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REVIEW

Training, competence, and quality improvement in echocardiography: the European Association of Cardiovascular Imaging Recommendations: update 2020

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The primary mission of the European Association of Cardiovascular Imaging (EACVI) is 'to promote excellence in clinical diagnosis, research, technical development, and education in cardiovascular imaging'. Echocardiography is a key component in the evaluation of patients with known or suspected cardiovascular disease and is essential for the high quality and effective practice of clinical cardiology. The EACVI aims to update the previously published recommendations for training, competence, and quality improvement in echocardiography since these activities are increasingly recognized by patients, physicians, and payers. The purpose of this document is to provide the general requirements for training and competence in echocardiography, to outline the principles of quality evaluation, and to recommend a set of measures for improvement, with the ultimate goal of raising the standards of echocardiographic practice. Moreover, the document aims to provide specific guidance for advanced echo techniques, which have dramatically evolved since the previous publication in 2009.

Keywords echocardiography • recommendations • training • competence • quality

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Introduction

The writing committee developed this document with the following aims (i) to update the previously published recommendations for training, competence, and quality improvement in echocardiography[1] (new/amended text is highlighted in ***bold italics***); (ii) to provide specific guidance for the advanced echocardiography techniques; and (iii) to represent echocardiography in a broader group of recommendations about training, competence and quality improvement, covering the whole spectrum of cardiovascular imaging modalities.

Echocardiography has contributed to the reduction in mortality from cardiovascular diseases over the past four decades.[2] In the early years, availability of echocardiography was limited and there were no specific training requirements to perform and interpret echocardiographic studies. However, modern echocardiography demands specific training experience in transthoracic, transoesophageal, and stress echocardiography as well as incorporating increasingly sophisticated techniques, such as three-dimensional, strain, and interventional echocardiography. Indeed, the breadth of echocardiographic techniques has expanded dramatically in recent years, making echocardiography 'a multimodality technique' in itself. Therefore, the provision of updated and specific guidance regarding the latest echocardiographic techniques has become a timely necessity. Currently, those performing echocardiography must demonstrate a commitment to quality and the consistent delivery of accepted standards for effective imaging. Attempts to improve quality have encouraged continuing efforts to monitor and regulate laboratory organization, patient selection, study performance, image interpretation, and the communication of results. High-quality education is required to reduce the variability of measurements in reports and improve the diagnostic accuracy of echocardiographic studies.

Terminology

Certification of personnel and accreditation of imaging departments by official scientific authorities are critical processes to guarantee high-quality examinations. Several certification-accreditation processes exist in cardiovascular imaging, with the aim of ensuring that echocardiographers and other imaging specialists are fully competent within any given modality.

Although the terms certification, accreditation, competence, and credential seem similar, they are quite different and often used without a well-defined understanding of the differences between them.[3,4]

A *certification* is an authorized document declaring a level of accomplishment of training of an individual. An *accreditation* is provided by an authority to a laboratory or department or hospital 'to state officially that something is of adequate standard'. However, accreditation does not apply directly to an individual.

Competence is the recognition of capability or legal authority. An echocardiographer can be competent to perform an ultrasonographic examination based on his/her knowledge, skills, and attitude. The two pillars of the current European Society of Cardiology (ESC) Core Curriculum[5] in terms of training in imaging are the prominence of a multimodality approach and the redefinition of the levels of independence in performing and interpreting diagnostic techniques, including echocardiography. These new levels are now explained as '***Entrustable Professional Activities***' ***(EPA)*** (*Table 1*). The hitherto usable categorization in three levels (I, II, and III) is still described in this document since all the current publications related to competence are based on this previous scheme.

Level I: Experience of selecting the appropriate diagnostic or therapeutic modality and interpreting results or choosing an appropriate treatment for which the patient should be referred. This level of competence does not include performing a technique, but participation in procedures during training may be valuable.

Level II: In addition to Level I requirements, the trainee should acquire practical experience, but not as an independent operator. Trainees should have assisted in or performed a particular technique or procedure under the guidance of a trainer. This level also applies to circumstances in which the trainee needs to acquire the skills to perform the technique independently, but only for routine indications in uncomplicated cases.

Level III: In addition to Level I and II requirements, the trainee must be able independently to recognize the indication, perform the technique or procedure, interpret the data, and manage the complications.

Competence does not award the *credential* to perform the procedure in a clinical setting. An institution acknowledges competence through a credentialing process. Since credentials are hospital or health system specific, they are not necessarily transferable from one institution/system to another.

The competence requirements for all echocardiography modalities are the same for cardiologists and non-cardiologists (i.e. anaesthesiologists, emergency physicians, intensive care specialists, cardiac surgeons, or cardiac physiologists). In principle, all the recommended competence requirements should be reached at the same level of expertise through a training programme similar with the one for general cardiologists, with additional theoretical learning on certain cardiovascular conditions.

General aspects of training in echocardiography

A comprehensive echocardiography study requires continuous integration of the images seen with understanding of cardiac anatomy and pathophysiology, pattern recognition of diagnostic findings, and appropriate application of echocardiography modalities and equipment controls. Therefore, descriptive texts related to echocardiography practice, such as Core Curriculum and Core Syllabus, were considered to be essential guiding tools for the competence of the operators.[5,6]

The fundamental knowledge required for competence in echocardiography can thoroughly be accessed in the periodically updated ESC Core Curriculum. *Table 2* summarizes the current objectives, classified under the headings of knowledge, skills, attitudes, and assessment tools. For each objective, it is defined what needs to be achieved.

Training duration

Although for most areas of cardiovascular medicine the traditional three levels of competence have been set and used for a long time, there were notable differences between the existing definitions as a consequence of different training schemes and requirements.

In particular, in the previous ESC Core Curriculum of 2013,[7] level III competence demanded for the operator of each modality the

Table 1 Competence levels

Entrustable professional activities (EPA) levels	Previous categorization
1. Observe	Level I
2. Direct supervision	Level II
3. Indirect supervision	
4. Distance supervision	Level III
5. No supervision/able to teach	

ability to independently perform the procedure (unsupervised), which commonly had to be achieved during the general cardiology training. In contrast, the training requirements of the American Society of Echocardiography (ASE), (COCATS 4) are more challenging by adding to knowledge and technical skills of the operator, the performance and interpretation of complex studies in special populations, engaging in research, direction of an academic echocardiography laboratory, and the ability to train others in advanced aspects of echocardiography.[8] Lately, the ACC/AHA and the ASE released a new statement on advanced training on echocardiography, aiming to define selected competencies beyond those expected of all cardiologists.[9] As a result of the above requirements, these advanced competencies are usually not covered during the general cardiology fellowship but require additional training during which they are integrated with training in other imaging modalities.

Another important feature of training documents is the anticipated change in terms of minimal training requirements (i.e. duration, number of cases). Several authorities have already published relevant training schemes, with significant variations in requirements.[10,11] ***The task force of the updated ESC Core Curriculum revised the procedural independence defining 5 strengths of EPAs*** (*Table 1*), while still avoiding to mention procedural numbers as the main criterion for adequacy of a training program or for the acquired competence of a fellow. The obvious intention was to avoid a reductionistic approach, i.e. performing a number of procedures without enough perspective for developing the necessary expertise. Moreover, the numerous European healthcare systems, with wide-ranging variability in terms of educational appointments and quality (mainly due to governmental reimbursement), make the creation of comprehensive guidance an unrealistic goal.

The European viewpoint is that it is not enough for the trainee to perform a specific number of procedures for acquiring the necessary competence. Therefore, although it may be reasonable to ask for a minimum exposure as a prerequisite, the Task Force decided to not focus on numbers. The Task Force encouraged a continuous assessment by several means [e.g. logbooks, Direct Observation of Practical Skills (DOPS), imaging meetings, etc.]. The goal is to develop knowledge, well-defined skills, behaviour, and attitudes (*Table 2*). In contrast, the most updated statement about training in echocardiography endorsed by the ASE is more focused on the number of cases, procedures, and experience that are based on published guidelines and other competency statements, as well as expert opinion.[8]

Based on the above differences in defining levels of competence and training requirements, this European Association of Cardiovascular Imaging (EACVI) writing committee still recommends two levels of expertise for training in echocardiography: *basic* and *advanced*. The *basic level* is meant to be achieved by every general cardiologist who uses echocardiography to take clinical decisions about patients' management in common clinical scenarios and urgent clinical situations. The *advanced level* is addressed to cardiologists undertaking echocardiography as their main subspecialty and who should be able to perform comprehensive echocardiographic examinations and provide pertinent information for patient management. It has to be emphasized that for the achievement of advanced level for transthoracic echocardiography (TTE) during the fellowship period, most of the available time must be dedicated to echocardiography.

For each level, minimal requirements for training duration and number of examinations performed are proposed. As there is limited evidence for required training duration and number of studies performed, the figures mentioned in *Table 3* represent a consensus view among the writing committee members. This is derived from current EACVI certification processes requirements,[12] ESC core curriculum,[5] COCATS 4,[8] 2019 ACC/AHA/ASE statement,[9] and practical experience.

Although recommendations for training duration are used to facilitate the organization of a focused training programme, the emphasis remains not on a specific duration of training, but on obtaining the required expertise. A minimum number of echo studies in which a trainee participates is recommended.[13] However, the case-mix of patients to cover the full range of cardiovascular diseases (*Table 4*), and the quality of supervision is equally important.

Basic level

A trainee with a basic level of expertise should be able to independently perform a general TTE examination (***EPA level 5***; Level III in TTE) according to the recommendations for standardization of performance, digital storage, and reporting published by the EACVI.[14]

The trainee should acquire sufficient knowledge and technical ability to be able to answer common clinical questions and to be helpful in urgent clinical situations. A 6-month full-time training fellowship in echocardiography is the minimum recommended training period to achieve the basic level of expertise in TTE. Training time should be protected. If this period does not allow the trainee to achieve the required number of examinations or a well-balanced mix of pathologies, the training period should be extended.

During training for the basic level, the recommended number of TTE examinations performed by a trainee is of at least 350.[1] This portfolio must be completed within the 6-month period of continuous training. It should include an appropriate case-mix, though complex valvular and congenital diseases are not compulsory (*Table 4*).

It is expected that, after successful completion of this training level, a trainee should be able to undertake and pass the EACVI certification examination in TTE. Trainees will also be exposed to transoesophageal echocardiography (TOE) and stress echocardiography (SE) examinations, being able to perform a reasonable number of basic TOE studies under supervision (***EPA level 3***), but for SE an ***EPA level 2*** competence is considered adequate. EPA level 3 competence for TOE gives the ability to perform a procedure that is diagnostic, complete, and accurate. However, competence at this level is not entirely sufficient for a comprehensive autonomously performed

Table 2 Knowledge, skills, and attitudes required to perform echocardiography

Knowledge

- Recognize the role of echocardiography as a first-line cardiac imaging modality in most clinical settings, including acute and emergency situations.
- Describe the use of different techniques
  - M-mode, 2D, and 3D echocardiography
  - Doppler echocardiography
  - Contrast echocardiography
  - Transoesophageal echocardiography
  - Deformation imaging
  - Stress echocardiography modalities (exercise and/or pharmacological echocardiography)
- Distinguish the particular challenges of emergency echocardiography

Skills

- Manipulate the echocardiographic probe and operate the machine to perform
  - Transthoracic echocardiography
  - Transoesophageal echocardiography
- Use the techniques listed above for the following indications
  - Left and right heart chambers' anatomy and function
  - Ischaemic heart disease
  - Cardiomyopathies
  - Valve morphology and function
  - Valve prostheses and post-surgical repair techniques
  - Aorta/aortic diseases
  - Endocarditis
  - Pericardial disease
  - Cardiac masses
  - Congenital heart disease and shunt assessment
  - Pulmonary hypertension
  - Non-invasive haemodynamics
  - Liver congestion and venous flow
  - Emergency echocardiography practice
  - Awareness of non-cardiac structures that can be identified on scans or can cause artefacts
- Interpret the images obtained to provide a clinical report
- Explain the modality and the reason for its selection to the patient and their family

Attitudes

- Integrate echocardiography with history taking, clinical examination, and electrocardiogram (at rest and during exercise) as the baseline evaluation of the cardiac patient by the general cardiologist
- Recognize the strengths and weaknesses of echocardiography in a specific clinical situation and in relation to other imaging modalities
- Be willing to refer the patient for other imaging modalities whenever necessary
- Interact cooperatively with sonographers and paramedical staff for acquisition and handling of the data

Assessment tools

- Record of clinical experience (logbooks)
- Direct Observation of Practical Skills (DOPS)
- Participation in imaging review meetings and MultiDisciplinary Teams (MDTs)
- Achievement of certifications

examination. EPA level 2 of competence for SE does not require the trainee to perform the technique, but participation in the interpretation of studies is mandatory.

In summary, the recommended basic-level training corresponds to EPA level 5 competence in general adult TTE, EPA level 3 competence in TOE, and EPA level 2 in SE.

Advanced level

The advanced level training in echocardiography is reserved for trainees who already have the basic level, but who want to engage in more complex TTE studies and to become fully competent (***EPA level 5***) in special TTE procedures, such as complex valvular and congenital cases, additional use of 3D echocardiography, contrast

Table 3 Levels of competence and recommended procedures

Echocardiographic technique	Basic[a]	Advanced[b]	EACVI certification	Maintenance[c]
TTE	350	750 (350 + 400)[d]	250[e]	250
TOE	50[f]	125 (75)[g]	125 (75)[g]	50[h]
SE	50[f]	100[h]	–	100[h]

[a]Corresponds to the ESC Core Curriculum requirements for general training for cardiologists.
[b]Appropriate for cardiologists with subspecialty interest in echocardiography.
[c]Minimum number of examinations performed/year to maintain competence.
[d]Additional number of studies to which a candidate is exposed (either performed or interpreted).
[e]Total number of studies with prespecified pathologies (e.g. valvular heart disease, pericardial diseases).
[f]Recommended number by ESC general cardiology training programme in EsCel e-learning platform.
[g]If TTE certified.
[h]Minimum number of examinations by committee's consensus.

echocardiography, deformation imaging, or echocardiography during interventional procedures and also to be able to perform TOE and SE independently.

Examples of TTE examinations that require special expertise and would be outside the competence of a general cardiologist with only basic echocardiographic training are the comprehensive haemodynamic evaluation of patients with complex valve disease (including full quantitation), complex congenital heart disease, and the performance of more complex TTE procedures (e.g. deformation imaging, detection of subclinical disease including cardiomyopathies, eligibility for percutaneous valve implantation).

The advanced level of training is aimed at acquiring independence in performing and interpreting TOE studies—minimum 75 independently performed; SE studies—minimum 100 independently performed (*Table 3*). Competence at an advanced level implies an additional training period in echocardiography and participation (either performance or interpretation) in additional 400 TTE studies (750 in total), beyond those reserved for the basic level (*Table 3*). This higher level of dedicated training should be ideally acquired in echocardiography laboratories fulfilling the EACVI recommendations for advanced accreditation.[15]

The competence levels and their training requirements for echocardiography practitioners are summarized in *Tables 3* and *4*.

Training programme

The trainee in an echocardiography laboratory should keep an organized education programme to address the knowledge acquisition sessions. The training programme should incorporate hands on, theoretical learning goals, and ideally research activities. It has to be comprehensive, covering in addition to specific knowledge and skills, the development of appropriate behaviours and attitudes.

During the training period, trainees should consistently join departmental meetings reviewing topics, presenting and discussing difficult cases, indications, results, procedure-related complications, and comparisons with other modalities (including other imaging techniques, cardiac catheterization, and heart surgery). The trainee should attend at least once a year a national and/or international accredited echocardiography meeting.

Self-assessment needs to be highlighted, and web-based online learning programmes and products will play an important role in a fellow's overall knowledge during and after training. The trainee should have sufficient background knowledge for each level of training and must complete the recommended number of echocardiographic studies.

Training centres

Central to training is supervised practice in a high-quality learning environment. The importance of the institution in providing educational support, appropriate, up to date clinical material, and mentoring is recognized in the EACVI scheme for accrediting echocardiography laboratories. A crucial criterion for all accredited laboratories is the provision of adequate continuing education. Detailed information can be found in a previous publication.[15]

Specific training recommendations for specific procedures

TTE in adult patients

Principles for appropriateness have already been published,[16,17] with recommended strengths of indication for a spectrum of clinical scenarios. The trainee needs to understand, acquire, and document all the standard imaging planes, as recommended.[14]

However, limiting the examination to standard imaging planes may sometimes lead to disregarding important pathological findings and/or to reporting erroneous data. It is, therefore, important that the echocardiographer is able to adapt the examination on the basis of live interpretation of encountered findings. The supervisor has a central responsibility in teaching a trainee how to use the transducer and to modify appropriately the machine settings for the best technical quality of the study and, thus, to understand what represents the optimal data acquisition.

Transoesophageal echocardiography

TOE has become an indispensable technique in clinical practice. TOE is generally available in every echocardiography laboratory, as well as in every centre performing cardiac surgery or transcatheter procedures.[18]

Table 4 Case-mix for EPA level 5 competence basic level training in transthoracic echocardiography (corresponds to requirements for EACVI Certification Logbook[a])

Cardiac disease/clinical scenario	Knowledge and skills to be acquired
Valvular heart diseases	Display views for the diagnosis
Aortic stenosis	Recognition of diagnostic features
Aortic regurgitation	Evaluation/quantification of severity
Mitral stenosis	Distinction between chronic and acute lesions (regurgitant lesions)
Mitral regurgitation	Evaluation of the consequences on the size, geometry, and function of the cardiac chambers
Tricuspid stenosis	Criteria and timing for intervention, amenability for surgical repair, and suitability for percutaneous intervention
Tricuspid regurgitation	
Pulmonary stenosis	Echocardiographic (2D and Doppler) findings of normal function and malfunction of biological and mechanical valves
Pulmonary regurgitation	
Prosthetic valves	Judge the need for complementary diagnostic approaches
	Define the need for regular follow-up studies
Ischaemic heart disease	Recognition of the signs and consequences of myocardial ischaemia and infarction
Myocardial infarction (MI)	Localize segmental wall motion abnormalities in a standardized format
Ischaemic cardiomyopathy	Evaluation of infarct size and the amount of myocardium at risk
	Evaluation of global and regional LV systolic and diastolic function, including deformation imaging
	Diagnose mechanical complications of MI and their haemodynamic consequences
	Recognition of the prognostic implications of structural and functional parameters
Cardiomyopathies	Perform a complete M-mode, 2D, deformation imaging, and Doppler examination which allows to establish the diagnosis, accurately quantify disease severity and help to choose the most clinically useful and cost-effective modality(ies)
Dilated cardiomyopathy	
Myocarditis	
Hypertrophic cardiomyopathy	Make the differential diagnosis of athlete's heart vs. hypertrophic cardiomyopathy
Restrictive and infiltrative cardiomyopathies	Identify patients who are appropriate candidates for cardiac resynchronization therapy
Heart failure	Outline echocardiographic features of cardiomyopathies, coronary heart disease, valvular heart disease, myocarditis, constrictive pericarditis, pulmonary hypertension, and other conditions associated with heart failure
	Identify causes of acute heart failure
	Recognize the prognostic implications of functional parameters
	Recognize typical complications in heart failure (spontaneous echo contrast and thrombus formation, pleural effusion, etc.)
Hypertension	Calculation of LV mass, relative wall thickness, evaluation of LV geometry
	Assessment of LV systolic function and diastolic function
	Estimation of LV filling pressures
Infective endocarditis	
Emergency echocardiography	
Simple Adult Congenital Heart Disease cases (ACHD)	
Cardiac tumours and masses	
Sources of embolism	
Pulmonary embolism	
Pulmonary hypertension	
Diseases of the aorta	
Diseases of the pericardium	
Normal examinations	Not more than one-third of total studies[a]

[a]The training guidance shown matches the EACVI logbook requirements.

Training in TOE starts during fellowship and is best accomplished in high-volume centres (>500 TOE studies/year).[13]

EPA 1 (Level I) competency requires the trainee to be familiar with the appropriate indications for a TOE study, potential risks and contraindications, and know to interpret findings in routine TOE reports. Trainees may be exposed to routine clinical studies in the echocardiography laboratory for recognizing cardiac anatomy in TOE views and common pathologies.

EPA 2 and 3 (Level II) competency require the acquisition of practical skills in performing TOE under local supervision (direct and indirect) for routine indications. ***ESC e-learning platform recommends a minimum of 50 supervised oesophageal***

intubations and clinical examinations with large case-mix in conscious and sedated patients.[19] By enhancing the development of psychomotor and cognitive skills,[20]simulator-based training may facilitate and speed up the ability of trainees to acquire correct views and understand cardiac anatomy in TOE, yet cannot replace their clinical training.

EPA 4 and 5 (Level III) competency requires full autonomy of the trainee to perform, interpret and report TOE studies, experience in administration of conscious sedation and in managing potential complications. Whenever possible, this should cover advanced techniques (i.e. 3D TOE, contrast, etc.), as well as specific competencies (e.g. TOE in intensive care, interventional, intra- and peri-operative settings). Level III is recommended for physicians subspecializing in imaging. To be eligible for EACVI certification in TOE (EPA Level 5), the candidate has to submit a logbook of 125 unsupervised TOE studies with adequate case-mix, or 75 for those holding a valid TTE certification performed in maximum 24 months.

The specific knowledge and skills required to become competent in performing and reporting TOE studies are listed in *Table 5*.

Three-dimensional echocardiography

Three-dimensional echocardiography (3DE) has become a standard technique in most clinical echocardiography laboratories, in the catheterization laboratory, and in the operating theatre. 3DE is currently recommended by several EACVI/ASE guidelines, due to its important added value to evaluate cardiac functional anatomy and its higher accuracy and reproducibility in measuring chamber volumes and function in comparison with 2D methods.[21–25]

Accordingly, 3DE should no longer be regarded as an emerging advanced technology or a separate echocardiography subspecialty, ***but should become an integral part of advanced level III (EPA level 5)*** echocardiography training and competency.[26] Training in 3DE is best achieved if started during the echocardiography fellowship rotation. Similar to TOE, training in 3DE is best accomplished in high-volume centres (>500 3DE studies/year, including TTE and TOE examinations). Supervised 3D acquisitions and postprocessing by an EPA level 5 (level III) trained expert with adequate case-mix is recommended for trainees during their echocardiography fellowship. Head-to-head comparison of 3D measurements with reference measurements obtained by other imaging modalities (e.g. cardiac magnetic resonance imaging, computerized tomography, etc.) from the same patient, or by a 3DE expert supervisor from the same 3D data sets, may reduce the learning curve for performing cropping, orientation, and border tracing on 3D data sets. Training should cover practical skills with both semi-automated and automated quantification tools.

Full 3DE competency usually requires a large number of TTE and TOE exams performed unsupervised with a large case-mix (i.e. quantification of left and right ventricle, atria, cardiac valves, septal

Table 5 Knowledge and skills required for competence in transoesophageal echocardiography (EPA level 3)

Knowledge
Basic general knowledge related to echocardiography (see *Table 1*)
Strengths and weaknesses of TOE for a given indication
Added value of TOE compared with TTE and other imaging techniques
Indications, contraindications, risks, and complications of the TOE procedure
Infection control measures and electrical safety issues related to the use of TOE
Techniques and risks of local anaesthesia and sedation; pharmacology of the involved drugs
Anatomy of the upper gastrointestinal tract with special emphasis on potential problems and hazards during oesophageal intubation
Knowledge of normal and abnormal cardiovascular anatomy on TOE, and of the typical cross-sections used
Ability to communicate TOE examination results to the patient, to its relatives, and to other healthcare professionals
Skills
Ability to obtain a focused history of upper gastrointestinal disorders and to rule out contraindications
Ability to perform autonomously each step of a complete TOE examination (patient and probe preparation, local anaesthesia, conscious sedation, bite guard, operation of TOE probe and scanner controls, manipulation of the probe tip and of imaging plane orientation, etc.)
Knowledge to operate the echo machine to optimize image quality, acquire, and archive TOE examinations
Familiarity with techniques of oesophageal intubation in ventilated and non-ventilated patients
Ability to administer conscious sedation techniques and to manage complications
Proficiency in cardiopulmonary resuscitation
Ability to obtain typical sets of images using all available TOE imaging techniques (2D, Doppler, contrast, 3D) according to the specific indications and clinical questions
Ability to recognize anomalies of cardiac structure and function as imaged by 2D and 3D TOE
Ability to recognize artefacts
Ability to perform qualitative and quantitative analyses of the echocardiographic data (ideally 2D and 3D TOE)
Ability to produce a complete written report of the relevant TOE findings, including the possible clinical implications
Knowledge in disinfecting the probe and in recognizing technical defects, in particular in electrical insulation

defects, etc.). The knowledge and skills required to achieve competence in 3DE are listed in *Table 6*.

To date, EACVI does not have a certification process in place for 3DE, mainly due to the difficulties related to intervendor and inter-software differences. Recently, the EACVI and ASE have joined efforts with industry partners to standardize 3D data sets among vendors and allow intervendor readability and analysis of data. This is an essential step towards full clinical implementation of 3DE and certification of competency.

Interventional echocardiography

The rapid growth of transcatheter structural and electrophysiology interventional procedures and the need for echocardiographic monitoring to optimize outcomes and detect complications, has given rise to the new subspecialty of interventional echocardiography. Echocardiography (particularly TOE) is ideally suited for monitoring percutaneous catheter-based procedures.

In only few years, TOE guidance has become essential for transseptal puncture, Mitral Clip implantation, other mitral or tricuspid valve repair transcatheter procedures, paravalvular leak closure, left atrial appendage occlusion, septal defect closure, pulmonary vein ablation for atrial fibrillation, etc.

Adequate training in interventional echocardiography is dependent on the full understanding of the theoretical principles, specific indications and technical limitations of 2D vs. 3D TOE techniques applied in the Cath lab, as well as the individual steps of each procedure and their respective imaging requirements. Knowledge of specific terminology and of standard views and orientations to be obtained for various procedures is pivotal and, since imaging protocols are not standardized yet, these should be discussed with the interventional cardiologist.

Ideally, training in interventional echocardiography has to be completed in high-volume centres under the close supervision of a fully qualified imaging expert who performs and interprets a large number of such studies yearly. As the experience with this new subspecialty is growing, the requirements for achieving competency in interventional echocardiography are still evolving.[27]

Intraoperative TOE

Intraoperative echocardiography refers to ultrasound studies performed during surgery, whereas peri-operative echocardiography refers to ultrasound studies performed immediately before, during, or after surgery. Intraoperative echocardiography includes mainly TOE, and to a lesser extent epicardial or epiaortic ultrasound studies.

Intraoperative TOE requires understanding the particular challenges of the operating theatre environment, taking into account the variable haemodynamics of patients on and off cardiac bypass, communicating the relevant findings to the surgeons in a prompt and adequate manner, as well as the details and potential complication of each surgical procedure, which often require familiarity with local surgical techniques and vocabulary. Supervised training in intraoperative TOE should provide exposure to the entire spectrum of surgical procedures that a trainee is likely to encounter in his/her practice.

Similar to interventional TOE, intra-operative TOE is an application in which diagnostic findings have the potential to produce immediately major changes in the procedure itself, patient management, and outcome. To become proficient in intra-/peri-operative TOE, a minimum number of 125 comprehensive intraoperative TOE examinations performed, interpreted, and reported unsupervised by the trainee is recommended (***EPA level 5; level III***).

In many European countries, the intraoperative TOE studies are performed not only by cardiologists but also by anaesthesiologists with special training in TOE.

Stress echocardiography

The EACVI (formerly EAE) released an expert consensus document on stress echocardiography (SE) in 2008.[28] The document presents the different protocols used, with indications and contraindications, the diagnostic criteria and prognostic value of examination findings, and the possible complications and adverse events.[28] The additional

Table 6 Knowledge and skills required to achieve competence in 3D echocardiography (EPA levels 4 and 5—level III)

Knowledge:
Basic knowledge of ultrasound physics and 3D acquisition using matrix-array probe
Anatomy of the cardiac chambers and valves, and of the spatial relationships between various structures
Principles, strengths, and limitations of 3D TTE and TOE
Added value of 3DE compared with 2D echocardiography and other imaging techniques
Pros and cons of different 3D acquisitions (single-beat, multi-beat, zoom, 3D colour)
Standard 3D views and orientations ('surgical' view, 'en face' view, etc.)
Reference values developed specifically for 3DE and how they compare with reference values for 2D echocardiography and other imaging modalities
Skills:
Ability to obtain autonomously all types of acquisitions by 3D TTE and 3D TOE
Knowledge to operate the 3D echo machine to optimize image quality and temporal resolution, acquire, postprocess and archive 3D data sets
Ability to recognize abnormalities of cardiac structure and function as imaged by 3D TTE and 3D TOE
Ability to avoid pitfalls and to recognize artefacts affecting 3D data sets
Ability to perform qualitative and quantitative analyses of the 3D echocardiographic data
Ability to integrate relevant 3DE findings in the echocardiographic report and to communicate findings to the patient and other healthcare professionals

skills required for imaging the heart under stress conditions undoubtedly differ from studies at rest. Thus, it is sensible to practice SE only after completion of TTE training and authorized certification. Moreover, it has been reported that the interpretation of stress echocardiographic examinations by operator without specific training undermines the diagnostic potential of this technique.[29] For advanced level competence and independence in SE, EACVI recommends supervised performance and interpretation by an EPA level 5 (level III) trained expert, of more than 100 SE studies in a high-volume laboratory, ideally with the possibility of angiographic confirmation.[1,28,29] In the updated ESC Core Curriculum, the recommended level of competence during cardiology training is ***EPA level 2 (Level II)***, with a minimum recommended number of 50 studies (*Table 3*).

It is important to gain stress echo experience across a wide spectrum of clinical conditions beyond the evaluation of ischaemia (e.g. heart failure, valvular heart disease) using both pharmacological and exercise stress. However, since there is variation in the difficulty of performing and interpreting different stress echo scans, it is recommended to begin with those scans that are easier and safer to perform before progress to the more technically demanding and higher risk scans.[28] Trainees must also understand that for a given diagnostic accuracy, every observer has his/her own 'sensitivity/specificity curve', depending on whether images are aggressively or conservatively interpreted as abnormal and so it is important to use optimal consensus criteria for reading SE studies.[28,30] ***EPA 5 (Level III)*** experience includes superior training in and being competent with the application of SE for the evaluation of (i) abnormal haemodynamic responses in patients with valvular heart disease; (ii) patients with hypertrophic cardiomyopathy, and (iii) the assessment of myocardial viability.[31,32]

The training requirements for competence in SE are listed in *Table 3*, and the staff requirements of the SE laboratory are presented in *Table 7*.[28,30,33]

Contrast echocardiography

Contrast echocardiography is used widely in cardiology. Encapsulated microbubble ultrasound enhancing agents improve left ventricular (LV) endocardial definition and allow perfusion assessment. This improves the reproducibility of assessing LV myocardial structure, function, and microcirculation at rest and during SE and is also useful to detect intracardiac thrombi and masses.[34] In addition, agitated saline contrast helps in the diagnostic work up of patients with suspected intracardiac shunts or unexplained hypoxaemia.

Training in contrast echocardiography should include acquiring information about the composition and safety of microbubble contrast agents, contrast-specific imaging methods, indications and contraindications, and specific scenarios in which contrast is likely to add value.

The EACVI has updated the standards and processes for accreditation of echocardiographic laboratories in 2014.[15] Contrast echocardiography must be used, if needed, even for basic standard applications. In addition, according to the updated ESC Core Curriculum for the General Cardiologist, the trainees should be familiar and perform contrast echocardiography during fellowship,[5] although there are no specific details regarding numbers needed and/or specific imaging modalities. In the recent 2017 EACVI recommendations, the following requirements for operators using contrast echocardiography in TTE are listed:

(1) Participation in courses of contrast echocardiography.
(2) Basic life support training.
(3) Supervised performance and interpretation of at least 25 contrast echo studies.
(4) Maintenance of competency by performing at least 50 contrast echo studies per year.

For physicians who use contrast agents in SE studies, a minimum of 50 examinations under the supervision of an EPA level 5 (level III) reader trained in contrast imaging, in a high-volume laboratory, and ideally with angiographic verification of the results are recommended. For perfusion studies, a number of 100 supervised examinations in a high-volume centre is recommended.[28]

EPA 5 (level III) competency in contrast echocardiography requires extensive experience in resting and stress contrast echocardiography, as well as awareness of different imaging protocols, pitfalls, and artefacts, and certain machine settings to improve image quality.

Echocardiography for adults with congenital heart disease

The EACVI published an expert consensus document on imaging in adults with congenital heart disease (ACHD).[35] Echocardiography is the first-line imaging modality in the assessment and follow-up of ACHD patients.[35,36] To perform echocardiography in ACHD patients, it is recommended to hold CHD certification. ***The EACVI recommends to perform at least 100 ACHD exams under the supervision of an expert reader in a high-volume laboratory***, ideally with the possibility of comparing the echo results with other imaging modalities (e.g. Cardiac Magnetic Resonance or cardiac CT). Trainees must know the sequential segmental analysis, crucial in the assessment of complex congenital lesions, to avoid missing important findings. Echocardiography studies in ACHD should be supervised and reported by appropriately trained ACHD specialists.[35]

It is recommended to develop and follow lesion-specific imaging protocols for follow-up studies, to ensure the critical information for clinical decision-making is included in the imaging study, and for longitudinal data comparison. For example, TTE in repaired tetralogy of Fallot or Ebstein patients, has to include a more detailed assessment of right ventricular (RV) size and function and of the tricuspid valve, whereas in patients after aortic coarctation repair, a more detailed assessment of LV size, mass, and function must be included.[35,36]

In patients with poor quality transthoracic images, additional approaches are required according to the clinical question. Contrast echocardiography is helpful for visualization of intracardiac shunt, volume quantification, cardiac masses, and for myocardial perfusion, while TOE is the best approach for the detailed assessment of intracardiac anatomy and valve function.

Deformation imaging

Deformation imaging techniques have been developed for a better understanding of myocardial mechanics and their clinical applications are growing. Although not part of every echocardiographic study, they play an increasing role in modern cardiology. Global longitudinal strain (GLS) by speckle tracking echocardiography is the most robust deformation parameter, detecting alterations in global, and regional myocardial function. GLS is more sensitive than LV ejection fraction

Table 7 Training, competence, and staff requirements for SE

Training requirements for performance and interpretation of SE
Understanding the basic principles, indications, applications, and technical limitations of echocardiography
EPA 5 (level III) training in TTE
For advanced competence level specialized training in SE with performance and interpretation of 100 studies under appropriate supervision by an echocardiographer with EPA level 5 (level III) trained expert
Maintenance of competence in SE
Performance and interpretation of 100 or more SE studies per year
Participation in continuing medical education in echocardiography
At least two persons are required to record and monitor SE studies. One should be qualified in advanced life support, the other in basic life support.
A nurse should always be present to support the physician performing the test
If the study is performed by a sonographer/technician, a physician with expertise in both echocardiography and resuscitation should always be attending in case a life-threatening complication occurs

in detecting early cardiac dysfunction in different clinical settings (e.g. LV hypertrophy, heart failure with preserved ejection fraction, chemotherapy-induced cardiotoxicity, asymptomatic valvular heart disease).[37] Proper training under expert supervision can improve concordance and precision of GLS measurements.[38] Other applications of deformation imaging (e.g. RV and LA function) are less well standardized and more seldom applied in daily practice.[39] ***Independent performance of the spectrum of these techniques requires EPA Level 5 (level III) training*** under the supervision of an expert in a laboratory in which these procedures are performed on a daily basis.

Focus cardiac ultrasound (FoCUS)

Cardiac ultrasound can provide important, often life-saving information in critical/emergency settings. A FoCUS study uses ultrasound to provide adequate information for mostly qualitative gross evaluation of cardiac anatomy and function, reported as 'yes/no'[40] (*Table 8*). Medical professionals may learn to perform a FoCUS study independent of full training in comprehensive echocardiography. Those additionally training in comprehensive TTE will be able to apply the principles of critical care echocardiography and understand the influence of haemodynamic changes with different loading conditions, heart–lung interactions, and related physiology on echocardiographic findings.[41] EACVI emphasizes the need for specific training in order to fully utilize the benefits and minimize the drawbacks of this type of examination in critically ill patients.

Accredited core echocardiography laboratories should preferably be responsible for quality control and supervision of trainees, where their performed cases must be reviewed together with fully trained cardiologists.

A new certification scheme by EACVI is under development, with detailed required theoretical knowledge on cardiovascular disease and a logbook of FoCUS cases.[40]

Multimodality imaging

The EACVI is committed to a future based around multimodality imaging (MMI). This is defined as '*Imaging of the heart based around the patient, and their disease pathology and presentation, utilizing information from one or more imaging modalities performed separately or in combination and offering the most clinically effective and cost-effective testing for the patient*'.

The EACVI and the American College of Cardiology/American Society of Echocardiography have highlighted the importance of training in MMI.[42,43] The different modalities provide complimentary understanding of physics, physiology, anatomy, and pathology useful to aid learning but the time required to acquire skills in multiple modalities places a pressure on already full training programmes. Advanced imaging training may therefore need further time after completion of current specialist training programmes, for example, through fellowships and exchanges.

In certain situations, different imaging modalities to echocardiography may be better placed to assess a patient's clinical problem. The echocardiographer should have an understanding of these different approaches, even if they do not routinely perform these techniques so that best test is selected for the patient.

Assessing and maintaining competence

Requirements for competence in different echocardiography techniques, together with the minimal training requirements, have been discussed in previous sections. This section presents the general principles of assessing competence, maintaining competence, and the current status of the EACVI certification and re-certification for various echo modalities. This document focuses on updates, while more detailed information can be found in the previous publication.[1]

Proof of competence: certification

Individual competence cannot be distinguished from the competence of the team and facilities around them. This link is illustrated both in the fact that laboratories applying for EACVI accreditation must have evidence that their personnel is certified.[15] and equally in the fact that the American system for accreditation of echo laboratories requires submitted samples of each individual's work as part of the assessment.[44]

Table 8 Evidence-based targets of FoCUS examination and related emergency cardiovascular scenarios/conditions that might be addressed

Targets
Global LV and RV systolic size and function
Pericardial effusion
Intravascular volume assessment
Gross signs of chronic cardiac disease
Gross valvular abnormalities
Large intracardiac masses
Scenarios
Circulatory compromise/shock
Cardiac arrest
Chest pain/dyspnoea
Chest/cardiac trauma
Respiratory compromise
Syncope/presyncope
Conditions
Ischaemic LV/RV dysfunction
Mechanical post-myocardial infarction complications
Cardiomyopathies (i.e. DCM, HCM, Takotsubo)
Myocarditis
Cardiac tamponade
Pulmonary embolism
Hypovolaemia/shock

DCM, dilated cardiomyopathy; HCM, hypertrophic cardiomyopathy; LV, left ventricular; RV, right ventricular.

Proof of individual competence

Competence requires assessment that the candidate has appropriate knowledge, skills, and attitudes[5,11] and is measured with assessment tools in a combination of ways (see also *Table 2*):

a. Achievement of certifications with additional records of clinical experience (logbooks) and/or DOPS and
b. Participation in imaging review meetings and MultiDisciplinary Teams (MDTs) (see training programme paragraph).

As a method of assessment, examinations are much criticized and do indeed have many faults. They mainly test factual knowledge. However, they are widely accepted, validated, and very widely used in assessment processes. In echocardiography, questions should test theoretical knowledge and also the interpretation of images shown to the candidates.

Therefore, as part of the assessment of competency used to award EACVI certification, candidates undertake a multiple-choice question examination:

i. 75 items testing theoretical knowledge;
ii. 50 items testing the ability to interpret imaging from echo studies.

The pass mark is being adjusted by the examination committee after each examination on the basis of a combination of methods including benchmarking against a panel of experts and benchmarking against cohorts of candidates (who tend to have a consistent range of competence) derived from item response statistics. The examination is constantly revised and evaluated.[45,46]

The very practical nature of echocardiography means that a practical element to assessment is necessary. The practical element for EACVI certification consists of submission of a logbook of cases (250 for TTE and for ACHD echocardiography and 125 for TOE, unless candidate already has TTE accreditation where 75 suffice) performed by the candidate within either 12-month period (TTE) or 24-month period (TOE and CHD) after passing the written examination. The case-mix is prescribed to cover the range of pathologies normally seen. Especially for ACHD certification process, the relevant subcommittee decided to introduce the DOPS, giving to the local expert supervisor the responsibility to guarantee competence and assure quality. With this assessment tool, the supervisor directly observes all facets of the echocardiogram, while reviewing the ensuing interpretation of findings with the written report.

An electronic logbook has been in place for all modalities. For TTE and TOE ones, the certification process involves submission of six studies covering a range of key pathologies and a full range of echocardiographic views and modalities. The candidate uploads the studies into the web-based system at the Heart House (still frames and clips, properly anonymized) together with the reports of those studies. This electronic log book is then marked by independent EACVI graders. In combination, the supervisor's statement, and successful completion of the written examination, and practical log book provide evidence of competence and the award of accreditation by the EACVI.

Maintenance of individual competence

Re-certification

Although award of EACVI certification is valid for 5 years, recertification requires evidence of continuing practice (statement from laboratory head or assistant) and also evidence of CME activity (e.g. certificates of attendance).

The necessary requirements for EACVI re-certification in TTE are 250 studies per year and 50 h of CME, which must be collected over the 5 years that the candidate is certified for.[47] Individuals and labs are encouraged to have regular lab-meetings for reviewing cases and for discussing new publications and technologies. These teaching regular opportunities could be notified with the programme and the participating persons in a notebook illustrating the dynamism of the lab all over the years.

Laboratory accreditation

For the accomplishment and maintenance of high standards, individual expertise is insufficient and a suitable facility organization is also needed. As a consequence, the natural progression is from certifying individuals to establishing standards for echocardiographic laboratories, whereby the examinations and the equipment used are appropriate for clinical effectiveness.

The accreditation process in Europe is not regulatory, but in some other countries such as the USA, it is no longer just an award verifying a laboratory's quality, but instead, a condition for financial compensation. This motivation came not only from professional societies but also from payers. Yet, when one accepts accreditation as a practical appraisal of laboratory excellence, the question becomes what body is best suited to provide such an appraisal. The model may be a specific interrogation process that is executed under the auspices of one or various professional societies.

The EACVI laboratory accreditation process began in 2006 and evaluates laboratory facilities providing three echocardiographic modalities (transthoracic, transoesophageal, and SE) with two levels of standards. Thorough information can be accessed in the relevant publication.[15]

Quality improvement

Principles of quality measurement

Quality assurance (QA) is the systematic process by which one ensures echocardiograms provide timely, accurate, and clinically relevant information. Failure to do can cause serious consequences for patients and for the undertaking of research studies.

The definition of QA includes the planned, systematic activities that are necessary to ensure that a product or service fulfils its requirements. Echocardiography certainly falls within the category of a ‘product or service’.

QA requires attention to all elements of echocardiography, patient selection, patient experience, knowledge and skill of practitioners, workflow organization, equipment maintenance, output including systematic audit of studies undertaken. All aspects of a service should be measured, and wherever possible benchmarked against published standards.[15] Precision and reproducibility are both important parameters and multimodality imaging opportunities should be used to compare measurements, e.g. of ejection fraction.

Assessing quality in echocardiography

In the four following domains of QA, this document focuses only on worth mentioning updates. Any other relevant information can be accessed in the previous publication.[1]

Patient selection

In order to identify patients who would benefit most from echocardiography, the first essential action is the development of appropriate use criteria (AUC), listing the indications for which echocardiography may be considered appropriate.[16] AUC show temporal changes since their adoption after a decade even in their terminology; terms such as ‘uncertain’ and ‘inappropriate’ have been modified with ‘maybe appropriate’ and ‘rarely appropriate’.[48] Yet it has to be mentioned that their endorsement has been generally slow in several regions of the world (mainly outside North America).[3] Rates of reported appropriate use in imaging show improvements for TTE (>80% appropriateness) only, but not for SE or other stress imaging modalities and TOE.[2]

Study performance and patient’s safety

Quality of study performance relies on several main issues:

(1) Physician’s or sonographer’s knowledge about the strengths and weaknesses of TTE for a given indication, benefits compared with other echo modalities and other imaging techniques, indications, and appropriate use criteria.[17]
(2) Physician’s or sonographer’s knowledge of normal and abnormal cardiovascular anatomy, artefacts, skills and ability to perform a complete TTE examination, to operate the echo machine to optimize image quality, familiarity to apply different modalities including, conventional Doppler, tissue Doppler, speckle tracking, 3D with proper image acquisition, skills to obtain modified views whenever necessary for specific indications, ability to acquire qualitative, and quantitative data during the exam for a coherent, comprehensive written report of the echocardiographic findings adhering to recommendations.[21,50]
(3) Echo systems, organization, and supervision.
(4) Assessment of study and data reporting quality as mentioned above.

Patients safety relies on ensuring:

(1) Useful and timely delivered results for patient management;
(2) Accuracy of the study: this is ensured by supervision, certification of individual echocardiographers;
(3) Minimal procedural complications and proper instrumentation. Standard TTE exams are considered to be safe for the patients. However, special echocardiographic procedures, such as transoesophageal, SE or contrast use, pose potential risks to the safety of the patient. For this reason, an echo lab providing special echocardiographic procedures must have an emergency procedure plan, and emergency supplies readily available. Such laboratories should adhere to the standards recommended by the EACVI, as well as the physicians and sonographers who perform the special echo procedures.[15]

Study interpretation

The trainee should achieve a basic level of expertise on cardiac structure and both systolic and diastolic function to interprete TTE. The training for interpreting SE should be focused to recognize wall motion abnormalities at rest and during/after stress as well. The level of expertise should be more advanced when dealing with TOE in order to identify appropriately valvular malfunction, vegetations, and sources of emboli. The second step of training should include the achievement of a good capacity in integrating the qualitative and quantitative information of the different cardiac ultrasound techniques. This integration is fundamental to establish evidence and grading of LV and RV dysfunction, coronary and valvular heart disease, cardiomyopathies, pericardial, and congenital heart diseases. Training requirements are shown in *Table 3* and include a balanced number of exams performed in both clinical stable conditions and urgent situations. It is recognized that the SE interpretation by an operator without specific training substantially underestimates the diagnostic potential of this technique.[45]

Reporting and communication of results

The reporting of the echo exam should be consistent with the EACVI standardization of the echo reporting.[50] The abnormal findings should be highlighted. Modifications over time, compared with a previous echo exam, should be considered with caution, considering always the consistency (feasibility, reproducibility, and diagnostic accuracy) of the parameters used for the comparison. In general, the trainee should acquire sufficient capability to reporting an appropriate reply to clinical questions and to be helpful in urgent clinical conditions.

Table 9 Elements of a Quality Assurance Programme

(1)	Regular (at least annual) assessment of environment and equipment
(2)	Regular review of protocols for patient selection, patient information, indications for studies, triage, and study performance
(3)	Regular (annual) audit of parameters of process of care: Waiting times for studies, waiting times for reports, proportion of studies fulfilling appropriateness criteria/indications, number of studies performed, patient satisfaction
(4)	Regular (monthly) clinical governance review of safety (especially SE and TOE)
(5)	Documented programme of staff training including internal and external CME
(6)	Regular (e.g. weekly) meeting to discuss complex or interesting cases
(7)	Regular re-reporting of a randomly selected percentage of studies performed. Percentage depending on laboratory and individual echocardiographer workload and experience. Up to 10% for low volume/less experienced operators. Feedback mechanism for reporting differences and alert system for high difference rates
(8)	Regular programme of measurement variability assessment exercises

Implementation of quality-improvement recommendations

The outline of a comprehensive QA programme is listed in *Table 9*. Echocardiography laboratories will be at very different stages if mapped against such a programme and the challenges for progression should not be underestimated. Many centres currently operate under significant financial and resource strain and QA is often not perceived as a priority.

To implement a QA programme requires first and foremost agreement and indeed enthusiasm from all stakeholders, those working in the laboratory, and those in the institution with managerial responsibility. QA requires ongoing commitment and resource and while ultimately a high-quality laboratory is efficient and safe these benefits may not easily be recognized during the development and early implementation of the programme.

Although the implementation of the full programme is ideal an incremental approach may be more realistic in many centres. Item 6—a regular meeting for interesting or complex cases—is probably the most frequently adopted element. Annual audit of the laboratory environment, equipment, and pathways relatively achievable, with progression to systematic re-reporting, and exercises assessing measurement precision and variability.

National societies can assist centres by running QA activities which can complement local programmes.[15,43,51,52]

Reported experience of quality issues in echocardiography

Although the possibility of harm is limited in echocardiography, there is a sizeable risk from inadequate diagnostic accuracy. The role of evidence-based trials investigating both variability and accuracy shows that teaching activities generally improve precision of reported data. Measurements related to LV and RV performance and valvular heart disease are among the most common requested reasons to perform echocardiography.

The available studies for ejection fraction calculation are numerous[53–55] and emphasize the importance of a case-based process for reducing interobserver variability between operators. One report[53] indicated that in a wide spectrum of sonographers and physicians with different level of experience, teaching sessions over a period of 3 months resulted in a 40% reduction in interobserver variability. Another study investigated the correlation between the accuracy of interpretation of LV systolic performance and patient outcomes. In four academic centres, patient mortality was strongly related to LVEF as calculated by physicians certified in echocardiography. Thus, the reliability of examinations performed by certified personnel may represent a useful quality criterion affecting patient outcomes.[56] The interobserver variability of GLS measurements improves after training interventions, being superior to that of ejection fraction, highlighting the importance of training and experience in making novel parameters more useful for both research and clinical practice.[37,38] The implementation of conventional quantitative measurements of RV function has improved accuracy and inter-reader agreement compared to qualitative visual estimation alone.[57] The ongoing refinements in 3D echocardiography technology allow more accurate and reproducible measurements of LV volumes and ejection fraction compared with 2D echocardiography. Efforts to include RV volumes and function quantification algorithms in the automated, machine learning based techniques are underway.[58]

In terms of diastolic function evaluation, the updated 2016 ASE/EACVI[59] recommendations represent a step forward compared to the previous version,[60] allowing a good level of agreement in the estimation of LV filling pressure.[61] However, the complexity of diastolic function requires further improvements and continuous reassessment of proposed diagnostic algorithms.[62,63]

In valvular heart disease, the importance of multiparametric approach is always emphasized due to significant interobserver variability for assessing the lesions' severity. Consensus strategy about hierarchical multiparametric assessment, internal discussions of identifying causes of discordance, validation against CMR, and the additional use of 3DE are all means of improving the accuracy and variability of measurements.[64]

Conclusions and future directions

Best patient care requires proper use of echocardiography since this is typically the first-line imaging modality for cardiovascular disease. Imaging is continuously evolving and demands adequate training and quality control. The periodical update of requirements for training and competence in echocardiography is therefore required. In this statement, we present specific information about training, competence, and quality improvement.

In the absence of evidence-based trials, information about requirements for training in imaging is drawn from scientific societies' core curricula and expert consensus statements. We provide standards for learning through supervised knowledge acquisition and practice. Details of competency assessment through certification and accreditation processes have also been updated together with guidance on quality improvement activities. This statement provides a key contribution to fulfilling the core mission of the EACVI.

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