong evidence, including validated clinical prediction rules, consensus must be reached as to the appropriate indications.

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<th>Table 2. Radiologist professional model metrics</th>
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<td><strong>Component of Professional Model</strong></td>
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<td>Who should be imaged?</td>
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<td>What imaging approach?</td>
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<td>Imaging production</td>
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<td>How are studies interpreted?</td>
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<td>Patient outcome</td>
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for imaging. The consensus-based ACR Appropriateness
Criteria are an important starting point for guiding the
use of imaging, and there are also many other guidelines
from other medical societies and interest groups. Once
imaging indications are agreed on at either the local or
the national level, these too can form the basis of assessing
the quality of the selection of subjects for imaging.

Intrinsic to the role of radiologists in determining
whether imaging is appropriate for a given patient is the
potential for discouragement, or even the denial of
imaging services by radiologists in those situations in
which appropriate indications are not identified. Denial
of imaging is not a role in which radiologists may be
comfortable and realistically must be a collaborative pro-
cess, involving radiologists as well as referring clinicians,
that occurs before the patient arrives for imaging. Fur-
thermore, such decisions about who is to be imaged are
best made in advance at the local or national level rather
than on an individual level.

It also needs to be acknowledged that under the produc-
tion model that currently serves as the basis for reimburse-
ment, there is no financial incentive to radiologists or cli-
nicians to limit the use of imaging. Intrinsic to the radiologist
professional model is the development of a mechanism to
align financial incentives with the appropriate use of imag-
ing. Pay for performance represents a potential method of
realigning these incentives, because the appropriate use of
imaging can be rewarded as quality care, whereas the inap-
propriate use of imaging could be penalized [4]. Using the
example of head computed tomography (CT) cited above,
radiologists or radiology groups that perform imaging on
patients who do not meet one of the clinical criteria de-
scribed by the New Orleans group could be considered to be
practicing lower quality radiology, with the associated fi-
nancial consequences.

Which Imaging Is Appropriate?

A second role for radiologist professionals is the determination
of which specific imaging tests are appropriate if subjects re-
quire imaging. This is a consulting role in which a radiologist
works with a referring clinician to determine the best diagnostic
approach for a patient with a given set of clinical symptoms and
signs. Such consultation may occur locally, often informally, in
the course of daily practice, or it may occur at a broader level
through the development of evidence-based guidelines. Again,
however, the radiologist professional model requires more than
informal and occasional consultation; it demands responsibility
for the selection of the correct imaging approaches for patients.
Quality in radiology therefore is defined not simply by the
availability of a radiologist for consultation, but by the reality of
appropriate imaging strategies in subjects referred to the radiol-
ogist for care.

An example of this approach is the use of cervical spine
CT in trauma patients. The determination of which vic-
tims of trauma require imaging can be reliably made on
the basis of clinical prediction rules developed by the
Ottawa group [17] and the National Emergency X-Ra-
diography Utilization Study [18]. Once the decision has
been made, however, that imaging is appropriate, there
are two commonly used approaches, radiography and
CT. Computed tomography has been shown to be cost
effective in high-risk patients, but the high imaging cost
and high radiation dose render CT inappropriate for use
in all subjects. A validated clinical prediction rule can be
used to identify subjects who are at high risk for cervical
spine fracture (>4%), in whom CT is the appropriate
choice. On the basis of such information, the appropriate
use of CT of the cervical spine in trauma patients can be
assessed by looking at the diagnostic yield of the imaging
study. If CT is appropriate in the patients who are at 4% or
greater risk for fracture, the diagnostic yield of CT
should be at least 4%. A lower yield would imply that CT
is being used too broadly and that quality has been sac-
ificed. Of course, this approach requires evidence as to the
appropriate diagnostic yield for an imaging study, which is
unfortunately lacking for many imaging issues [19].

How Should Studies Be Interpreted?

Next in the quality assessment under the radiologist pro-
fessional model is how imaging studies are interpreted. In
the radiology production model, imaging reports are
fungible, and quality might be judged simply on the basis
of accuracy. However, in the radiologist professional
model, radiologists provide individualized care for spec-
cific patients and are able to adjust their interpretations as
appropriate for given clinical scenarios.

There is enormous variability in the interpretation of diag-
nostic imaging evaluations. This variability can be thought of as
occurring in two categories. The first of these is voluntary vari-
bility, meaning that this variability is based on the choices of an
individual radiologist as to whether to emphasize sensitivity or
specificity. In other words, different radiologists make the
choice to operate at different points on the receiver-operating
characteristic curve. A radiologist who emphasizes sensitivity
will have important differences in the interpretation of studies
with a radiologist who chooses to emphasize specificity. The
other component of variability is involuntary variability, which
is a function of differences in the skill, the equipment, the
interpreting environment, and even the imaged patient’s char-
acteristics.

The voluntary component of variability is another point
at which a radiologist professional can influence the medical
care of a patient. Using utility theory, one can determine the
optimal point on the receiver-operating characteristic curve
at which a study should be interpreted from the prevalence
of disease in the population and the ratio of the utilities of
false-positive and false-negative imaging results [20]. In
other words, whether sensitivity or specificity should be
emphasized in the interpretation of an imaging study is dependent on how likely a patient is to have the disease in question, how severe the consequences are of a false-positive imaging result, and how severe the consequences are of a false-negative imaging result. Using imaging for the diagnosis of acute appendicitis as an example, one can estimate the utility of false-positive diagnosis from the mortality related to laparotomy in patients who were subsequently found to have normal appendices (approximately 0.076%). One can compare this with the mortality associated with missed appendicitis that has progressed to perforation (0.51%). In patients at low probability of appendicitis, outcomes will be optimized if radiologists interpret studies with the highest possible specificity, even at the expense of sensitivity. In contradistinction, at a high probability of appendicitis, radiologists will provide the greatest benefit for their patients by interpreting at high sensitivity at the expense of specificity [21]. From the standpoint of quality metrics, this information can be used to develop an appropriate quality metric for imaging in appendicitis. This would not be simply accuracy but the ratio of false-positive to false-negative diagnoses or, even more simply, the acceptable range of false-positive diagnoses after imaging.

As a second example, in mammography, rates of interval or missed cancers, an estimate of the sensitivity of screening, are commonly tracked, as well as callback rates and biopsy yields, indicators of the specificity of imaging. However, on the basis of utility theory, it can be demonstrated that the optimal sensitivity and specificity will vary depending on a patient’s underlying risk for breast cancer. Therefore, the quality of care and patient health may be improved by interpretation with different sensitivity and specificity in subjects undergoing routine screening compared with those at high risk on the basis of their personal and genetic histories. Quality metrics could be devised for optimal interval cancer rates compared with biopsy rates for mammography in different groups of women.

**Effect of Imaging Results on Patient Care**

Almost the entire effect radiologists have on patients’ health is mediated through other medical providers. Radiologists provide information, which then guides the management of patients’ illnesses. Therefore, the final metrics of radiologist quality are the treatment that patients undergo after imaging and their final outcomes. Radiologist professionals bear responsibility not only for producing reports of diagnostic imaging studies but also for ensuring that appropriate action is taken on the basis of those reports.

The use of CT for suspected acute appendicitis serves as an example for this point. Computed tomography in this setting is more accurate than a physical examination [22]. Therefore, one would expect fewer nontherapeutic laparotomies in patients who undergo CT than in those who do not. However, there are at least some data suggesting that the rate of nontherapeutic laparotomy has not changed despite the increasing use of CT [23]. Although these data predate the multidetector CT era and are based on administrative databases, with all their inherent limitations, they are still provocative in raising the question as to why CT has not had the expected effect, despite high sensitivity and specificity. Possible explanations include that radiologists’ interpretations of CT scans were not made available quickly enough to influence surgical decision making. It is also possible that the communication of the results was delayed. It is possible that the surgeons lacked confidence in the CT interpretations and chose to ignore the results. In each of these scenarios, the radiologists bear at least partial responsibility for the inappropriate care that the patients received. Under the radiologist professional model, this constitutes poor-quality radiology. The responsibility of a radiologist does not end when a report is issued but only when a patient has received quality care. For appendicitis, a metric can be derived from the number of false-positive laparotomy results or delays in the diagnosis of appendicitis. If these instances of poor-quality care occur in subjects who have been imaged, then radiologists share responsibility for the adverse outcomes.

**DISCUSSION**

Current reimbursement in radiology is based purely on the production functions of image interpretation and report generation. However, quality in radiology includes an additional range of professional functions, including the selection of subjects for imaging, the determination of optimal imaging approaches, tailoring imaging interpretations to specific clinical scenarios, and ensuring appropriate management on the basis of imaging results. Most radiologists incorporate at least some of the functions of radiologist professionals into their practices, even though these are not activities for which they will be reimbursed. The new pay-for-performance quality emphasis can enable radiologists to practice medicine and improve patient care rather than simply providing technical services to other providers. Defining radiology quality on the basis of the radiologist professional model is an opportunity for radiologists to provide maximal value to patients and to other providers.

There are, however, real challenges with defining radiology quality using the radiologist professional model. The predominant challenge is that radiologists do not always perceive themselves as having control of who gets imaged and what imaging is performed. Radiologists in some situations have largely abdicated responsibility for using imaging appropriately. The practice pattern may be to perform whatever imaging is requested without questioning. In addition, institutional practice and policy may be to bypass radiologists in the determination of the appropriateness of
imaging. This approach may offer advantages of speed, efficiency, and financial gain and can prevent acrimony with referring clinicians. However, the performance of unnecessary imaging is clearly not quality care. Furthermore, radiologists do ultimately have control in their practices over who gets imaged and with what approach. Although referring clinicians can apply pressure, radiologists can refuse to provide inappropriate medical imaging and can interpose themselves between the ordering of studies and the performance of imaging. Of course, imaging is competitive, and radiologists risk the loss of market share if they refuse imaging requests. Clearly, under the radiologist professional model, the workable approach is a collaborative one in which radiologists work closely with referring clinicians to ensure the quality use of imaging. This happens to varying degrees now, but the radiologist’s time expended on such consultation is not currently funded. In effect, implementing quality markers and financial rewards for the appropriate use of imaging is necessary to enable radiologists to spend the time to provide quality care. In addition, increased reimbursement for quality practice potentially can offset the loss of revenue from declined studies.

Radiologists may also resist the radiologist professional model as too prescriptive. The evidence-based medicine approach is by nature based on guidelines, which may represent a paradigm shift for radiology practices. In addition, the use of any metrics, whether production or professional, represents a level of scrutiny unfamiliar to most radiologists (and other physicians). This change is now occurring, and radiology practices will have to adapt. Radiologists also may need further education to be able to implement aspects of the radiologist professional model into their practices.

In summary, the implementation of pay-for-performance metrics and the new emphasis on the measurement of quality in radiology puts our profession at a crossroads. We have been reimbursed in the past purely on the basis of a production model for imaging services. Although remunerative, this production model is limiting to radiologists and encompasses only a portion of the role they play in patient care. The radiologist professional model encompasses the components of the radiologist production model but also accounts for radiologists’ role in determining who should undergo imaging, what imaging should be performed, how imaging studies should be interpreted, and how the results of imaging studies should influence patient care. Quality metrics for radiology, whether as a component of a pay-for-performance scheme or as internal metrics radiologists use to evaluate themselves, should encompass all of the facets of radiologists’ role in patient care.

REFERENCES