American Society of Echocardiography Recommendations for Quality Echocardiography Laboratory Operations

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Ensuring a high level of quality in echocardiography is a primary goal of the American Society of Echocardiography (ASE). Establishing a definition of quality in cardiovascular imaging has been challenging, and there has been limited agreement on quality standards for imaging. Quality can be measured as adherence to established guidelines for the use of a technology to ensure patient satisfaction and outcomes. However, specific criteria to ensure quality must be established for each phase of the process, from considering a test for a patient to incorporating the results of the test appropriately into patient care. The purpose of this report is to provide a framework for echocardiographic quality assessment and improvement. Because this report builds on prior ASE efforts in this arena, some of the recommendations have been presented before.[1] Because this document establishes guidelines in the various components of quality in echocardiographic imaging services, the initial goal is to highlight general recommendations for minimum quality standards and provide some numerical or threshold values for compliance. Thus, the standards recommended in this document are realistic goals for the average practitioner. Although these recommendations focus on adult echocardiography, most are applicable or can easily be modified for pediatric, fetal, and intraoperative echocardiography. Objective studies linking quality measures in echocardiography to outcomes are frequently lacking, and thus statements expressed in this document are based primarily on expert opinion.

The committee used the "dimensions of care" framework for cardiac imaging reported recently.[2,3] This model divides the process of clinical echocardiography into the laboratory structure and the imaging process. The imaging process can be further separated into five areas that may influence patient outcome: patient selection, image acquisition, image interpretation, results communication, and the incorporation of results into care. In all of these domains, distinct benchmarks of quality can be established.

LABORATORY STRUCTURE

The laboratory structure can be divided into a minimum of four components: the physical laboratory, the equipment, the sonographer, and the physician. The ASE has previously addressed the issue of quality of the laboratory, sonographers, and physicians in its proposed local coverage determination (http://www.asefiles.org/LCD.pdf).

Physical Laboratory

Existing echocardiography laboratories should be accredited by the Intersocietal Commission for the Accreditation of Echocardiography Laboratories. New laboratories should have processes for moving the laboratories toward laboratory accreditation by submitting applications within 2 years of the onset of operation. The ASE recognizes that the process of lab accreditation is resource intensive and may require the commitment of additional personnel.

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Abbreviations

ASE = American Society of Echocardiography

CQI = Continuous quality improvement

LV = Left ventricular

LVEF = Left ventricular ejection fraction

RV = Right ventricular

TEE = Transesophageal echocardiographic

TTE = Transthoracic echocardiographic

Laboratory accreditation alone, however, is not sufficient, as there are facets of laboratory operation and needs for laboratory policies that are not currently addressed by the laboratory accreditation process of the Intersocietal Commission for the Accreditation of Echocardiography Laboratories. For example, in addition to the typical methods for requesting an echocardiographic study, a mechanism should be in place for ordering urgent echocardiographic studies and for communicating the urgency of studies to the laboratory staff members and interpreting physicians. This mechanism should be understood by all ordering physicians. Sufficient support staff members should be available to assist with scheduling and reporting of studies and to ensure the timely relay of results to ordering clinicians. Sufficient laboratory staff members must be able to recognize and respond to common medical emergencies and have competency in basic life support skills.

The laboratory space must have the necessary sanitizing equipment, ranging from a designated room to perform high-level disinfection of transesophageal echocardiographic (TEE) probes to necessary cleansing products for the transthoracic echocardiographic (TTE) transducers, ultrasound machines, and beds. Sinks and approved hand cleaners must be readily available in each area in which echocardiography is performed.

Equipment

The equipment available for the performance of echocardiographic procedures must be capable of performing two-dimensional, M-mode, and color and spectral (both flow and tissue) Doppler imaging. The display must be able to identify the institution, patient name, and date and time of study. The electrocardiogram and depth or flow velocity calibrations must be present on all displays. The machines should have the capability to display other physiologic signals, such as phases of respiration. If the laboratory performs stress echocardiography, a sufficient number of machines must have software that allows split-screen and quad-screen display for simultaneous image comparison. Transducers that can provide high-frequency and low-frequency imaging, as well as a dedicated nonimaging continuous-wave Doppler transducer, must be available for transthoracic imaging.[1] Pediatric laboratories must have transducers that cover the proper frequency range for high-resolution imaging of patients of the variety of sizes present in the pediatric population. Transesophageal imaging probes should be multiplane. All machines should have harmonic imaging capabilities and other instrument settings to enable the optimization of both standard and contrast-enhanced ultrasound exams.

Each machine must also have a digital image storage method that should be compatible with Digital Imaging and Communications in Medicine standards.[4] Study images must be maintained for the time period mandated for medical record retention in individual states.

Contrast agents and intravenous supplies should be available for staff members to use for patients who are difficult to image. Echocardiographic imaging beds, which include a drop-down portion of the mattress to facilitate apical imaging, are recommended. Equipment required to treat medical emergencies, including oxygen, suction, and "code" carts, must be available.

The accuracy of all laboratory imaging equipment should be tested, and laboratories should adhere to manufacturers' recommendations regarding preventive maintenance. The results of this testing and all service records for all equipment must be maintained in the laboratory.

Sonographer

Each sonographer should achieve and maintain minimum standards in education and credentialing within 2 years of the start of employment. This includes the initial education required to be eligible for credentialing exams and the continuing education required to ensure competency, maintain credentials, and become familiar with the latest technologies. Credentialing can be as a registered diagnostic cardiac sonographer through the American Registry of Diagnostic Medical Sonographers or as a registered cardiac sonographer through Cardiovascular Credentialing International. For sonographers who perform pediatric or fetal echocardiography, the minimum standard includes more specialized credentials. Some sonographers may be required to have a work experience component prior to eligibility for credentialing exams, and so it is recognized that laboratories may employ some sonographers who may not yet have credentials. However, in such circumstances, a credentialed sonographer should be immediately available to provide supervision. A majority of the echocardiographic studies in a laboratory should be performed by a credentialed sonographer, and a majority of the sonographers should have appropriate cardiac sonographer credentials. The laboratory should demonstrate a process aimed at having all sonographers credentialed. Local or state requirements, including licensure, may also exist for sonographers and must be fulfilled.

Physician

All physicians independently interpreting echocardiograms must have a minimum of level II training in TTE imaging as defined by the American College of Cardiology/American Heart Association/American College of Physicians-American Society of Internal Medicine Task Force on Clinical Competence in Echocardiography or its equivalent and must meet annual criteria to maintain that competence.[5] Those who trained prior to the incorporation of this level of training in fellowship programs must have achieved adequate training through an experience-based pathway and must meet annual criteria for maintaining competence.[5] Demonstration of special competency and board certification through passing a National Board of Echocardiography examination is desirable. Each laboratory should have a physician director who has completed level III training in echocardiography.[6] If this is not feasible, a combination of level II training and current certification from the National Board of Echocardiography is acceptable, though less desirable.

The different types of echocardiographic studies will require different levels of physician supervision. For diagnostic tests billed to the Centers for Medicare and Medicaid Services, specific levels of physician supervision are mandated. Currently there are three categories determined by the Centers for Medicare and Medicaid Services: those requiring "general supervision" (a physician provides general oversight and need not be on site), those requiring "direct supervision" (a physician must be in the office suite and immediately available), and those requiring "personal supervision" (a physician must be in the room). The physician lab director must ensure that the

various types of echocardiographic studies are appropriately supervised. At a minimum, the Centers for Medicare and Medicaid Services regulations should be followed. However, some laboratories may impose more stringent requirements.

IMAGING PROCESS

Patient Selection

The appropriate selection of patients for echocardiography is essential to the delivery of effective and cost-conscious care to avoid overuse, underuse, or misuse of echocardiography. Only when the prior probability of patient benefit is sufficiently high and exceeds the risks of the test should echocardiography be performed. The goal of processes to improve patient selection for echocardiography is to minimize inappropriate studies. However, it is recognized that criteria alone cannot be used to judge appropriateness, as individual patient considerations and physician judgment should take precedence over rigid adherence to published appropriate use criteria.[7,8]

To the extent possible, laboratories should track rates of appropriate and inappropriate requests for echocardiography by tracking the reasons for ordered studies and other patient information required to ascertain appropriateness. However, it is recognized that in current practice, echocardiography laboratories may not have sufficient clinical information or the resources available to determine the appropriateness of all studies. Nonetheless, it is reasonable that echocardiography laboratories should (1) ensure that all staff members understand the appropriate use criteria; (2) develop processes to reduce the number of inappropriate referrals, including the education of referring physicians; and (3) actively apply appropriate use criteria to selected procedures. On the basis of this understanding, the following recommendations regarding echocardiography utilization are made:

1. At a minimum, the American College of Cardiology Foundation and ASE appropriate use criteria documents pertaining to echocardiography should be available for review in every echocardiography laboratory. As part of its quality improvement program, each laboratory should formally review these criteria annually with all sonographers and interpreting physicians.[7,8] Appropriate use criteria cover the common circumstances for which echocardiographic exams may be used, but they are not intended to be all inclusive. Laboratories should also regularly review published performance measures related to imaging and national quality measures pertaining to cardiovascular ultrasound. In addition, laboratories should aim to develop and implement strategies to educate their referring providers about the appropriate use criteria, clinical scenarios in which echocardiography is commonly overused and underused, and other national standards pertaining to the optimal utilization of cardiovascular ultrasound. Multiple approaches will probably be necessary to influence physician practice behavior. Possible strategies include, but are not limited to, (1) the integration of these standards into the test ordering process, aligning the choices for procedural indication with the appropriate use criteria (see below); (2) direct mailings, faxes, or e-mails of the appropriate use criteria or summaries to referring physicians; and (3) explicit discussion of the appropriate use criteria and other optimal use standards at local continuing medical education conferences. Not all of these options will be achievable by all laboratories.
2. Because TEE imaging is an invasive procedure requiring performance by a specially trained physician and involves small immediate risks for serious adverse events, all echocardiography laboratories should carefully track appropriateness of referrals for this procedure. The primary operator should be knowledgeable about the patient's medical history and present state of health and the indication for the procedure. This level of involvement places the primary operator in a position to assess the appropriateness of the procedure he or she is being asked to perform, which should be systematically assessed for all TEE studies prior to their performance. Audits on a periodic basis of random samples of TEE reports and patient records for procedural appropriateness should be considered.
3. Similarly, for stress echocardiography, all echocardiography laboratories should monitor the appropriateness of referrals. The physician or the specially trained person who directly supervises the stress test should be knowledgeable about the patient's medical history and symptomatic status and the reason for the test so that he or she can confirm that the stress echocardiographic study is indicated and that the best mode of stress is used. Audits on a periodic basis of random samples of stress echocardiographic reports and patient records for test appropriateness should be considered.
4. In the future, for best practice, a level that may not be achievable by all, laboratories should develop processes that enable them to determine if each echocardiographic study is ordered appropriately or not. This would eventually allow for systematic review of the mix of appropriate and inappropriate indications, comparison with national norms, and feedback to ordering physicians.
5. With regard to other considerations, at this time, the benefits of systematic approaches to enhance the proportion of appropriate echocardiographic exams and the optimal strategies for achieving this goal have not been established. However, these recommendations provide quality metrics and a framework for internal practice assessment and improvement.

Other issues related to test utilization and patient selection should also be part of a quality echocardiography laboratory. These include the following:

1. Access: A mechanism should be in place that allows tracking of the wait times for both inpatient and outpatient echocardiographic studies, and each laboratory should have standards regarding the timeliness of test performance.
2. Test selection: A mechanism should be in place for the determination of the proper or best test components to be performed for each test request. This is to ensure that the correct components of a TTE or TEE study (i.e., rest, stress, limited, Doppler, three-dimensional, M-mode, shunt assessment) or the optimum stress modality (pharmacologic or exercise) is performed on the basis of the reason for the test and the characteristics of the patient.

Image Acquisition

Adequate image acquisition in echocardiography relies on a variety of components, including the patient's condition and body habitus, satisfactory ultrasound equipment, competent technical manipulation, and consistent methods of acquisition. Sonographer credentialing helps ensure quality by verifying knowledge of technology, image acquisition, and manifestations of disease. Laboratory accreditation verifies institutional practices relating to image acquisition, by mandating consistent and complete imaging protocols. The standard integration of two-dimensional, color, and spectral Doppler modalities is required to provide a comprehensive evaluation by TTE and TEE imaging. Assessment of the number of complete studies with all components (two-dimensional, color, and Doppler) reported provides a method to estimate compliance with current imaging standards. This should be measured for each sonographer annually.

Advances in technology have led to improvements in the visualization of cardiac structures with echocardiography. All laboratories must have quality assurance policies to minimize uninterpretable or nondiagnostic studies. Such policies might include the use of contrast or other imaging modalities. In patients with technically difficult images, left-heart contrast agents provide a tool to decrease the number of nondiagnostic procedures by enhancing endocardial border definition.[9] Laboratories should have written policies for the use of contrast agents. This should include the requirements for, and the content of, written orders for contrast administration, which may vary by site. Quantifying and monitoring the number of nondiagnostic exams

determines the effective integration of contrast in the echocardiography laboratory. A *complete* TTE or TEE study is one that images all cardiac chambers, valves, and great vessels from a series of multiple views and performs Doppler assessment of antegrade and retrograde flow across all cardiac valves, as well as the atrial and ventricular septa.

Sufficient time must be allotted for each study according to the procedure type. Forty-five to 60 minutes should be allotted for the acquisition of the images for a complete TTE study. An additional 15 to 30 minutes may be required for complicated cases.

All studies should document the patient's height and weight so that measurements can be indexed, when appropriate, to parameters of body size. Blood pressure and heart rate at the time of the examination should also be recorded.

Digital acquisition should include as many cardiac cycles as needed to accurately assess the cardiac structures. This may be one to two beats for image planes of normal structures, two or more beats for image planes that include abnormalities, and more extended captures for patients with arrhythmias, complex congenital heart disease, agitated saline contrast images or when diagnoses are being considered in which cardiac physiology or structure can be affected by the respiratory cycle.

The recommended images for a *complete or comprehensive two-dimensional* TTE study including spectral and color Doppler are listed in Table 1. For all imaging protocols, if any view or Doppler signal that is recommended cannot be adequately obtained, it still should be recorded to demonstrate that it was attempted.

Two-dimensional images should provide adequate endocardial definition to accurately assess morphology and motion. The images should be viewed in the standard planes, with all structures visualized within that plane. Measurements are performed and reported only when there is confidence that they are accurate and reproducible. If a measurement of a structure cannot be performed, a qualitative assessment of that structure should be included in the report unless that assessment is also not feasible. In valvular regurgitation, a minimum of two imaging planes should be used to evaluate color flow Doppler. In valvular stenosis, multiple views should be used to evaluate the degree of stenosis and to obtain the highest flow velocity across the stenotic valve. For aortic stenosis, for example, this should include interrogation from at least three views. Quantitation of right ventricular (RV) systolic pressure (and thus pulmonary artery systolic pressure in the absence of pulmonic stenosis) should always be attempted whenever tricuspid regurgitation is present. If the tricuspid regurgitation jet signal is weak and the estimation of pulmonary artery systolic pressure is clinically important, enhancement of the Doppler signal with agitated saline is recommended. The nonimaging continuous-wave Doppler transducer should be used from multiple windows in all cases in which the severity of valvular stenosis or the RV systolic pressure is equivocal from the continuous-wave Doppler velocity profile obtained by other transducers. A complete exam should be performed whenever possible, the exceptions being when completing a full exam would delay critical treatment and when a previous complete echocardiographic study has been performed within a reasonable period of time and the issue to be readdressed was among those fully assessed on the initial exam (e.g., "Is a pericardial effusion still present?").

Limited TTE exams can be tailored to specific patient needs and diagnostic information. This exam should be performed only if the patient has had a complete transthoracic exam performed within a reasonable period of time and a repeat exam is requested to reassess a specific issue well documented on the prior exam. They should include all views necessary to answer the question (e.g., flow variation for pericardial effusion, color and specific site sampling for valvular heart disease, and follow-up ventricular function assessment should include diastolic and systolic measurements). It is anticipated that most limited studies will incorporate no more than 30% of the components of a complete transthoracic exam.

Stress echocardiography should be performed only on echocardiographic equipment that can trigger the acquisition from the electrocardiogram. The equipment must be able to display images in side-by-side and quad-screen formats both by stage and by view. The system should have the editing capability to reduce the time duration of the image clips to allow review of portions of the cardiac cycle. Other equipment required includes a 12-lead electrocardiographic system, a blood pressure cuff, and a mode of stress (i.e. treadmill, bicycle, or drugs for pharmacologic stress). As with any stress testing laboratory, resuscitation equipment and medications must be available. For pharmacologic stress echocardiography, a protocol must be established that specifies the pharmacologic stress drug, its doses, times of change in dose, maximal dose, end points and guidelines for use of other drugs. The required images for exercise and pharmacologic stress echocardiography are listed in Table 2 and discussed in detail in the ASE guidelines and standards document for stress echocardiography.[10]

A *complete TEE* study should be performed in a methodical fashion using a specific protocol. The specific echocardiographic views and the order of the views may vary in TEE imaging protocols as a function of the question being posed. A sample TEE imaging protocol can be found in Table 3.

For all of the exams described above, a clear electrocardiographic signal must be present on the recorded images. For the assessment of various diseases, such as valve stenosis, valve regurgitation, diastolic dysfunction, and the quantification of cardiac structures, the specific imaging recommendations discussed in the respective ASE guidelines and standards documents should be followed.[11-19]

A consensus statement for the use of *echocardiographic contrast agents* has recently been published by the ASE.[9] Contrast can be combined with any of the echocardiographic examinations described above. For resting studies, contrast should be used in patients with poor endocardial border visualization, especially for quantification of chamber dimensions, volumes, and ejection fraction and for the assessment of regional wall motion. Poor endocardial border delineation is defined as inability to adequately visualize two or more contiguous segments in any of the three apical views. Contrast should also be used to assess conditions such as apical hypertrophic cardiomyopathy, noncompaction of the left ventricle, for enhancement of poor spectral Doppler signals, or when left ventricular (LV) thrombus is suspected. For stress echocardiography, contrast should be used when resting images show inadequate endocardial definition for detection of LV wall motion in each coronary artery territory or when adequate images cannot be obtained quickly during stress. When contrast is used appropriately, <5% of TTE studies should be identified as nondiagnostic for the assessment of LV function, and <10% of stress echocardiographic studies should be nondiagnostic for the assessment of regional LV function.[20,21]

Recommendations for tracking quality of the image acquisition process are presented below under "Quality Assessment and Implementation of Quality Improvement Programs."

Image Interpretation

Physicians must allocate sufficient time for image interpretation. The complete TTE interpretation must include assessment of all cardiac

Table 1 Recommended images for complete adult 2D transthoracic echocardiography with Doppler*

Parasternal long axis
2D image
M mode of left ventricle and left atrium/aorta (if lab standard)
Color flow Doppler of valves
RV inflow view
Color and spectral Doppler
Parasternal short axis
Short-axis view at the aortic valve level and RVOT
Color flow Doppler should be used to evaluate pulmonic, aortic and tricuspid valves
Spectral Doppler of RVOT and pulmonic valve
Left ventricle at MV level
Left ventricle at mid level
M mode if lab standard
Left ventricle at apex
Apical four chamber
2D imaging of the four chambers (maximizing length of left ventricle)
Color flow Doppler of valvular inflow and regurgitation should be assessed at the valves
Pulsed-wave Doppler of all valves should be assessed
Pulsed-wave Doppler of pulmonary veins (for diastolic function)
Doppler tissue imaging (for diastolic function)
Strain and strain rate are optional
CW Doppler to evaluate valves
Multiple views should be used to get highest velocity of abnormal flows.
Transmitral color M mode is optional
Color Doppler of interatrial septum
Apical five chamber
2D imaging
Color flow Doppler of LVOT
Pulsed-wave Doppler of LVOT if aortic stenosis or insufficiency is present or suspected or for calculation of stroke volume/cardiac output
CW Doppler of aortic valve if aortic stenosis is present or suspected
Apical two chamber
2D imaging
Color flow Doppler of MV
Apical long axis
2D imaging
Color flow Doppler to visualize aortic and mitral forward and regurgitant flow
Pulsed-wave Doppler of LVOT if aortic stenosis or insufficiency is present or suspected or for calculation of stroke volume/cardiac output
CW Doppler of aortic valve if aortic stenosis is present or suspected
Subcostal views
Four chamber
2D imaging, including assessment of interatrial septum
Color flow at interatrial septum to assess for shunt
Short axis
Complementary to parasternal views
IVC assessment
IVC images to evaluate size and dynamics
Doppler of hepatic veins, when appropriate
Suprasternal notch
Long-axis view of the aortic arch
Pulsed-wave Doppler in descending aorta in cases of aortic regurgitation
Other views as indicated for further clarification or assessment of specific pathologies
Right parasternal view
Long-axis view to evaluate the ascending aorta
Agitated saline contrast
At rest and with release of Valsalva maneuver for intra-cardiac or intra-pulmonary shunting

In the setting of aortic valvular stenosis (native or prosthetic), a CW Doppler transducer should be used in at least three positions from among the apical, right sternal border, suprasternal notch, and subcostal windows. If an imaging CW Doppler transducer is used, the nonimaging CW Doppler transducer should be used from the multiple transducer positions when the initially obtained velocity profiles are inadequate or equivocal. The use of this nonimaging probe for other valve lesions is at the discretion of the individual laboratory.
CW, Continuous-wave; *IVC*, inferior vena cava; *LVOT*, LV outflow tract; *MV*, mitral valve; *RVOT*, RV outflow tract; *2D*, two-dimensional.
*For each image plane, it is assumed that the depth is optimized to include all structures in that view.

structures, cardiac function and the performance of all measurements when technically feasible. Errors of omission on the interpretation can be avoided by following a list of structures and measurements to be included in the interpretation, such as those listed for TTE imaging in Tables 4 and 5. Additional elements will be required for some cases depending on the indication for the examination and the findings. Measurement conventions have been previously reported by the ASE.[11] The amount of time required to interpret a complete TTE study will vary depending on the complexity of the study, the equipment used for the interpretation and report generation, and the experience of the reader.

Interpretation of limited transthoracic examinations focuses on a smaller number of the key elements. TEE studies may be complete exams assessing all structures or focused exams of a particular structure or abnormality. Thus, the interpretation elements of the TEE study will vary depending on the extent of the image acquisition and complexity of the study. Stress echocardiography interpretation includes at a minimum an assessment of regional and global LV function at rest and stress and an overall interpretation of the findings. Depending on the reason for the study, the stress echocardiographic study may require quantitation of valvular regurgitation, stenosis, diastolic function, or RV systolic pressure. The electrocardiographic portion of the stress test may be interpreted as part of the stress echocardiogram or separately.

The interpretations should also include a summary or synthesis of the findings so that the key abnormalities are highlighted, particularly if a series of abnormalities all support a unified finding or diagnosis. The interpreting physician should also correlate the findings with the reason for the study. Last, a comparison with the images from at least the most recent prior study should be performed to highlight findings that are new, unchanged, or progressive. The details of this comparison must be provided in the summary or conclusion section.

Results Communication

Components of this part of the imaging process include key elements for reporting the interpretation (the "report"), amending the report,

Table 2 Stress echocardiography: required images

1. Two-stage exercise stress echocardiography
a. Baseline images: images must be obtained at appropriate depths to focus on LV function
i. Parasternal long axis
1. May be substituted with apical long axis
ii. Parasternal short axis at mid LV level
1. May be substituted with subcostal short axis
iii. Apical four chamber
iv. Apical two chamber
b. Peak or postexercise images
i. Same four images as baseline
2. Four-stage pharmacologic stress echocardiography
a. Baseline images
i. Same as in two-stage exercise echocardiography
b. Low-dose images
i. Same image planes as in baseline
c. Peak-dose images
i. Same image planes as in baseline
d. Secondary images, such as prepeak, second set of peak, or recovery
i. Same image planes as baseline

Images must be the same plane and depth as baseline images to assess for ischemic changes. If all segments cannot be visualized, contrast should be used. The images must be acquired within 60 sec after exercise if performed on a treadmill. The images should be acquired at peak exercise when performed on a supine bicycle. For supine bicycle stress echocardiography, images can also be acquired during early stages of exercise.
Baseline images prior to stress should include a screening assessment of cardiac chambers and valves unless this assessment has been recently performed.[9]

Table 3 Recommended transesophageal imaging planes

1. Midesophageal views
a. Four-chamber view
b. View of left atrial appendage
c. Two-chamber view of left ventricle
d. Cross-commissural view of MV
e. Long-axis view of left ventricle, MV, aortic valve, and aortic root
f. Short-axis view at the level of the aortic valve
g. Views of pulmonic valve, pulmonary artery and bifurcation
h. Bicaval view
i. Views of pulmonary veins
2. Transgastric view
a. Short-axis view of left ventricle
b. Two-chamber view of left ventricle
c. Long-axis view of left ventricle (includes LV outflow tract)
d. Long-axis view of right heart
e. Short-axis view of right heart
3. Views of descending thoracic aorta
a. Short axis
b. Long axis
4. Views of aortic arch
5. Views of ascending aorta

Two-dimensional imaging of each of these standard image planes can be obtained by adjusting the transducer angle along with withdrawal, advancement, flexion, retroflexion, and/or rotation of the probe. Color flow Doppler of all four valves and the atrial septum should be performed. Spectral and continuous-wave Doppler should be performed when assessments such as RV systolic pressure, diastolic LV function, valve gradients, pulmonary venous flow, or left atrial appendage velocities are necessary. Agitated saline may be required to assess shunting at the level of the interatrial septum.
MV, Mitral valve.

timeliness of reporting, and reporting of critical results. Quality can be assessed in each of these areas as compliance to standards.

Key Elements of the Echocardiographic Report. All echocardiographic reports should follow a uniform outline and common language that includes notation of key elements of cardiac structures and cardiac measurements so that all reports for a laboratory are similar in structure and wording.[22-24] Laboratories should strike a balance between an overly lengthy report and one that is too abbreviated by providing a list of evaluated cardiac structures with concise statements on both cardiac anatomy (structure) and function that are appropriate for the pathology at hand. Although a simple notation of normal implies both normal structure and function, when there is an abnormality of a specific cardiac structure, the report must include comments on both the anatomy and function of that structure. An electronic reporting system will best facilitate compliance, but a worksheet with structured elements is an adequate alternative.

Specific key elements of the report must include (1) demographics, (2) echocardiographic findings, and (3) a summary statement. Demographics must unambiguously identify the patient, the reason for the examination, and where the recorded images are archived (Table 6).[23,24] Echocardiographic findings include measurements and qualitative assessment of the cardiac structures imaged (Tables 4 and 5). If required structures are visualized inadequately, so that an assessment cannot be completed, this should be noted rather than leaving out the required element in the report. The summary statement should identify the salient findings and abnormalities, correlate them to the reason for the study, and compare them with old studies.

Reports should include all key elements, findings, and a summary to be considered complete. The technical quality of the study should be clearly noted. Technically suboptimal exams may not allow for full completion of all findings, and this should be noted on the report. Image acquisition omissions that require a patient to undergo additional imaging in a second session should be separately documented and the report amended once the patient has completed all aspects of the study. Such amendments to the original report must be clearly identified, along with the date of the additional assessment. The dates of any amendments to the original report and signatures of those providing amended interpretations must be clearly identified in addition to the date and signature of the original interpretation.

The final report must be reviewed and signed by the interpreting physician. Documentation of the date and time of signing must be available. If the report is electronically signed, the laboratory must have policies for security and limited system access, use of operational and authority checks, compliance, and privacy enforcement with system administrators. This must include a log of the name, date, and time of all who reaccess or modify the electronic report.

Report Amendments. Amended reports, including changes to the interpretation, must include the time and date of the amendment. The key difference between the initial or prior amended reports should be included in the summary. If the amendment results in

Table 4 Recommended TTE findings

Left ventricle
Left atrium
Right atrium
Right ventricle
Aortic valve
Mitral valve
Tricuspid valve
Pulmonic valve
Pericardium
Aorta
Pulmonary artery
Inferior vena cava
Pulmonary veins
Interatrial septum
Interventricular septum

Each structure should be characterized by (1) size and function, (2) measurement of an object in the section, (3) spectral or color Doppler exam, or (4) a comment that the structure was not well visualized and could not be evaluated. For pediatric exams, additional structures are included, such as coronary arteries. For a limited study, the exam is focused, and the report does not need to include a comment on all sections.

Table 5 Recommended TTE measurements

LV internal dimension at end-diastole
LV internal dimension at end-systole
Posterior wall thickness
Interventricular septum
Left atrial anteroposterior dimension
Aortic root
Ascending aorta
Valve and Doppler measurements
LV volumes
Left atrial volumes
LV ejection fraction
RV size
RV systolic function
RV systolic pressure
Regional LV function
Segment-by-segment assessment: normal, hypokinetic, akinetic, dyskinetic, not visualized
LV diastolic function

Table 6 Demographics required on report

Patient first name
Patient middle name
Patient last name
Patient name alternate (i.e., maiden name)
Unique patient identifier
Date of birth (ddmmyyyy)
Sex
Indications for the test
Free text
List of descriptors tied to ICD codes
Height (in or cm)
Weight (lb or kg)
Referring physician identification
Interpreting physician identification
Media location
Date and Coordinated Universal Time
Study ordered
Study performed
Study interpreted
Report transcribed
Report verified
Report amended
Location of patient
Outpatient
Inpatient
Room location
Location where study performed
Sonographer performing exam
Transcriber name
Echocardiographic instrument identifier
Description of study quality
CPT codes or descriptors of exams performed

CPT, Current Procedural Terminology; *ICD*, International Classification of Diseases.

a substantial change, then a notation in the summary should describe the action taken (e.g., "ordering physician notified by telephone").

Timeliness of Report. Studies should be categorized as stat or routine. Stat reports should be interpreted and communicated by a qualified physician immediately, if possible, and final transcribed reports should be available by the end of the next business day. Routine studies should be interpreted by a qualified physician and a report available within 1 business day, while the final transcribed report should be available within 48 hours after interpretation. Preliminary reports should be prepared in a manner consistent with current Intersocietal Commission for the Accreditation of Echocardiography Laboratories guidelines. Notations by sonographers should never be used for clinical management or final reporting.

Critical Values. Each laboratory should have a policy for reporting critical values and a method to communicate these findings to the referring physician. Possible critical values might include aortic dissection, a new large pericardial effusion, findings consistent with cardiac tamponade, a new cardiac mass or thrombus, new severe LV or RV dysfunction, new valvular vegetations, new severe valvular regurgitation or stenosis, and high-risk stress echocardiographic findings. Documentation of physician-to-physician communication of the critical values must be present in the report, an addendum, or the patient's medical record. The laboratory should have a procedure for tracking compliance of this reporting policy.

Incorporation of Results Into Care. Although echocardiography laboratories are not directly responsible for revising care plans on the basis of the results of echocardiograms, they often represent a unique locus of expertise on how best to place those results into the context of a patient's illness. Accordingly, echocardiographers not only should be skilled in the interpretation of images but should aim to develop and implement strategies to educate their referring providers about what echocardiography can and cannot measure, when to use it, and what findings mean for both diagnostic and therapeutic decision making. Multiple strategies may be effective, from direct communication and case discussion with a referring

Table 7 Recommended elements to be assessed on reviews of quality of echocardiographic interpretation

Transthoracic echocardiography
Chamber and aorta sizes
LV wall thickness
Global LV function
Ejection fraction
Regional LV function
Location and severity of regional wall motion abnormalities
Diastolic function
RV function
Valvular structure and function: quantitation of regurgitation and stenosis
Quantitation of RV systolic pressure
Recognition of major abnormalities
Transesophageal echocardiography
Assessment of valvular structure and function: quantitation of regurgitation and stenosis
Global LV function
Ejection fraction, when possible
Regional LV function, when possible
RV function
Assessment of ascending and descending aorta
Recognition of major abnormalities (including left atrial appendage thrombus)
Stress echocardiography
Resting and peak stress global LV function
Resting and peak stress regional LV function
Low-dose dobutamine regional LV function (when applicable)
Resting and peak stress LV size
Adequacy of stress test (target heart rate or workload)
Overall conclusion

physician at the time an unusual or unexpected finding is noted to regular continuing medical education conferences.

QUALITY ASSESSMENT AND IMPLEMENTATION OF QUALITY IMPROVEMENT PROGRAMS

Image Acquisition

On a quarterly basis, laboratories should quantify the percentage of complete and limited studies performed in aggregate and by individual sonographers. Completeness of echocardiographic acquisition is judged not just by the inclusion of all views but also by visualization of all structures in those views. Annual review of five to 10 studies per sonographer (TTE imaging) and physician (TEE imaging) should be performed to quantify adherence to the imaging protocol. On these cases being reviewed, a minimum of 90% of the component images of the appropriate protocol should be performed. For valve stenosis cases, at least 90% of the echocardiographic image sets reviewed should include all the components necessary for quantification of peak instantaneous valve gradient, mean valve gradient, and valve area.

Image Interpretation

To improve quality and consistency in the echocardiographic interpretations among all members of the laboratory, a continuous quality improvement (CQI) plan consisting of case reviews and cross-modality comparison is recommended. Many aspects of a CQI process for echocardiography have been presented before.[1]

On a quarterly basis, at least two echocardiograms for each modality (i.e., TTE imaging, stress echocardiography, TEE imaging) interpreted by each reader should be randomly selected and blindly interpreted by another echocardiographer. The interpretations should be compared and differences noted. Recommended elements for this assessment are listed in Table 7. Documentation of a measured LV ejection fraction (LVEF) should be included on at least 90% of TTE interpretations.

On at least an annual basis, the quantitative results of 4 TTE studies for each interpreting physician should be compared with other tests. For example, these could include comparisons of LVEF, valve gradients, and areas or presence of pericardial tamponade. Ideally, at least one of the comparisons should be of aortic or mitral stenosis gradients and valve area compared with the results of catheterization. For those who interpret stress echocardiograms, an annual comparison of the results of four stress echocardiograms with other tests documenting coronary artery disease should be performed. For those who perform and interpret TEE studies, an annual comparison of the results of four exams should be performed with complementary imaging tests or operative or pathologic findings.

Laboratories should develop processes to annually assess the interobserver and intraobserver variability in LVEF and valve regurgitation assessments by all interpreting physicians. In addition, a process must be in place to reduce such variability. For example, goals of this process could be that intraobserver variability for LVEF be within 10 percentage points of each other on two measurements, that interobserver variability for LVEF be within a similar range, and that variability for valve regurgitation be a difference of one grade or less.

A written summary of each interpreter's performance in all of the above areas should be maintained. This summary or log should provide details of the key findings of each study so that over time, efforts can be made to ensure that each interpreter will have studies evaluated that demonstrate normal findings, abnormal LV function, abnormalities of regional LV function, at least moderate valve disease, cardiac tamponade, and congenital heart lesions.

On at least an annual basis, the studies that have significant variances between interpretations or with the comparison test should be reviewed by all members of the laboratory during a conference, and the proceedings of this meeting should be documented in the CQI log. In addition, the meeting or series of meetings should include review of the current criteria for quantifying key findings such as valvular stenosis and regurgitation and LV function.[11-15] For example, presentation and discussion of cases that demonstrate varying degrees of valvular regurgitation and LV function will help all participants (1) understand the guidelines, (2) establish consistent lab criteria for these conditions, and (3) reduce variability among all interpreters. The goal of such a process is to improve thoroughness and accuracy of interpretation and to reduce laboratory variability.

It is recognized that providing a single recommendation or formula for CQI to be applied to laboratories of different sizes may not be ideal. For example, comparing echocardiographic results with those of other imaging modalities for internal validation may be challenging in smaller laboratories if multiple imaging modalities are not present at one site. Overseeing the quality process can be time consuming, and in some laboratories, a specific position with adequate time dedicated to this process will be necessary. It is also recognized that these types of reviews may need to be different in the different settings. For

example, in a hospital setting in which competing practitioners might undergo this review together, it may best be done in the setting of a formal peer review, which accords proper legal protections. Regardless of the setting or the specific process, the goal is to provide feedback to the laboratory members in the spirit of learning and quality improvement, while keeping in mind that reasonable and equally competent people can sometimes differ in their review of echocardiographic results.

Results Communication

At a regular interval, randomly selected reports from each interpreting physician should be reviewed for completeness and timeliness. In addition, compliance with reporting of critical values should be assessed. Ideally, the results of these reviews should be discussed at a regular quality assurance laboratory meeting.

CONCLUSIONS

A goal of the ASE is that the ordering, acquisition, interpretation, and communication of all echocardiographic studies adhere to high-quality standards. The recommendations presented in this document, although only advisory, are realistic goals for all. We expect that many of the recommendations presented here will be refined and redefined over time. It is our hope that following such standards will lead to continued quality improvement, patient and provider satisfaction, and improved patient outcomes.

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