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FOCUS ISSUE: CARDIAC IMAGING

State-of-the-Art Paper

Quality in Cardiovascular Imaging

Achieving Quality in Cardiovascular Imaging

Proceedings From the American College of Cardiology–Duke University Medical Center Think Tank on Quality in Cardiovascular Imaging

Developed in Collaboration With the Cardiovascular Imaging Collaborative Quality Work Group, American College of Radiology, American Heart Association, American Society of Echocardiography, American Society of Nuclear Cardiology, Coalition of Cardiovascular Organizations, Heart Failure Society of America, Heart Rhythm Society, Intersocietal Accreditation Commission, Society of Atherosclerosis Imaging and Prevention, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance, and Society for Vascular Medicine and Biology

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For a complete list of the ACC–Duke Think Tank participants and their affiliations, please see Appendix 1. For a complete list of the Writing Group's relationships with industry, please see Appendix 2.

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Abbreviations and Acronyms

ACC = American College of Cardiology
ACR = American College of Radiology
ASE = American Society of Echocardiography
ASNC = American Society of Nuclear Cardiology
COCATS = Core Cardiology Training Symposium
CT = computed tomography
JCAHO = Joint Commission on the Accreditation of Healthcare Organizations
MR = magnetic resonance
SPECT = single-photon emission computed tomography

ABSTRACT

Cardiovascular imaging has enjoyed both rapid technological advances and sustained growth, yet less attention has been focused on quality than in other areas of cardiovascular medicine. To address this deficit, representatives from cardiovascular imaging societies, private payers, government agencies, the medical imaging industry, and experts in quality measurement met, and this report provides an overview of the discussions. A consensus definition of quality in imaging and a convergence of opinion on quality measures across imaging modalities was achieved and are intended to be the start of a process culminating in the development, dissemination, and adoption of quality measures for all cardiovascular imaging modalities.

INTRODUCTION

Imaging has transformed cardiovascular medicine by improving the prevention, diagnosis, and management of cardiovascular disease. The sustained growth of imaging shows the central role that imaging plays in the care of patients with known or suspected cardiovascular disease. Ensuring a high level of quality has now become an important focus for patients, physicians, and payers because of advances in existing imaging technologies and the emergence of new modalities.

Quality of care has been defined by the Institute of Medicine as "the degree to which health care systems, services, and supplies for individuals and populations increase the likelihood for desired health outcomes in a manner consistent with current professional knowledge" (1). Several initiatives to improve quality for patients with cardiovascular conditions have been implemented (2,3). However, these programs have predominately focused on evaluating the use of evidence-based therapies (4,5), and quality in imaging has been relatively hidden from view. Although few studies have shown marked geographic variation in imaging use (6,7), there is little information about where quality gaps exist and how they ultimately affect patient care and outcomes.

To respond to this need, the American College of Cardiology (ACC) and Duke University convened a meeting of representatives of cardiovascular imaging societies, private payers, government agencies, industry, and experts in quality measurement in January 2006. This report provides a review of the discussions and proposes efforts to establish quality standards for cardiovascular diagnostic imaging, beginning with an emphasis on valid quality measurement tools. The meeting achieved a consensus definition of quality in imaging and a convergence of opinion toward the development and dissemination of quality measures for each imaging modality within 18 months.

PRINCIPLES OF QUALITY MEASUREMENT

The conference embraced Donabedian's (8) methodology of quality assessment by applying his structure-process-outcome model to cardiovascular imaging. *Structure* represents the infrastructure through which care is delivered, such as equipment, staff training, and laboratory protocols. *Process* refers to those actions performed in delivering care to patients, and includes such concepts as patient selection, image acquisition, interpretation, and reporting. *Outcomes* are the events that occur as a result of the impact of imaging on clinical decision making, and they can encompass mortality, morbidity, quality of life, cost, and satisfaction. Performance measures are the discrete parameters of structure, process, or outcome whose attainment defines good quality care.

Currently, quality assessment of cardiac imaging laboratories primarily occurs through voluntary accreditation through the Intersocietal Accreditation Commission and its relevant agencies (Table 1). The American College of Radiology (ACR) also provides accreditation for vascular ultrasound (9) and nuclear cardiology (10) laboratories, and is developing accreditation processes for cardiac magnetic resonance (MR) and cardiac computed tomography (CT) imaging. The Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) provides an implicit accreditation of a facility that has a cardiac catheterization laboratory. By remedying inconsistent adherence to published standards and guidelines, accreditation can ensure an objective baseline level of care and provide a mechanism for implementing quality improvement initiatives. The ACC, the American Society of Nuclear Cardiology (ASNC), the American Society of Echocardiography (ASE), the Society for Vascular Medicine and Biology, and the ACR strongly support accreditation of echocardiography, vascular ultrasound, and nuclear cardiology laboratories (11,12).

Table 1. Intersocietal Commission for Accreditation Members

Intersocietal Commission for Accreditation of Vascular Laboratories (ICAVL) (33)
Intersocietal Commission for Accreditation of Nuclear Laboratories (ICANL) (36)
Intersocietal Commission for Accreditation of Echocardiographic Laboratories (ICAEL) (46)
Intersocietal Commission for Accreditation of Magnetic Resonance Laboratories (ICAMRL)
Intersocietal Commission for Accreditation of Cardiac Computed Tomography Laboratories (ICACCTL)—under development

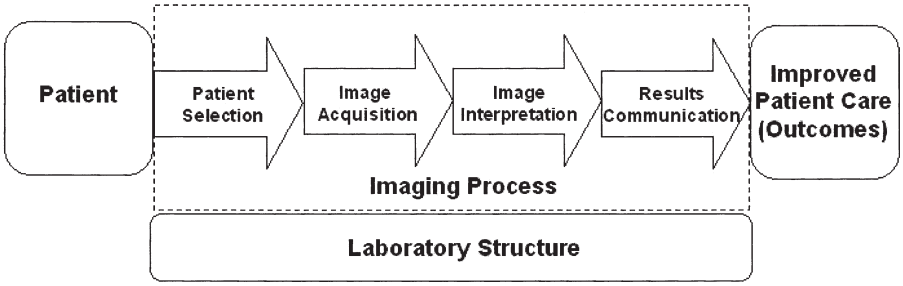

Figure 1. Dimensions of care framework for evaluating quality of cardiovascular imaging.

However, quality measurements beyond accreditation are needed for the following reasons: 1) accreditation identifies outliers who fall below baseline standards but provides less information on the quality of care delivered by typical performers who treat the majority of patients; 2) accreditation typically describes conditions during a snapshot in time, whereas ongoing monitoring for continued quality improvement is more desirable; and 3) the value of accreditation depends on the appropriateness of the accreditation criteria; for example, some accrediting bodies allow laboratories to select what will be reviewed, which may provide an unrepresentative assessment. Thus, the conference participants concluded that ongoing quality monitoring would be valuable even in accredited facilities, and should include novel quality indicators based on clear clinical evidence, validated on suitable patient populations, and amenable to appropriate standardization and risk adjustment.

QUALITY MEASUREMENT IN IMAGING

A taxonomy and model for evaluating cardiovascular imaging. The conference participants used methods described in recent reviews on creating quality measures (13). An initial step in creating quality measures is to define a model of the dimensions of care that defines a taxonomy for the imaging process and identifies areas for quality improvement (Fig. 1). The proposed model consists of 4 distinct domains of process that affect clinical outcome: patient selection, image acquisition, image interpretation, and results communication. Elements of laboratory structure (e.g., equipment, staffing, protocols, and infrastructure) influence and support the 4 process domains.

The process begins with the referral for a cardiovascular imaging procedure to address one or multiple indications. The first phase of assessing quality is to ensure appropriate patient selection for a particular study on the basis of evidence or consensus that it is reasonable, will affect medical decision making, and will lead to quantifiable patient benefits. Next is the acquisition of images using well-functioning equipment, proficient laboratory staff, and protocols that safely and reproducibly obtain diagnostic-quality images optimized for individual patients. The images are then interpreted with goals of high accuracy and reproducibility. Finally, test results must be communicated to referring physicians in a complete, clear, clinically relevant, and timely manner to optimize patient treatment and ultimately improve health outcomes.

Quality measures should be developed for each step in this conceptual framework. General concepts of cardiovascular imaging quality and potential action plan items are summarized in Table 2. Because certain quality elements are

Table 2. Quality Goals and Action Items in the "Dimensions of Care" Framework for Cardiovascular Imaging

	Quality Goals	Action Items
Laboratory structure	Ensure baseline standards for equipment and staff proficiency	Mandate laboratory accreditation Develop physician training and certification requirements Support technologist certification Develop additional laboratory accreditation processes for all modalities
Patient selection	Appropriateness	Develop appropriateness criteria for all imaging modalities
Image acquisition	Diagnostic quality images Patient safety	Define key acquisition elements of imaging protocols and sequences
Image interpretation	Reproducibility Accuracy	Develop standard methods for determining inter-reader and intrareader variability
Results communication	Interpretability Clarity Definitiveness Completeness Timeliness	Develop timeliness criteria Develop standards for completeness and definitiveness Define key structured reporting data elements Create structured reports for all modalities
Improved patient care (outcomes)	Satisfaction Impact on clinical management Morbidity Mortality	Develop standard methods for determining cross-modality correlation Develop methods for measuring patient outcomes and impact on medical decision making

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more relevant to particular modalities, a discussion of modality-specific quality issues follows in the text and in Table 3.

Quality in the dimensions of care for cardiovascular imaging. PATIENT SELECTION. The growth and costs of cardiovascular imaging have focused attention on how these tests are used (14). The goal of patient selection is to identify patients who would benefit from each imaging modality while minimizing inappropriate testing and optimizing the opportunity for imaging to define therapeutic strategies that improve patient outcomes. Simply stated, quality in patient selection means referring the right patient for the right test at the right time.

Appropriateness criteria can be a guide to whether an imaging procedure is a "reasonable" approach for a given clinical circumstance. In 2005, the ACC established the Appropriateness Criteria Working Group to describe indications for which imaging procedures may be considered appropriate for generating information that has positive consequences for a patient's care (15). Although many acceptable indications outside of these appropriateness criteria exist, measuring the degree of adherence to the clinical situations covered by such criteria would be valuable for assessing quality of patient selection. The ACR also developed appropriateness criteria for a variety of indications, including chest pain, but used a different approach (16).

The conference emphasized the importance of developing appropriateness criteria for each modality. Appropriateness criteria for myocardial perfusion imaging were recently published (17) with criteria for other modalities under development. The ACC and the American Heart Association in conjunction with Society for Cardiovascular Angiography and Interventions have published guidelines for coronary angiography that could serve as a foundation for appropriateness criteria (18).

One challenge in evaluating appropriateness is the limited patient information available to the imaging laboratory. Although the physician who supervises and interprets the study is ultimately responsible for quality, the imaging test is often performed solely in response to the referring physician's request without engaging the imaging specialist as a consultant. Educational efforts must also include providing ordering health care providers with the latest data regarding test performance and value for clinical applications.

Devising and implementing measures of appropriateness will require time-efficient methods of data collection of study indications and relevant clinical history. The consensus was that this clinical information should be provided by the referring provider to the imaging laboratory. As a first step, the conference participants recommended that the ACC and relevant imaging societies develop standardized information about test indications to provide feedback to referring providers about their test ordering behavior. Although more work is needed, optimizing patient selection is important because it impacts on downstream testing, procedures, and costs (19).

IMAGE ACQUISITION. High-quality image acquisition depends on modality-specific processes, including specific protocols and sequences that optimize the likelihood that images are of sufficient diagnostic quality. Adherence to such laboratory protocols could be a potential means of evaluating quality. Modality-specific quality measures may include quantifying causes of inadequate studies (e.g., excessive patient motion, lack of adequate contrast utilization, and so on), and use of "standard" modality-specific techniques (e.g., dose modulation for cardiac CT, gated single-photon emission computed tomography [SPECT] for nuclear cardiology, and so on). The availability and expertise of medical physicists are also important for optimizing image quality. Factors related to patient and staff safety such as radiation training and dosages, limiting use of potentially nephrotoxic contrast agents, and avoidance of metallic objects within a magnetic field can provide measurements of acquisition safety.

Accuracy and reproducibility can be evaluated with the use of standard phantoms. For example, a standard phantom for cardiac catheterization laboratories is available to assess image quality and radiation dosimetry (20). Alternatively, serial examinations or standardized patients may be used to assess ultrasound, nuclear cardiology, or cardiovascular (CMR) studies.

The skills, training, and certification of technologists who operate imaging equipment are also important considerations. Cardiovascular-specific specialty credentialing is available and encouraged for echocardiography (21) and nuclear medicine (www.nmtcb.org). There are also advanced certifications for technologists in MR and CT and vascular ultrasound. The percentage of studies performed by technologists with advanced credentials in imaging is a potential example of a quality measure of staff proficiency.

IMAGE INTERPRETATION. The training and expertise of physician readers are important standards for assessing the quality of image interpretation. Guidelines for physician training for each modality have been described by the ACC's Core Cardiology Training Symposium (COCATS) (22). Clinical competence statements have also been published recently for cardiac CT and MR imaging by the ACC and the ACR (23,24) and already exist for echocardiography (25), stress echocardiography (26), and nuclear cardiology (26). In addition, specialized examinations of physician proficiency are available in nuclear cardiology (Certification Board of Nuclear Cardiology, www.cbnc.org), echocardiography (National Board of Echocardiography, www.echoboards.org), and vascular ultrasound (American Registry for Diagnostic Medical Sonography, www.ardms.org).

However, high-quality imaging interpretation cannot be guaranteed simply by the certification of an imaging specialist. Providing objective evidence of accuracy and reproducibility should be a major component of quality in cardiac imaging. Mechanisms to assess accuracy include comparing the results from one study with those from a different

Table 3. Examples of Quality Measures and Action Items Proposed by the Cardiovascular Imaging Modality Working Groups

	Echocardiography	Vascular Ultrasound	Nuclear Cardiology	Cardiac CT	Cardiac MR	Diagnostic Angiography
Laboratory structure	• **Laboratory accreditation (ICAEL)** • % labs accredited* • % of studies by credentialed sonographers* • % of sonographers with advanced credentialing* • Interpreters with ≥ COCATS Level II training (tracking those with NBE certification)*	• **Laboratory accreditation (ICAVL, ACR)***	• **Laboratory accreditation (ICANL, ACR)** • % with laboratory accreditation • % of studies interpreted by CBNC-certified physicians	• Develop accreditation standards* (ICACCTL, ACR)	• Laboratory accreditation (ICAMRL, ACR) • % of MR technologists with advanced credentialing	• **Laboratory accreditation (JCAHO)***
Patient selection	• Develop appropriateness criteria* • % studies meeting appropriateness criteria	• **Appropriateness criteria** • Track indications of normal studies	• **Appropriateness criteria** • Develop instrument to evaluate appropriateness* • % studies meeting appropriateness criteria*	• **Appropriateness criteria** • Develop instrument to evaluate appropriateness* • % studies meeting appropriateness criteria	• **Appropriateness criteria** • % studies with indication recorded*	• Develop instrument to evaluate appropriateness*
Image acquisition	• Define minimum criteria for examination elements* • Formalize guidelines for use of contrast* • % studies performed with contrast	• % studies uninterpretable* • Repeat studies for reproducibility	• Compliance with existing imaging standards • % of nondiagnostic studies • Recording of corrective actions	• Develop standard protocols* • % complete studies • % studies uninterpretable • % studies using dose modulation • % studies with incidental findings	• Develop standard protocols* • % studies uninterpretable*	• Measure radiation dose • Annual radiation safety training • Contrast volume • Quarterly image quality assessment • Weekly conferences
Image interpretation	• Inter-reader and intrareader variability • Internet-based standard image set* • Ongoing quality improvement	• 5% or 50 studies reviewed • Physician interpretation examination	• Inter-reader and intrareader variability* • Internet-based standard image set • Evaluation of serial testing for variability • Time to reading high-risk findings	• 5% overread with examination of variability • Internet-based standard image set • Concordance with catheterization		• Inter-reader and intrareader variability
Results communication	• Define key report data elements* • Develop timeliness guidelines for reports • % studies with critical parameters (e.g., LVEF)	• Define key report data elements • Define timeliness guidelines for reports	• **Define key report data elements** • Develop timeliness guidelines for reports • % reports with complete data • >90% definitely reported as normal or abnormal*	• Define key report data elements*	• Define key report data elements • Develop timeliness guidelines for reports • Develop clarity guidelines	• Define key report data elements
Improved patient care (outcomes)	• Correlation with other modalities* • Cost effectiveness	• Correlation with other modalities*	• Correlation with other modalities • Rate of coronary angiography without CAD after abnormal perfusion study	• Rate of coronary angiography without CAD after abnormal CT angiogram*	• Correlation with other modalities • % uninterpretable studies • Patient and physician satisfaction survey	• Normal coronary angiography rates* • Data collection via ACC CathKit, NCDR*

Completed items in **bold**. *Highest priority items.

ACR = American College of Radiology; CAD = coronary artery disease; CBNC = Certification Board of Nuclear Cardiology; COCATS = Core Cardiology Training Symposium; CT = computed tomography; ICACCTL = Intersocietal Commission for Accreditation of Cardiac Computed Tomography Laboratories; ICAEL = Intersocietal Commission for Accreditation of Echocardiographic Laboratories; ICAMRL = Intersocietal Commission for Accreditation of Magnetic Resonance Laboratories; ICANL = Intersocietal Commission for Accreditation of Nuclear Laboratories; ICAVL = Intersocietal Commission for Accreditation of Vascular Laboratories; JCAHO = Joint Commission on the Accreditation of Healthcare Organizations; LVEF = left ventricular ejection fraction; MR = magnetic resonance; NBE = National Board of Echocardiography; NCDR = National Cardiovascular Data Registry.

imaging modality through periodic clinical conferences or analysis of computerized databases (27). Reproducibility can be quantified by measuring intrareader and interreader variation by selecting, on a regular basis, a master set of cases for review by each reader within a laboratory. Further evaluation could include a periodic external review of a set of studies by a core laboratory or other external reviewers. A standard set of images for common diagnoses could be created to calibrate interpretations and thereby reduce variability. Even the comparison of an older examination to the current study may serve as means of determining reproducibility. The effect of adding computerized quantitation to subjective interpretation to reduce variation and improve accuracy should be explored. Regardless of the approach taken, it is critical that some form of ongoing measurement of accuracy and reproducibility be performed routinely, and that reasonable standards for both are implemented.

RESULTS COMMUNICATION. Reporting unambiguous conclusions and developing image reporting standards are critical opportunities to ensure high-quality reports that are complete and easily interpreted by referring physicians. Standardized report formats have been published for echocardiography (28) and nuclear cardiology (29), although further delineation of report content is necessary because future electronic medical records will contain uniform structured data fields that span many modalities. The 17-segment model for left ventricular function is an example of collaboration between various cardiovascular imaging modalities to develop a common language (30). Each modality should identify the minimal set of data elements that compose a high-quality report. The ASNC has recently defined data elements to be used by nuclear cardiology reports with the goal of creating a uniform national database (31). Once structured reporting is in place, measures of quality can be developed such as the percentage of reports that contain specific data (e.g., ejection fraction in studies for which that measure is appropriate); the percentage that are "complete," containing all required data elements; or the proportion of reports with definitive conclusions rather than indeterminate results.

Imaging results must be communicated in a clear and timely fashion, and devising objective measures of timely reporting was encouraged. High-risk imaging findings must prompt the rapid notification of the ordering physician. Timeliness standards should be developed that are specific to the clinical situation and imaging modality. Finally, developing reporting mechanisms that assist referring providers by indicating the significance of particular findings may prove valuable.

IMPROVED PATIENT CARE AND CLINICAL OUTCOMES. Appropriate, high-quality imaging leads to improved decision making and patient care. However, clinical outcomes themselves did not emerge as a feasible initial quality measure. Although imaging provides abundant information regarding diagnosis and risk stratification, few randomized clinical studies have examined its effect on clinical decision making or patient outcomes; this is a fertile area for further research. Referring physician satisfaction is an indirect outcome but one that could be measured. Other potential measures include the rate of false-positive findings after comparison with a gold standard, or examining the rate of false-negative results that subsequently led to undesirable patient outcomes.

QUALITY MEASUREMENT BY CARDIOVASCULAR IMAGING MODALITY

Although many cross-modality quality themes were identified, each imaging modality had its own prioritization of quality measures during the conference (Table 2). These proposals are preliminary and need to be confirmed by each imaging society, but they represent early efforts for quality measurement development, as well as the consensus of conference participants.

Echocardiography. The ASE recommends mandatory laboratory accreditation through Intersocietal Commission for Accreditation of Echocardiographic Laboratories as a requirement for reimbursement (11), recommends image acquisition by credentialed sonographers and interpretation by physicians with at least COCATS level II training (11,32), and supports physician certification by the Examination of Special Competence in Adult Echocardiography from the National Board of Echocardiography (www.echoboards.org). Appropriateness criteria are in development by an ACC Foundation Working Group with participation by ASE. The ASE will assist in defining key elements of image acquisition (scan protocol), including appropriate rates of contrast use for left ventricular opacification. Development of data elements and structured reporting standards are necessary, as well as identifying items critical for inclusion in all reports (e.g., left ventricular ejection fraction). Recommendations for the timeliness of reports will be generated. Proposed interpretation quality measures include the use of web-based case studies to assess variation of interpretation and for comparison against a national gold standard. The Echo Tool Kit under development by the ASE may be a valuable tool for quality measurement and improvement.

Vascular ultrasound. Vascular laboratories must be accredited by Intersocietal Commission for Accreditation of Vascular Laboratories (ICAVL) (33) or the ACR (9) in most states to be eligible for reimbursement. A consensus document on clinical competence in vascular medicine has been published (34), and a vascular interpretation examination was recently initiated for physician credentialing (www.ardms.org/examinations/pvi.htm). The appropriate indications for vascular studies will be reviewed shortly (35). The working group recommended tracking the number of normal studies by referring physician, the rate of uninterpretable/non-diagnostic studies, and repeating a percentage of studies to determine reproducibility.

Metrics that define an adequate study need to be developed. The key data elements for a vascular laboratory report are defined by ICAVL (www.intersocietal.org/icavl/apply/standards.htm). Also recommended are internal and external review processes, including review of the lesser of 5% or 50 studies annually to establish intrareader and interreader variability.

Nuclear cardiology. The ASNC supports mandatory accreditation of laboratories and mandatory certification of physicians practicing nuclear cardiology by January 1, 2008; new laboratories should be allowed 2 years to become accredited (12). Laboratories can be accredited via Intersocietal Commission for Accreditation of Nuclear Laboratories (36); the ACR also mandates accreditation and provides an accreditation program (10). Physician certification can be obtained via the Certification Board of Nuclear Cardiology, and physician readers should have at least COCATS level II training (37). Appropriateness criteria for SPECT imaging have been published (17). The working group recommended that an instrument for measuring the appropriateness of individual procedures be developed and piloted in the near future. The first step is to ascertain the key elements needed to measure and assess the frequency of complete data. The percentage of interpretable studies should be determined in each laboratory, with a focus on corrective actions within a continuous quality improvement plan. Intrareader and interreader variability should be evaluated by review of a standard set of studies, either internal or Internet-based. The elements for structured reporting have been defined (31); quality metrics examining the completeness and definitiveness of reports are under development. The timeliness of reporting is critical, and timelines will be established and monitored for compliance. The impact of SPECT imaging may be assessed by the frequency with which patients with abnormal SPECT examinations referred for angiography are subsequently found to have normal coronary arteries.

Cardiac CT. Training guidelines were recently published for cardiac CT by the ACC (23,38) and ACR (24). Laboratory accreditation is under development by the Intersocietal Commission and the ACR. The ACC Foundation also published appropriateness criteria for cardiac CT in 2006 (39). The development of standard protocols such as dose modulation is critical. Radiation dosimetry and contrast usage are suggested metrics to monitor safety. It was suggested that the lesser of 5% of studies or 50 studies be over-read annually to assess interpretative variability, and that accuracy be directly evaluated by comparison with invasive coronary angiography. Standard reporting data elements will soon be identified, with a movement toward a standardized report. As measures of outcome, impact on catheterization laboratory referrals and false-positive CT angiogram rates may serve as initial quality metrics.

Cardiovascular MR. The Society for Cardiovascular Magnetic Resonance is working to provide a mechanism for accreditation under the Intersocietal Accreditation Commission umbrella. The ACR will also offer accreditation for cardiac MR imaging by early 2007. Established training requirements for the performance and interpretation of CMR studies published by the ACC and ACR (24,40,41) can ensure interpreter proficiency. The ACC Foundation has published appropriateness criteria for CMR (39), and methods for the evaluation of patient selection will follow, such as the frequency of an appropriate indication being included on an ordering form. The Society for Cardiovascular Magnetic Resonance will create standard scan protocols and publish imaging guidelines. Evaluation of intrareader and interreader variability and correlation with other modalities should be implemented and reviewed in each laboratory on a regular basis. Interreader variability assessments may require collaboration among multiple centers or the use of an Internet-based standard image set. Reporting standards are yet to be established, but key data elements will soon be identified. As potential initial outcome measures, patient and referring physician satisfaction should be evaluated.

Diagnostic angiography. A review of an invasive angiography laboratory is usually included within hospital accreditation by organizations such as JCAHO. Efforts are underway to develop appropriateness criteria for the use of diagnostic coronary angiography. Patient radiation exposure either by fluoroscopic time or dose area product should be tracked for all cases (42), because radiation skin injury is a JCAHO-reviewable sentinel event. As an additional measure of safety, contrast volume, complications, and risk-adjusted mortality should be assessed. Radiation exposure monitoring and annual radiation safety education should be provided to all employees involved with ionizing radiation (42). The working group discussed the importance of image acquisition quality assessment and dosimetry techniques such as the National Electrical Manufacturers Association Society for Cardiovascular Angiography and Interventions XR-21 phantom (20). Although considered essential, using a standardized phantom was not a formal recommendation at this time. Intrareader and interreader variability may be assessed through conferences or by review of standard images. Reporting of results should include key data that are subsequently incorporated into a standardized report. The working group is developing an outline of key elements for the catheterization report to assist the individual laboratory. Finally, the working group recommended participation in registry programs, such as the ACC National Cardiovascular Data Registry and use of quality improvement tools, such as ACC-CathKit, to provide valuable reference data regarding quality outcomes, including the rate of normal angiograms.

IMPLEMENTATION ISSUES

Achieving quality in cardiovascular imaging requires the sustained, coordinated efforts of many stakeholders. Professional organizations can play a pivotal role by defining what aspects of care ought to be measured, developing data standards and quality measures, and supplementing existing standards and guidelines. They must also convince their members of the benefits of participating in quality improvement initiatives and develop the tools to facilitate provider involvement. Subspecialty societies are encouraged to continue to establish committees whose focus is quality improvement and should form coalitions that can commit resources to supporting data collection, analysis, and reporting.

The Cardiovascular Imaging Collaborative of the ACC and cardiovascular imaging societies can coordinate professional society efforts and liaise with other groups such as payers. Its membership should be expanded to interested payers, regulators, credentialing/accreditation bodies, and quality experts. Both private and government payers must look beyond cost control and actively support quality initiatives. The Medical Directors' Institute, an ACC-led consortium of payers and physicians, has already identified cardiovascular imaging as a high priority and can establish formal lines of communication. The Cardiovascular Imaging Collaborative and ACC have also partnered with Integrating the Healthcare Enterprise (www.acc.org/ihe.htm) to provide a mechanism for promoting uniform data reporting and structured report formats for each modality, as well as connectivity and cross-domain document sharing among vendors across health information systems.

Approval and support from the provider community is essential. Although there may be reluctance from providers already encumbered with reporting requirements, history suggests that many are committed to quality improvement. Nonetheless, the initial approach must encourage participation and reward demonstrated quality and/or quality improvement.

Collecting even the simplest measures requires expertise, time, and money, even if the data collection is limited to an on-site local process. External and internal reviews carry additional costs for data transmission and review, particularly if a core laboratory or expert panel is involved. Information systems that incorporate quality assurance tools, such as proper ordering information, standardized reporting, and database construction, are also costly. However, we must invest in the processes and procedures that will improve cardiovascular care.

Concerns regarding the handling of medical errors detected in the quality assessment process are relevant. This process is driven by our desire to optimize patient care and create a mechanism for correcting errors without exposing a provider participant to liability. National efforts directed at reducing medication errors can be models (43).

RESEARCH ISSUES

Traditionally, imaging research has focused on pathological or physiological correlations, often with methodological limitations (44). Much less is known about the application of imaging in practice, including variability in patient referrals, imaging acquisition, interpretation, and reporting. There is a paucity of research on the incremental benefits of imaging in medical decision making and few rigorous comparisons of different diagnostic strategies on meaningful patient outcomes. Thus, existing guidelines are largely not evidence based, but rather formed by expert consensus, which limits the development of valid quality measures (45).

Table 4. Research Agenda for Assessing Quality in Cardiovascular Imaging

Evaluate current quality measurement programs and strategies for maintaining high performance and continuous improvement in cardiovascular imaging.
Identify important quality gaps in cardiovascular imaging.
Compare different cardiovascular imaging strategies and their impacts on clinical practice and outcomes.
Create evidence-based methods to validate new cardiovascular imaging quality measures.
Develop new clinical evidence when there is an absence of data that link appropriateness of cardiovascular imaging with improved patient outcomes.
Assess the benefits and unintended consequences of quality measurement of cardiovascular imaging.
Investigate feasibility of randomized clinical trials, registries, and decision-analytic models within cardiovascular imaging.
Conduct cost-effective analyses of cardiovascular imaging strategies and potential methods of collaboration between payers and providers.

Future research must expand beyond the traditional narrow focus on technology and test characteristics of individual modalities (Table 4). First, we need to understand how quality is currently measured and what are the best methods to ensure their continued effectiveness. Second, identifying specific gaps in care will be necessary to identify targets for quality improvement research. Third, comparisons of the benefits of different imaging strategies must be conducted in representative populations to identify optimal approaches to diagnosis in clinical practice. Fourth, comprehensive validation of evidence-based quality measures should be performed that assesses both the benefits and unintended consequences. Finally, future studies should include explicit considerations of cost.

Ideally, the benefits of new cardiovascular imaging technologies should be proven in rigorous randomized trials, but many important questions may not be amenable to the traditional clinical trials for ethical, cost, or feasibility reasons. In these cases innovative investigative approaches should be considered, such as the use of imaging registries that incorporate test indications, results of imaging, subsequent patient treatments, and health outcomes. Decision analysis also may be a useful approach for comparing the benefits, risks, and costs of different imaging strategies (46).

Regardless of the methods used, generating the data needed to optimize the use of cardiovascular imaging will require substantial resources. Because a natural alignment exists between the goals of practitioners, imaging quality researchers, and payers of healthcare services (whose budgets for cardiovascular imaging have increased exponentially), productive collaboration between investigators and payers should be explored.

CONCLUSIONS

The ACC–Duke quality in imaging meeting was an extraordinary collaboration of stakeholders in cardiovascular imaging that accomplished multiple important steps leading to improved quality. The consensus development of the dimensions of care framework for assessing quality identified common themes and concerns that lay the foundation for subsequent work for each imaging modality. It is hoped that each subspecialty society and its members will commit to move rapidly from theoretical discussions to the creation and implementation of specific measures. We anticipate an annual series of stakeholder meetings to encourage efforts, measure progress, and ensure coordination.

Strong leadership is needed to accomplish these perhaps costly, perhaps difficult, but necessary undertakings. To be successful, this effort will require commitments from a broad range of practitioners, payers, and policymakers. Committed individuals should work with the ACC, cardiovascular imaging societies, payers, and industry to continue to develop the tools and processes described. Each laboratory should embrace continuous quality improvement and implement agreed-on measures to achieve a high level of performance. It is a professional mandate for all stakeholders to ensure that cardiovascular imaging is subject to the same quality considerations as more invasive or potentially directly harmful treatments.

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APPENDIX 1. ACC–Duke Think Tank Participants

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APPENDIX 2. Writing Group Relationships With Industry

Committee Member	Research Grant	Speakers Bureau	Stock Ownership	Board of Directors	Consultant/Advisory Member
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Robert Hendel, MD, FACC	None	None	None	None	None
James Jollis, MD, FACC	None	None	None	None	None
Ami E. Iskandrian, MD, FACC	• CV Therapeutics • Molecular Imaging • GE • BMS • Astellas • Berlex • Pfizer	None	None	None	• CV Therapeutics • Astellas
Harlan M. Krumholz, MD, FACC	None	None	None	None	None
Frederick Masoudi, MD, FACC	None	None	None	None	• UnitedHealth
Emile Mohler III, MD, FACC	None	None	None	None	None
Robert L. McNamara, MD, MHS, FACC	None	None	None	None	None
Manesh R. Patel, MD	None	None	None	None	None
Eric Peterson, MD, FACC	None	None	None	None	None
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