American Society of Echocardiography/ Society of Cardiovascular Anesthesiologists Recommendations and Guidelines for Continuous Quality Improvement in Perioperative Echocardiography

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The American Society of Echocardiography (ASE), established in 1975, has long encouraged the assessment of quality in the practice of echocardiography. To that end it has published and continues to develop documents establishing guidelines for the practice of echocardiography.[1-8] In 1995, the ASE published a series of recommendations specifically for continuous quality improvement (CQI) in echocardiography.[9] The accelerated growth of the clinical application of echocardiography combined with the complexity of ultrasound technology, conduct of examinations, and interpretation of results were cited as some of the reasons for developing a CQI program. In the following document, the ASE and the Society of Cardiovascular Anesthesiologists (SCA) seek to establish recommendations and guidelines for a CQI program specific to the perioperative environment. Using the prior ASE publication on CQI as the foundation, we will: (1) present a rationale for CQI in the perioperative period; (2) define the components of a perioperative echocardiography service; (3) establish the principles of CQI as they relate to the practice of perioperative echocardiography; and (4) assess whether CQI programs are effective in the perioperative period. The recommendations and guidelines set forth in this document are to be applied to any echocardiographic procedure performed in the intraoperative period and to any in the immediate preoperative or postoperative period when it is performed independently of the CQI program of an established Level III echocardiographic service.

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RATIONALE FOR ASSESSING QUALITY

The integration of continuously evolving and complex scientific principles and technology into the health care environment can sometimes be challenging. In the last decade, the use of echocardiography in the perioperative period and, in particular, intraoperative transesophageal echocardiography (TEE) has expanded rapidly. The conduct, interpretation, and clinical application of echocardiography in the perioperative environment are complex and require appropriate knowledge, technical skills, and complete familiarity with operative concerns. Moreover, diagnostic interpretation of these examinations has been reported to vary widely, especially during congenital heart surgery.[10] CQI programs are, therefore, equally necessary in the perioperative environment. CQI is recommended for physicians performing and interpreting perioperative studies to ensure comprehensive data acquisition and accurate interpretation. In addition, a CQI program may be used to assess and prevent underuse, overuse, or misuse of perioperative echocardiography.

In the last 5 years, the goal of improving quality in health care has gained national prominence, triggered in large part by a publication on medical errors from the Institute of Medicine (IOM).[11] This report galvanized the public and private sectors and

the medical profession into a collaborative effort at building a safer health care system. A centerpiece of that strategy has been the assessment and improvement of quality in health care delivery. Recently, the Centers for Medicare and Medicaid Services have initiated several programs to improve quality in health care services that can best be described as "pay for performance."[12] The first of these initiatives aims to improve quality of inpatient care to Medicare beneficiaries by providing financial incentives. Given the purported early success of this program,[13] expansion of the program to all health care services including echocardiography should be anticipated. Perioperative echocardiographers who establish CQI programs and demonstrate improvements in quality measures of their practice are likely to be well positioned for this future.

DEFINITIONS FOR CQI

Perioperative Echocardiography

Perioperative echocardiography involves the use of cardiac ultrasound in surgical patients immediately before, during, or after their operation, and includes transesophageal, epicardial, epiaortic, and transthoracic approaches. Practice locations may include the operating room, recovery room, intensive care unit, and echocardiography laboratory. The various modalities that comprise perioperative echocardiography include M-mode and 2- and 3-dimensional imaging and pulsed wave, continuous wave, color flow, and tissue Doppler. The echocardiographic data are obtained in real time and interpreted by a physician in a timely manner to direct the clinical treatment of surgical patients. These techniques may be combined with a variety of adjuncts such as contrast agents, and may be used during a variety of physiologic conditions including pharmacologic stress.

CQI

The IOM has defined quality as "the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge."[14] CQI is a management methodology adapted by health care providers from business and industry that is designed to identify and analyze problems in health care delivery. More importantly, once a problem is identified, CQI encourages the development, testing, and implementation of solutions without assigning blame. The essential elements of CQI include an "orientation towards customers and systems (processes), a commitment to understanding and minimizing process variations, and the development of teams that can broaden vision and implement solutions."[15] CQI in perioperative echocardiography is a continual process characterized by 3 assumptions about quality: (1) technologic advancements in echocardiography may redefine quality and, therefore, the ensuing recommendations; (2) assessments of quality often require comparisons; and (3) quality is enhanced by repetitive practice.[9]

COMPONENTS OF PERIOPERATIVE ECHOCARDIOGRAPHY

Equipment and Recording

An ultrasound machine with full diagnostic capabilities is required to provide a comprehensive perioperative echocardiographic examination. At a minimum, the system should be equipped with the capacity for 2-dimensional Doppler (pulsed wave, continuous wave, and color flow), and M-mode imaging. Each console should have a video screen that can be made visible either directly or by another monitor screen to the surgeon and other clinicians responsible for the patient's medical care. All ultrasound systems must also possess a system for permanently recording data onto a media format that allows for offline review or analysis. Recently, the ASE made an unequivocal recommendation for an all-digital capture, storage, and review process.[7] All perioperative echocardiographers are, therefore, urged to move toward this digital standard by incorporating the Digital Imaging and Communications in Medicine (DICOM) format, high-speed networking, and permanent storage with built-in redundancy.[7] TEE probes used in the perioperative period should be capable of multiplane imaging.

Request for Echocardiographic Services

In nonemergency settings outside of the operating department, a request for an echocardiographic examination should be activated by an order in the patient's hospital chart. The intraoperative setting, however, is unique in that medical therapy delivered therein does not require individual and specific orders recorded on an order sheet. Because delivered therapy is always documented on the anesthesia record, intraoperative echocardiographic services may be requested by the anesthesiologist and documented on the anesthetic record. In many institutions, requests for intraoperative therapy are made by the surgeon and, thus, requests for intraoperative echocardiographic services may also be listed on the posted surgical schedule. In all instances, the indications for performing perioperative echocardiography should be documented clearly in the patient's medical record, either in the anesthesia record or on the report of echocardiographic findings.

Patient Interactions

The decision to perform perioperative echocardiography begins with a careful clinical history and physical examination that is used to detect relative or absolute contraindications to performing the examination (eg, unstable neck injuries, esophageal trauma, varices, strictures, cancer, dysphagia, active upper gastrointestinal bleeding, or a history of chest radiation). Clinical information such as heart failure, coronary artery disease, atrial fibrillation, stroke, structural heart disease, or active endocarditis may help in evaluating the natural history of the patient's disease, and assist the echocardiographer in guiding perioperative clinical decisions. An explanation of the echocardiographic procedure including the indications, risks, and benefits should be provided to every patient and/or legal guardian whenever possible (ie, elective procedures). It is also recommended that informed consent, in which the specific risks and benefits to the patient from the procedure are discussed with the patient before the examination, be obtained and documented in the patient's chart, either separately or as part of the general anesthetic consent.

Role of the Physician and the Sonographer

The cardiac sonographer in the echocardiography laboratory plays a well-respected and integral role in acquiring comprehensive echocardiographic examinations by applying independent judgment and problem solving skills. He or she has specific training in obtaining accurate images and integrating diagnostic information during the performance of the examination. However, the role of the sonographer in the performance of TEE is limited to maximizing image quality by the manipulation of the controls on the ultrasonography system as stated in the "Guidelines for Cardiac Sonographer Education: Recommendations of the ASE Training and Education Committee."[16] In addition, the American College of Cardiology/American Heart Association Clinical Competence Statement on Echocardiography states that "training for the performance and interpretation of TEE is best obtained during a formal fellowship in cardiovascular medicine or its equivalent (ie, cardiology, cardiovascular anesthesiology, cardiovascular surgery, or critical care medicine)."[2] Furthermore, the Intersocietal Commission for the Accreditation of Echocardiography Laboratories (ICAEL) Standards do not recognize sonographer performance of a TEE and specifically states, "TEE is a semi-invasive test which, if performed incorrectly, can lead to serious harm to patients and therefore, should be performed by appropriately trained personnel." TEE is generally safe, but insertion and manipulation of the TEE probe can produce pharyngeal and/or laryngeal trauma, dental injuries, esophageal and/or gastric trauma or bleeding, arrhythmias, respiratory distress, and hemodynamic effects.[17,18] In addition, performing procedures on patients who are sedated or anesthetized requires special training that sonographers do not receive. Thus, a sonographer may assist the physician in manipulation of the controls on the ultrasonography system, however, the physician must always be present to insert the TEE probe, perform a perioperative TEE (PTEE) examination, interpret the echocardiographic data, and assist the surgeon by providing information pertinent to surgical decisions.

Performance and Interpretation Time

The time needed to complete a comprehensive perioperative examination will vary depending on the complexity of the case. No minimal time has been established to perform a comprehensive evaluation; however initial study time may last 10 to 45 minutes, including time for discussion between cardiologists, surgeons, and anesthesiologists. Additional time may be needed for important Doppler calculations and complementary evaluations (eg, contrast echocardiography or pharmacologic stress testing). It is also recognized that the entire duration of an intraoperative examination may total several hours, as repeated sequential examinations are conducted to assess acute hemodynamic changes or the adequacy of surgical repair.

Echocardiographic data that will influence the surgical plan should be interpreted and reported to the surgeon in an ongoing and timely manner. A verbal report must be provided throughout and, in particular, at the completion of the initial examination to both the surgical and anesthesia care teams. A written or electronic description of the findings should be left in an obvious location within the operating room on completion, so that it is available for immediate reference. Furthermore, a written or electronic report (preliminary or final) outlining key findings should be included in the medical record by the end of the procedure. Official reports of all the intraoperative data may be generated after completion of the surgical procedure, and should be consistent with the real-time interpretation provided to the surgeon. Such a report should be legible, placed in the patient's medical record within 24 hours of operation, and include: (1) a description of the echocardiographic procedure; (2) indications for the procedure; and (3) important findings.

Comprehensive Versus Limited Perioperative Examination

A comprehensive echocardiographic study is "one that examines all cardiac chambers, valves, and great vessels from multiple views, then uses the available information to define completely any recognized abnormalities."[9] For PTEE, we recommend that perioperative echocardiographers follow the guidelines

previously outlined for performing a comprehensive intraoperative TEE examination.[6] Although not all components of the comprehensive examination may be needed in every patient, the practitioner should attempt to acquire all 20 of the recommended views accompanied by appropriate Doppler data in the event they are needed for remote consultation.[19] We also recommend that echocardiographers strive to derive all the hemodynamic data that are pertinent to each patient from the available Doppler techniques.

Although a comprehensive examination is always recommended, a limited or focused study may be occasionally indicated. Typically, these patients have had a recent comprehensive examination with no expected interval change other than in the area being re-examined. A limited intraoperative TEE examination may also be warranted after a request to determine the cause of acute hemodynamic compromise such as during an intraoperative cardiac arrest.

Specialized Echocardiographic Procedures

Epiaortic and epicardial echocardiography are separate procedures that may be used to obtain additional echocardiographic data not acquired by TEE.[20,21] They may also serve as a substitute for TEE imaging when TEE probe insertion is contraindicated or cannot be performed. Additional probes with varying ultrasound frequencies are required to perform echocardiography with these approaches. Guidelines for the use of epicardial and epiaortic echocardiography are forthcoming from the ASE Council for Intraoperative Echocardiography.

PRINCIPLES OF CQI

Acquisition of Primary Training and Technical Skills

Minimal competence required for performing and interpreting perioperative echocardiography in adult patients requires basic cognitive and technical knowledge of ultrasound physics as well as instrumentation and transducer manipulation for image and data acquisition, and a fundamental understanding of cardiac and great vessel anatomy, physiology, and pathology. In addition, an appreciation of the interaction between surgical techniques and the pathophysiology of the disease process under study is essential. A comprehensive perioperative echocardiographic examination is performed predominantly through the TEE approach, although epicardial and epivascular techniques continue to have a role during surgery, particularly for the echocardiographic assessment of the ascending aorta, or rarely when TEE probe insertion can not be accomplished or is contraindicated.[17] Training guidelines for less frequently used procedures in the perioperative period such as transthoracic echocardiography,[22] stress echocardiography,[23] echocardiography for pediatric patients,[1] and echocardiography using hand-carried ultrasound devices[22] have been previously detailed. Because TEE is the dominant perioperative procedure, the remainder of this document will focus on the use of TEE. TEE evaluation of the patient with congenital heart disease is more complex and practitioners in this arena require special expertise. We, therefore, endorse the recommendations published by the Pediatric Council of the ASE.[1]

Table 1 Fundamental cognitive skills required for competence in perioperative echocardiography[19]

- Knowledge of physical principles of echocardiographic image formation and blood flow velocity measurements
- Knowledge of instrument settings required to obtain an optimal image
- Knowledge of normal cardiac anatomy
- Knowledge of pathologic changes in cardiac anatomy caused by acquired heart disease and CHD
- Knowledge of fluid dynamics of normal blood flow
- Knowledge of pathologic changes in blood flow caused by acquired heart disease and CHD

CHD, Congenital heart disease.

Training requirements represent the minimal training experience that is considered necessary to achieve the skills for performing perioperative echocardiography. The essential components of training include independent work, directly supervised activities, and assessment programs.[22,24] Through a structured independent reading and study program, trainees must acquire an understanding of the principles of ultrasound and indications for perioperative echocardiography. This independent work should be supplemented by regularly scheduled didactics such as lectures and seminars designed to reinforce the most important aspects of perioperative echocardiography.[19,22,24]

Specific guidelines on training in perioperative echocardiography have been published by an ASE/SCA task force.[19] These recommendations, which were initially developed mainly for anesthesiologists and cardiologists, recognized that perioperative echocardiography can be practiced at different levels. Both basic and advanced levels of perioperative echocardiographic training refer to specialized training that typically extends beyond the minimum exposure to echocardiography that occurs during normal residency training. The knowledge and skills necessary to practice perioperative echocardiography at the basic and advanced levels are summarized in Tables 1 to 3.[19,22,25]

Trainees undergoing basic training should learn indications and contraindications and how to place the TEE probe, operate the ultrasound machine, and

Table 2 Cognitive and technical skills needed to perform perioperative echocardiography at a basic level[19]

Cognitive skills
• Basic knowledge outlined in Table 1
• Knowledge of the equipment handling, infection control, and electrical safety recommendations associated with the use of TEE
• Knowledge of the indications and the absolute and relative contraindications to the use of TEE
• General knowledge of appropriate alternative diagnostic modalities, especially transthoracic and epicardial echocardiography
• Knowledge of the normal cardiovascular anatomy as visualized by TEE
• Knowledge of commonly encountered blood flow velocity profiles as measured by Doppler echocardiography
• Detailed knowledge of the echocardiographic presentations of myocardial ischemia and infarction
• Detailed knowledge of the echocardiographic presentations of normal and abnormal ventricular function
• Detailed knowledge of the physiology and TEE presentation of air embolization
• Knowledge of native valvular anatomy and function, as displayed by TEE
• Knowledge of the major TEE manifestations of valve lesions and of the TEE techniques available for assessing lesion severity
• Knowledge of the principal TEE manifestations of cardiac masses, thrombi, emboli, cardiomyopathies, pericardial effusions, and lesions of the great vessels
Technical skills
• Ability to operate the ultrasound machine, including controls affecting the quality of the displayed data
• Ability to perform a TEE probe insertion safely in the patient who is anesthetized and intubated
• Ability to perform a basic TEE examination
• Ability to recognize major echocardiographic changes associated with myocardial ischemia and infarction
• Ability to detect qualitative changes in ventricular function and hemodynamic status
• Ability to recognize echocardiographic manifestations of air embolization
• Ability to visualize cardiac valves in multiple views and recognize gross valvular lesions and dysfunction
• Ability to recognize large intracardiac masses and thrombi
• Ability to detect large pericardial effusions
• Ability to recognize common artifacts and pitfalls in TEE examinations
• Ability to communicate the results of a TEE examination to patients and other health care professionals and to summarize these results cogently in the medical record

TEE, Transesophageal echocardiography.

perform a TEE examination, all under direct supervision by another physician who has already acquired advanced training. Trainees should be encouraged to master the comprehensive examination defined by the ASE and SCA.[6] A basic practitioner should be able to acquire all 20 of the recommended cross sections. Thus, basic training does not prepare the practitioner to influence the surgical plan without the assistance of a physician with advanced training in perioperative echocardiography.[19] For basic training, 150 complete examinations should be studied under appropriate supervision. These examinations must include the full spectrum of commonly encountered perioperative diagnoses, and at least 50 comprehensive PTEE examinations personally performed, interpreted, and reported by each trainee (Table 4).[19,22,25]

Advanced training should take place after basic training in a program designed specifically to accomplish comprehensive training in perioperative echocardiography.[19,22,25] Physicians with advanced training are able to use the full diagnostic potential of PTEE. In this regard, cardiovascular lesions are diagnosed, and the information is used to influence the patient's perioperative treatment including assisting the surgeon in planning the surgical procedure. For advanced practice, the comprehensiveness of training is paramount.[22,24] The ASE/SCA Task Force recommends that 300 complete examinations be studied under direct supervision of another physician who has already acquired advanced training.[19] These examinations must include a wide spectrum of cardiac diagnoses and at least 150 comprehensive PTEE examinations that are personally performed, interpreted, and reported by the trainee (Table 4). Physicians should also take the Examination of Special Competence in PTEE and aspire to achieve board certification in perioperative echocardiography through the National Board of Echocardiography (www.echoboards.org).

The director of the training program must be a physician with advanced training and proven expertise in perioperative echocardiography, who has performed at least 450 complete examinations, including 300 PTEE examinations, or has equivalent experience (Table 4).[19] As advanced trainees acquire more experience, they may be allowed to work with more independence, but the immediate availability and direct involvement of an advanced supervisor during the examination is an essential component of advanced training.

Training requirements represent the minimal training experience that is considered necessary to achieve the skills for performance at a particular level. Such training is expected to occur under the direct supervision of a practitioner who has already acquired advanced training, and for the most part, occurs during formal fellowship training in either cardiovascular medicine, cardiovascular anesthesiology, cardiovascular surgery, or critical care medi-

Table 3 Cognitive and technical skills necessary to perform perioperative echocardiography at the advanced level[19]

Cognitive skills
- All the cognitive skills defined for the basic level (Table 2)
- Knowledge of the principles and methodology of quantitative echocardiography
- Detailed knowledge of native valvular anatomy and function
- Knowledge of prosthetic valvular structure and function, detailed knowledge of the echocardiographic manifestations of valve lesions and dysfunction
- Knowledge of the echocardiographic manifestations of CHD*
- Detailed knowledge of echocardiographic manifestations of pathologic conditions of the heart and great vessels (eg, cardiac aneurysms, hypertrophic cardiomyopathy, endocarditis, intracardiac masses, cardioembolic sources, aortic aneurysms and dissections, pericardial disorders, and postsurgical changes)
- Detailed knowledge of other cardiovascular diagnostic methods for correlation with TEE findings

Technical skills
- All the technical skills defined for the basic level (Table 2)
- Ability to perform a complete TEE examination
- Ability to quantify subtle echocardiographic changes associated with myocardial ischemia and infarction
- Ability to use TEE to quantify ventricular function and hemodynamics
- Ability to use TEE to evaluate and quantify the function of all cardiac valves including prosthetic valves (eg, measurement of pressure gradients and valve areas, regurgitant jet area, effective regurgitant orifice area), ability to assess surgical intervention on cardiac valvular function
- Ability to use TEE to evaluate congenital heart lesions, ability to assess surgical intervention in CHD*
- Ability to detect and assess the functional consequences of pathologic conditions of the heart and great vessels (eg, cardiac aneurysms, hypertrophic cardiomyopathy, endocarditis, intracardiac masses, cardioembolic sources, aortic aneurysms and dissections, and pericardial disorders), and ability to evaluate surgical intervention in these conditions if applicable
- Ability to monitor placement and function of mechanical circulatory assistance devices

CHD, Congenital heart disease; *TEE*, transesophageal echocardiography.
*Requires additional training as outlined in the Guidelines for Training in Pediatric Echocardiography.[1]

Table 4 Training recommendations for basic and advanced perioperative echocardiography[19]

	Basic	Advanced
Minimum number of examinations interpreted and reported under appropriate supervision	150	300
Minimum number of examinations personally performed, interpreted, and reported under appropriate supervision	50	150
Program director qualifications	Advanced perioperative echocardiography training	Advanced perioperative echocardiography training plus at least 150 additional perioperative TEE examinations
Program qualifications	Wide variety of perioperative applications of echocardiography	Full spectrum of perioperative applications of echocardiography

TEE, Transesophageal echocardiography.

cine.[22,24] However, physicians trained before the development of these techniques may have properly learned their use while in practice, and can achieve appropriate training in perioperative echocardiography without enrolling in a formal training program.[22,24] Nonetheless, the same prerequisite medical knowledge, medical training, and goals for cognitive and technical skills apply to them as they apply to physicians in formal training programs. They should work with other physicians who have advanced TEE training or equivalent experience to achieve the same training goals and case numbers as the training levels previously delineated. Physicians seeking basic training by this pathway should also have at least 20 hours of Continuing Medical Education (CME) devoted to echocardiography. Physicians seeking advanced training by this pathway should have at least 50 hours of CME devoted to echocardiography. The CME in echocardiography should be obtained during the time that trainees are acquiring the requisite clinical experience in TEE.

The supporting surgical program must have the volume and diversity to ensure that trainees will experience the wide spectrum of diagnostic challenges encountered in perioperative echocardiography and learn to use TEE effectively in all its established perioperative applications. The perioperative echocardiography training program should ideally have an affiliation with an echocardiography laboratory so that trainees can gain regular and

Table 5 Documentation and maintenance of competence in perioperative echocardiography[19]

Documentation of competence	Maintenance of competence
• NBE certification or • Letter or certificate from the director of the perioperative echocardiography training program	• At least 50 examinations per year with 25 of these being personally performed • Obtain a minimum of 15 hours every 3 years of Category I Continuous Medical Education credits in echocardiography • Participation in CQI program

CQI, Continuous quality improvement; *NBE*, National Board of Echocardiography.

frequent exposure to teaching and clinical resources within that laboratory.

Both basic and advanced trainees must be taught how to convey and document the results of their examination effectively. Formal and informal evaluations of the progress of each trainee should be conducted during training at a minimum of twice a year. All trainees should document their experience in detail in a log of the examinations they performed, and should be able to demonstrate training equivalent in depth, diversity, and case numbers to the training levels previously delineated. The experience and case numbers acquired during basic training may be counted toward advanced training if the basic training was completed in an advanced training environment.

Proof of competence consists of a set of requirements that provide some assurance that physicians have gained the expertise needed to perform according to recognized standards. Documentation of competence can be achieved by means of letters or certificates from the director of the perioperative echocardiography training program (Table 5). This documentation should state the dates of training, and that trainees have successfully achieved or surpassed each of the training elements. All echocardiographic facilities should have on file appropriate documents attesting to the adequacy of physician training. The file should be kept up to date with the addition of a new record for additional physicians as they arrive. Records of individuals leaving a facility should be kept for at least 10 years.[9]

Maintenance of Technical Skills

Clinical competence in perioperative echocardiography requires continued maintenance of cognitive and technical skills in perioperative echocardiography. On completion of the above training requirements, a minimum of 50 examinations per year, with at least 25 personally performed, is required to remain proficient in performing perioperative echocardiography (Table 5).[22,24] In addition, CME in PTEE is essential to keep pace with technical advances, refinements in established techniques, and application of new methods. Physicians practicing perioperative echocardiography should obtain a minimum of 15 hours every 3 years of Category I CME credits in echocardiography, as recommended recently by the ICAEL[26] (Table 5).

Periodic Review

Periodic review is the cornerstone of any CQI program and consists of a review of caseload, performance, interpretation, record keeping, and equipment. In many areas of medicine, caseload and experience have been directly associated with outcome.[27,28] Minimal caseload requirements for training at the basic and advanced level, designation as program director, and maintenance of skills are outlined in Tables 4 and 5. In addition to these, a minimum of 25 intraoperative TEE studies per month should be performed by a perioperative echocardiographic service. An inability to meet these requirements and plans to address deficiencies should be documented monthly as part of the CQI process. For the purpose of verifying caseloads, limited studies are not included. A case is defined as a single patient encounter resulting in a complete 2-dimensional and Doppler echocardiographic examination.

In addition to minimal caseloads, CQI requires intermittent review of study performance and interpretation. This review should include all types of procedures performed by members of the perioperative echocardiography team, including but not limited to transesophageal, transthoracic, epiaortic, and epicardial examinations. Ideally, this review is conducted by an immediate repetition of the study by a second echocardiographer. However, because intraoperative echocardiography is relatively invasive, the performance review by a second physician skilled in echocardiography may be conducted by a review of stored images. Components of this review include an assessment of: (1) the documentation of the indications for the procedure and patient consent; (2) appropriate use of ultrasound system technology and controls; (3) the adequacy and presentation of the imaging planes; and (4) concurrence between the recorded images and the written report (ie, do the recorded images document the echocardiographic findings provided in the written report). It is recommended that a minimum of 5 cases for each echocardiographer in a service be subjected to such review every 12 months. In a similar fashion,

Table 6 Summary of continuous quality improvement recommendations

Equipment
- Ultrasound machine with full diagnostic capabilities
- 2D, Color, PW and CW Doppler, and M-mode imaging
- Video imaging screen
- Digital capture, review, and permanent storage of data with redundancy and using DICOM format
- Multiplane TEE

Request for echocardiographic services
- Order for ultrasound study must be documented on surgical schedule, anesthesia record, or permanent medical record

Patient interactions
- Determine relative or absolute contraindications to examination
- Use clinical history in conjunction with echocardiographic data to guide decisions
- Review risks and benefits of procedure
- Document informed consent

Examination components
- Comprehensive 2D echocardiographic and Doppler examination with pertinent hemodynamic data should be performed in most patients
- Limited or partial examination may be performed:
  - In those with a recent examination in whom no interval change is expected other than in the specific area being re-examined or
  - In those with intraoperative hemodynamic instability such as cardiac arrest (ie, "rescue" echocardiography)

Performance and interpretation time
- Acquisition, interpretation, and dissemination of data should occur in a timely fashion for use in surgical decision making
- Report of echocardiographic findings available to OR staff in easily accessible manner
- Written or electronic report (preliminary or final) outlining key findings included in the medical record by the end of the procedure
- Legible formal report in patient's medical record within 24 hours of operation and should include:
  - A description of the echocardiographic procedure
  - Indications for the procedure
  - Important findings
- Formal report should be consistent with findings presented to OR team

Training requirements
- Program director with advanced training (450 TEEs) and certification
- Surgical caseload with adequate volume and diversity of cases
- Affiliation with echocardiography laboratory
- 150 TEEs for the basic level and 300 for advanced level
- 50 Hours of CME in echocardiography for individuals seeking advanced certification outside fellowship training
- Review of trainee's progress at least twice per year
- Trainee case logs
- Provide documentation of successful completion of training to trainee
- Maintain records of training for 10 years

Maintenance of technical skills
- 50 Examinations per year, 25 of these should be personally performed
- Average of 5 hours Category I CME credits in echocardiography per year
- Didactic monthly conference of at least 30 minutes
- Completion of 25 comprehensive TEE studies per month to be designated as a perioperative echocardiographic service

Periodic review
- Performance review to occur every 12 months on 5 cases from each echocardiographer's caseload and include:
  - Documentation of the indications for the procedure and patient consent
  - Appropriate use of ultrasound system technology and controls
  - Adequacy and presentation of the imaging planes
  - Concurrence between the recorded images and the written report
- Interpretive review to occur every 12 months on 5 cases from each echocardiographer's caseload

Equipment review
- Electrical systems should be checked for current leakage according to industry standards
- TEE probes should be checked for leakage at a minimum of every 3 months.
- Regular preventive maintenance service should be conducted according to manufacturer's recommendations
- Ultrasound system and ECG cables should be wiped carefully with an antiseptic solution after each patient use
- TEE probes cleaned according to institutional guidelines

Use review
- Yearly review
- Indication for the study
- Appropriate use of technology
- Comprehensiveness of the study

Table 6 Continued

- Timely completion of the interpretive report
- Note whether the examination answered the question for which the procedure was ordered

CQI documentation

- Review compliance with JCAHO guidelines
- Obtain hospital review of CQI process
- Make official policy manual available to all service members
- Document all aspects of CQI process including compliance and corrective action

CME, Continuing Medical Education; *CQI*, continuous quality improvement; *CW*, continuous wave; *DICOM*, digital imaging and communications in medicine; *ECG*, electrocardiogram; *JCAHO*, joint commission on accreditation of healthcare organizations; *OR*, operating room; *PW*, pulsed wave; *TEE*, transesophageal echocardiography; *2D*, 2-dimensional.

an interpretation review should be conducted every year on 5 of the cases for each physician in the service. Here the focus is not on the performance variables but rather on whether the examination has been accurately interpreted. The two interpretations should be compared and any differences discussed with the primary physician. Changes to the echocardiographic report that occur as a result of an interpretation review should be made only after consultation with and the agreement of the physician responsible for the initial report. Documentation of the occurrence of performance and interpretation reviews and the feedback provided to those subjected to review is to be maintained as part of the CQI process.

A final component of the periodic review process is that of equipment review. All electrical systems should be checked for current leakage according to industry standards. TEE probes should be checked for leakage at a minimum of every 3 months. Regular preventive maintenance service should be conducted according to manufacturer's recommendations. In the intraoperative environment, it is critical that echocardiographic equipment such as the TEE probes be cleaned according to institutional guidelines. In addition, the ultrasound system and electrocardiographic cables should be wiped carefully with an antiseptic solution after each patient use. A review of the adequacy and safety of the cleaning process with appropriate documentation should be conducted every 6 months.

Continuing Education

As discussed previously, an average yearly minimum of 5 hours of Category I CME dedicated to echocardiography is necessary for the maintenance of skills. In addition, every perioperative echocardiographic service should conduct a service conference lasting between 30 and 60 minutes at least once a month. This conference should cover a wide assortment of echocardiographic topics and may range in format from case reviews to formal didactic presentations. Category I CME may be obtained from this activity but should not account for more than 2 hours of the average annual total of 5. Certification of adequate CME for each physician in the perioperative echocardiography service is to be collected on a yearly basis and should total 15 hours over 3 years.

Documentation of CQI Process

The measures outlined in this document and summarized in Table 6 are the necessary components of an acceptable CQI program. Practitioners are strongly encouraged to develop and participate in the CQI processes to enhance individual and departmental growth. Accreditation agencies such as Joint Commission on Accreditation of Healthcare Organizations (JCAHO) have established guidelines regarding many aspects of patient care and these guidelines should be considered when building the CQI process for a perioperative echocardiography service. Hospital or departmental quality assurance committees should also be involved in the review and approval of developed documents. Finally, the proposed CQI process should be readily available to all members of the echocardiography team for review.

Use Review

Indications for perioperative echocardiography change as surgical techniques are developed, and as imaging modalities are enhanced. Criteria for a comprehensive transesophageal, transthoracic, epicardial, and epiaortic examination are available[2,6,21] and should be followed. Moreover, a periodic review of the indications for perioperative echocardiography should be undertaken to improve use of echocardiographic services. A yearly use review includes not only the components defined in the section on "Periodic Review" but also an evaluation of the appropriateness of the indication for a study, and whether the use of technology was appropriate, the study was comprehensive, the interpretive report was completed in a timely manner, and whether the examination answered the question for which the procedure was ordered.

CQI IN PRACTICE

Few perioperative services have reported on their experience with a CQI program but the limited literature indicates that incorporating CQI into daily practice can be beneficial. In 2002, a report from an intraoperative service examined the interpretive skills of a group of 10 cardiac anesthesiologists practicing in an academic environment.[29] These investigators determined that the intraoperative interpretation of a comprehensive TEE examination compared favorably with the offline interpretation provided by two physicians whose primary practice was echocardiography. Through the CQI process, they were also able to identify areas where additional training was required. Similarly, the provision of educational aids and performance feedback to anesthesiologists increased their ability to record a basic intraoperative TEE examination.[30] These authors concluded that their attempt to assess compliance with published guidelines for basic intraoperative TEE produced marked improvement in practice.

Conclusion

Aside from being a mandate of various accreditation agencies, CQI is a process that will aid perioperative echocardiographers in improving the delivery of care to patients. Although no set of guidelines will guarantee an improvement, the guidelines and recommendations presented in this document and summarized in Table 6 should serve as a foundation on which each perioperative service can build a future defined by the consistent delivery of a high-quality product. CQI in the perioperative environment is feasible but must move from the periphery to the core of the echocardiography service.

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APPENDIX

MEMBERS OF THE COUNCIL FOR INTRAOPERATIVE ECHOCARDIOGRAPHY

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