

# Emergency echocardiography: the European Association of Cardiovascular Imaging recommendations

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## Introduction

It is widely recognized that echocardiography is the single most versatile and cost-effective imaging technique to assess patients with unstable cardiovascular diseases. Mobility and relative low cost of echocardiographic machines, including hand-held devices, allow their use virtually everywhere.<sup>1–4</sup>

In addition, in expert hands, echocardiography may provide instantaneous and comprehensive assessment of cardiac structure and function as well as haemodynamics, with minimal discomfort or risk for the patient, without using radiological contrast media or ionizing radiations. Since the physician who performs echo may be the same who is managing the patient, the echo data can be readily used to speed up the decision-making process.

These characteristics make the technique even more attractive in the emergency setting, since it is safely and easily repeatable any time there is a change in patient haemodynamics, or a need to follow-up previously detected abnormalities.

Accordingly, echocardiography is already included into patient management algorithms for the majority of cardiovascular emergencies. However, although general diagnostic power of echocardiography could be hardly challenged, for an adequate interpretation

in particular clinical situations it is essential to fully understand its advantages and limitations, in order to reduce the likelihood of potential catastrophic diagnostic and therapeutic errors. The expanding use of echocardiography examinations by non-cardiologists or cardiologists with insufficient formal training in the emergency setting urged scientific societies to set standards for optimal education and training, and to identify the level of competence in echocardiography that should be reached by emergency health-care professionals. Precise and strict requirements need to be defined in order to ensure the quality and the accuracy of the data obtained by echocardiography, particularly in the emergency setting.

## Purpose

The purpose of this document is to provide recommendations for the safe and efficient use of echocardiography to assess patients presenting with cardiovascular emergencies and to set up/propose standards for adequate education and training of physicians performing echocardiography in the emergency setting.

In addition, the principles, practical aspects, and specific considerations related to echocardiography in the emergency settings are

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discussed. Detailed description of echocardiographic signs of particular cardiovascular entities that may be presented to emergency physicians can be found elsewhere.<sup>4</sup>

## Document format

The present document is released by the European Association of Cardiovascular Imaging (EACVI) and developed in accordance with the principles outlined in the European Society of Cardiology (ESC) Core Curriculum,<sup>5</sup> European Association of Echocardiography (EAE) core syllabus,<sup>6</sup> and EAE recommendations for training, competence, and quality improvement in echocardiography,<sup>1</sup> and is intended to complement them by addressing key issues specifically related to the use of echocardiography in cardiac emergencies.

## Definition of emergency echocardiography

The term emergency echocardiography throughout this document refers to the use of echocardiography in the assessment of patients with unstable cardiovascular diseases. It should be distinguished from the routine use of echocardiography in emergency environments. For example, the use of stress echocardiography in chest pain units is not considered as emergency echocardiography, since it is applied in clinically stable patients. Emergency echocardiography is a comprehensive echocardiographic study,<sup>7</sup> which should also be distinguished from the focused cardiovascular ultrasound or examinations performed with pocket-size imaging devices (echo scanning), which may be a part of the clinical examination. Thus, the term emergency echocardiography is reserved for an investigation performed by a person who is able to independently perform the study using

a fully equipped echocardiographic machine and interpret results unaided.

## Training and competence for performance and interpretation of emergency echocardiography

Performing an echocardiographic examination in a patient with suspected or known cardiovascular disease presenting as an emergency case may be challenging. Key decisions should be made quickly, in a stressful situation, characterized often by difficulties in acquiring good images. Physicians in charge are frequently forced to interpret suboptimal studies, having limited time for consultations with colleagues. Under these circumstances, interpretation errors or missing critical abnormalities are likely to occur more often and they might seriously affect patient's management and outcome.

From the ethical point of view, emergency echocardiography should be performed by anyone who knows how to get valuable information from it and use it in the decision-making process. 'Know how' includes: ability to obtain adequate images (imaging technique) and ability to interpret them in the specific clinical context (reading/interpretation). Improperly acquired and/or poor-quality images may result in inaccurate reading, with misleading and potentially dangerous conclusions.

Cardiologists are not the only medical professionals who are taking care of patients presenting with cardiovascular emergencies. In the real world, emergency cardiac diagnostics is also performed by emergency physicians, anaesthesiologists, intensive care specialists, cardiac surgeons, or even fellows and general practitioners. In addition, apart from physicians, properly trained sonographers may also be capable to provide crucial, life-saving information by using transthoracic echocardiography (TTE) in emergency cases.

The ESC Core Curriculum<sup>5</sup> defines the different levels of competence on several diagnostic techniques and states the level expected for a given area of subject matter. Level I—experience on selecting the appropriate diagnostic modality and interpreting results; this level does not include performing the technique (e.g. advanced methods of imaging, such as cardiac magnetic resonance); Level II—practical experience, but not as independent operator (the trainee has assisted in or performed the procedure under the guidance of a supervisor); Level III—able to independently perform the procedure and interpret results unaided (for the general cardiologist, this includes TTE).

Echocardiography in every single emergency case, if not personally performed and interpreted, should at least be supervised by an expert physician with advanced level of competence in echocardiography (Table 1).<sup>1,5</sup>

## Requirements for reaching competence in emergency echocardiography

Emergencies require a level of competence which should be at least equivalent as for elective cases. Considering this, it is the consensus of this writing committee of the EACVI that emergency echocardiography can be performed by 'any general cardiologist'

**Table 1** Summary of levels of expertise for echocardiographic practitioners according to EAE recommendations for training, competence, and quality improvement in echocardiography (modified from Popescu et al.<sup>1</sup>)

Levels of expertise according to EAE recommendations	Levels of competence to be achieved according to ESC Core Curriculum <sup>5</sup>
Basic echocardiography (corresponds to ESC Core Curriculum requirements for general training for cardiologists)	<ul style="list-style-type: none"> <li>• Level III in general adult TTE</li> <li>• Level II in TEE</li> <li>• Level I in stress echocardiography</li> </ul>
Advanced echocardiography (appropriate for cardiologists with subspecialty interest in echocardiography)	<ul style="list-style-type: none"> <li>• Level III in general adult TTE</li> <li>• Level III in complex adult TTE</li> <li>• Level III in TEE</li> <li>• Level III in stress echocardiography</li> </ul>

**Table 2** Training requirements to achieve basic and advanced level of expertise in echocardiography<sup>1,5</sup>

Echocardiographic technique	Minimum number of examinations performed to become competent	Level of competence <sup>a</sup>	Minimum number of examinations performed/year to maintain competence
TTE	350 (basic) 750 (advanced)	III III	Reasonable exposure 100
TEE	75 (advanced)	III	50
Stress echocardiography	100 (advanced)	III	100

<sup>a</sup>According to ESC Core Curriculum.<sup>5</sup> See text.

**Table 3** Minimal requirements for training and expertise for cardiologists and non-cardiologists<sup>a</sup> for unaided performing/interpretation of adult echocardiography in emergency settings (modified from Popescu *et al.*<sup>1</sup>)

Level of competence in emergency echocardiography	Profile of individual performing emergency echocardiography	Minimal number of examinations performed to become competent <sup>b</sup>	Achieved level of expertise according to EAE recommendations	Level of competence to be achieved according to ESC Core Curriculum <sup>c</sup>	Additional education/training requirements
Independent operator	Cardiologists (completed training according to ESC Core Curriculum requirements for general training for cardiologists)	350 (TTE)	Basic echocardiography	<ul style="list-style-type: none"> <li>Level III in general adult TTE</li> <li>Level II in TEE</li> <li>Level I in stress echocardiography</li> </ul>	Highly recommended <ul style="list-style-type: none"> <li>150 emergency cases interpreted/reported</li> </ul>
	Non-cardiologists <sup>a</sup> (completed training in their own specialties, but not in cardiology)	350 <sup>d</sup> (TTE)	Basic echocardiography	<ul style="list-style-type: none"> <li>Level III in general adult TTE</li> <li>Level II in TEE</li> <li>Level I in stress echocardiography</li> </ul>	Mandatory <ul style="list-style-type: none"> <li>Theoretical: specific knowledge on emergency cardiovascular diseases/conditions (see list, <i>Table 4</i>),</li> <li>Practical skills: 150 emergency cases interpreted/reported; 50 of which personally performed and documented</li> </ul>
Expert operator	Cardiologists (completed training appropriate for cardiologists with subspecialty interest in echocardiography)	750 (TTE) 75 (TEE) 100 (stress echo)	Advanced echocardiography	<ul style="list-style-type: none"> <li>Level III in general adult TTE</li> <li>Level III in complex adult TTE</li> <li>Level III in TEE</li> <li>Level III in stress echocardiography</li> </ul>	No additional training required (expert operators in emergency echocardiography provides: education, training, and supervision)

<sup>a</sup>Anesthesiologists, intensive care specialist, emergency physicians, and cardiac surgeons. Sonographers and fellows are not included.

<sup>b</sup>Programme directors directly involved in education and training process in emergency echocardiography must have advanced level of expertise in echocardiography (according to EAE recommendations<sup>1</sup>), and achieved Level III of competence in general adult TTE, TEE, and stress echocardiography (according to ESC Core Curriculum<sup>5</sup>).

<sup>c</sup>The ESC Core Curriculum<sup>5</sup>. See text.

<sup>d</sup>Additional training is mandatory.

whose training fulfils the requirements outlined in the ESC Core Curriculum.<sup>5</sup> According to the EAE recommendations for training, competence, and quality improvement in echocardiography,<sup>1</sup> this corresponds to the 'basic level of competence' in

echocardiography (*Table 1*). However, it is strongly recommended that all cardiologists who are involved in emergency cardiac care on a daily or regular basis pass an additional training programme consisting of interpretation/reporting of at least 150

**Table 4** Proposed list of emergency cardiovascular diseases/conditions to be included in additional theoretical learning program

- Acute coronary syndrome/acute myocardial infarction
- Mechanical complications of acute myocardial infarction
- Acute aortic syndrome/aortic dissection
- Acute pulmonary embolism
- Acute heart failure/cardiogenic shock
- Acute pericarditis
- Cardiac tamponade
- Acute myocarditis
- Pneumothorax
- Cardiomyopathies
- Aortic stenosis
- Acute valvular regurgitation
- Hypertrophic cardiomyopathy
- Takotsubo cardiomyopathy
- Prosthetic valve dysfunction
- Cardiac sources of embolism (tumours and masses)
- Ventricular assist device malfunction
- Acute complications of interventional procedures in the catheterization and electrophysiological laboratories
- Acute complications of cardiac surgery
- Endocarditis
- Traumatic injuries of the heart

echocardiographic examinations in critical or life-saving scenarios, in order to further improve technical skills and build experience in emergency echocardiography.

For 'non-cardiologists', who intend to use echocardiography in emergency settings (anaesthesiologists, emergency physicians, intensive care specialists, cardiac surgeons), the position of the EACVI is that they should achieve the same level of expertise through a training programme as requested for a general cardiologist (Tables 2 and 3). However, since the body of knowledge on cardiovascular diseases in these specialties is limited compared with cardiologists, additional education and training is mandatory for non-cardiologists to act as independent operators in emergency echocardiography. This programme should include both specific theoretical knowledge on emergency cardiovascular diseases/conditions (see list, Table 4) and additional hands-on training to acquire technical skills needed for performing adequate echocardiography study in unfavourable emergency settings (Table 5). Thus, to reach independent operator proficiency in emergency echocardiography, interpretation/reporting of additional 150 emergency echocardiographic cases, with a case-mix covering the full range of emergency cardiovascular conditions, should be mandatory in a training process for non-cardiologists. At least 50 of these examinations must be personally performed, documented, and interpreted under close supervision (Table 3).

It is essential that all programme directors directly involved in the education and training process in emergency echocardiography have advanced level of expertise in echocardiography (according to EAE recommendations),<sup>1</sup> and achieved Level III of competence in general adult TTE and transoesophageal echocardiography (TEE) (according to ESC Core Curriculum).<sup>5</sup>

**Table 5** Subjects of special training interest to be included in additional programme of learning practical skills for cardiologists and non-cardiologists

- Indication and limitations of emergency echocardiography
- Knowledge about technical settings, artefacts, and pitfalls of echocardiography
- Knowledge about anatomy and topography of the heart and the great thoracic arteries and veins
- Standardized echocardiographic examination and documentation; value of non-standardized views
- Analysis of left and right cardiac chamber size and function
  - Detection of cardiogenic shock and its differentiation from other causes of shock
  - Detection of regional left-ventricular dysfunction
  - Detection of right-ventricular function, including right heart infarction
  - Detection of acute pulmonary embolism
- Detection of acute valvular disease
- Analysis and detection of pericardial effusion
  - Differentiation between effusion and haematoma
  - Differentiation between haemodynamically stable situations and tamponade
  - Differentiation between pleural and pericardial effusion
- Analysis of intra- and extravascular volume status
  - Detection of hypovolaemia
  - Detection of normal and pathological vein status
  - Differentiation between different causes of increased central venous pressure
  - Detection of increased extravascular lung water (B-lines—lung comets)
- Analysis of the thoracic aorta
  - Detection of acute aortic dissection (haematoma, ulcer)
  - Detection of ectasia and aneurysm
- Detection of prosthetic valve malfunction
- Detection and differential diagnosis of cardiac masses—cardiac sources of embolism
- Assessment of patient with chest trauma

'Sonographers' and 'fellows' in training should not routinely perform emergency echocardiography examinations unsupervised. Only in potentially life-saving scenarios, where any delay in decision making is likely to be lethal, sonographers or fellows can function alone. Of note, such examinations must be always carefully re-interpreted as soon as possible by the experts. Establishing optimal logistics of the 'emergency echocardiography service' (see in what follows) should make these situations uncommon. Continuous supervision is a key for success of such a service.

## Experience in emergency echocardiography

In emergencies, more than in any other settings, the person performing/interpreting echocardiography should have a respectable knowledge of cardiology and the capacity to fully integrate echo information into clinical decision-making process. The more comprehensive education and the larger experience of the physician performing echo, the higher will be the diagnostic accuracy and,

consequently, the better patient management. Emergency echocardiography is not only to identify cardiovascular pathologies which are easy to detect, like pericardial effusion, severe global left-ventricular dysfunction, and hypovolaemia. In experienced hands, it is also powerful in uncovering difficult and rare pathologies and in clarifying the cause of acute conditions.

Medical professionals should be aware of the existing gap between adequate competence and experience needed to properly address both simple and complex issues in the emergency setting, and the trend towards the use of echocardiography by non-cardiologists and cardiologists with insufficient formal training.

Therefore, it should be emphasized that echocardiography in the emergency setting is a highly demanding procedure and, due to serious implications of the examination result, should not be attempted by inexperienced operators without supervision.

### Proposed levels of competence in emergency echocardiography

We recommend two levels of competence in emergency echocardiography: the independent operator level and the expert operator level (Table 3).

Independent operator level is achieved by definition by cardiologists and also by non-cardiologists who successfully completed education and training according to the proposed recommendations. According to local logistics they can work alone or in a team with a sonographer or fellow.

Expert operator level is the highest level of competence in emergency echocardiography and is reserved for cardiologists specialized in echocardiography, equivalent to advanced echocardiography level of expertise by the EAE recommendations.<sup>1</sup> This includes specific training and competence for special echocardiographic procedures, such as TEE, and contrast echocardiography.<sup>1</sup> Expert operators should be individually certified in echocardiography at the highest national or international level. They should be responsible for education, training, supervision, and quality control, and act as key persons in establishing institutional emergency echocardiographic service (see in what follows).

Completion of an appropriate training programme does not necessarily ensure the competence. Competence should be formally assessed through a certification process. Currently, such process for emergency echocardiography is not established by the EACVI, but individual certification for various echo modalities and laboratory accreditation are offered. Considering proposed requirements for an independent operator level in emergency echocardiography (Table 3), individual certification can be achieved through standard EAE certification process for TTE.<sup>8</sup> Besides this, for expert operator level, individual national/EAE certification in TEE is recommended.<sup>8</sup>

As individual competence, especially in emergency medicine, is strongly related to the competence of the team and facilities around them, successful EAE laboratory accreditation<sup>9,10</sup> is likely to guarantee a favourable environment for providing high-standard service in all echo modalities, including emergency echocardiography.

### Maintenance of competence in emergency echocardiography

Ongoing practice and learning is required to maintain competence in emergency echocardiography over time.

Basic requirements for re-certification in TTE have been established by the EAE.<sup>8</sup> They combine requirements for ongoing practice with proof of continuing education through participation at relevant scientific meetings (e.g. certificates of attendance). Health systems where physicians largely report studies performed by sonographers may distinguish between the number of studies reported and studies performed for ongoing competence.

For emergency echocardiography, an exposure to 50 emergency cases/year (discussed, performed, and/or interpreted) with an adequate case-mix can be considered as reasonably sufficient for maintenance of competence for both cardiologists and qualified non-cardiologists.

### Echocardiographic techniques used in emergency settings

#### Transthoracic echocardiography

Transthoracic echocardiography is the main source of information in the emergency setting. Appropriateness criteria for TTE have been recently published, with strengths of indication for specific clinical scenarios, including acute settings (Table 6).<sup>11</sup>

Two-dimensional and spectral and colour-Doppler techniques are cornerstones for evaluation in cardiac emergencies. Newer techniques, like tissue-Doppler imaging and myocardial deformation imaging, as well as three-dimensional echocardiography, currently have a limited role in the emergency setting.

The vast majority of echocardiographers dealing with cardiovascular emergencies are trained in standard TTE. However, it is important to note that restriction of the TTE examination to standard imaging planes only<sup>7</sup> may be associated with missing important pathological findings and producing inaccurate reports, especially in emergency situations. Thus, it is crucial for echocardiographers to be also able to obtain and to understand non-

**Table 6** Conditions for which TTE is rendered as highly appropriate in the acute setting<sup>11</sup>

- Evaluation of hypotension or haemodynamic instability of uncertain or suspected cardiac aetiology
- Evaluation of acute chest pain with suspected myocardial ischaemia in patients with non-diagnostic laboratory markers and ECG and in whom a resting echocardiogram can be performed during pain
- Evaluation of suspected complication of myocardial ischaemia/infarction, including but not limited to acute mitral regurgitation, hypoxemia, abnormal chest X-ray, ventricular septal defect, free-wall rupture/tamponade, shock, right-ventricular involvement, heart failure, or thrombus
- Evaluation of respiratory failure with suspected cardiac aetiology
- Evaluation of patient with known or suspected acute pulmonary embolism to guide therapy (i.e. thrombolytics and thrombectomy)

standardized views of the heart, in order to acquire optimal images for interpretation in a given situation.

## Transoesophageal echocardiography

In the emergency setting, TEE can be used as a first choice technique, or after TTE, when this is non-diagnostic.<sup>11</sup> TEE may reasonably be the first choice when TTE suboptimal images are expected on the basis of patient characteristics and situation (e.g. mechanical ventilation, intra-operative, recent post-operative or intraprocedural study, severe chest wall deformation/injury, lung emphysema)<sup>11</sup> Also, TEE can be the first choice test in particular clinical scenarios when visualization of certain cardiac structures is necessary to confirm or reject a suspected diagnosis which, if overlooked, is associated with high morbidity and mortality (e.g. acute aortic syndrome, acute valvular regurgitation, acute prosthetic valve dysfunction, acute massive pulmonary embolism, chest trauma/aortic transection). TEE should also be used as a first choice test in patients with symptomatic atrial fibrillation/flutter to facilitate clinical decision-making (e.g. cardioversion).<sup>11</sup>

## Contrast echocardiography

The EAE has recently published recommendations for the clinical use of contrast echocardiography.<sup>12</sup> Evaluation of global and regional systolic performance is often critical, and a good visualization of the endocardium with second generation contrast agents<sup>13</sup> improves confidence of the operator in a rapid distinction between acute heart failure due to systolic and diastolic dysfunction, in detection and ruling-out of post-infarction left-ventricular pseudoaneurysm,<sup>14</sup> and left-ventricular thrombus formation.<sup>15</sup> Contrast agent may also facilitate diagnosis of aortic dissection.<sup>16</sup> In addition, injection of agitated saline may be used to generate contrast and define the tip of the needle during echo-guided pericardiocentesis.

Although ultrasound contrast agents have proven utility in the diagnosis and management of critically ill patients,<sup>17–20</sup> there were concerns regarding the safety of these compounds, particularly in these patients. Recently published studies demonstrated no mortality increase in patients undergoing contrast echocardiography in comparison with patients undergoing non-contrast-enhanced examinations, including the critically ill.<sup>21–24</sup>

## Lung ultrasound examination

In recent years, lung ultrasound (LUS) has been proposed as a useful point-of-care tool in emergency.<sup>25</sup>

The LUS examination can be performed with any commercially available 2-D scanner, including pocket-size devices, by using a cardiac, convex or microconvex transducer, with the patient in the near-supine, supine, sitting, or even standing position.

In addition to the detection of pleural effusion, LUS may help in the diagnosis of acute dyspnoea, allowing the differential identification of pneumothorax, pulmonary consolidations, acute respiratory distress syndrome, and cardiogenic pulmonary oedema.<sup>25</sup> The absence of multiple bilateral B-lines, a sign of increased extravascular lung water, excludes cardiogenic pulmonary oedema with a negative predictive value close to 100%.<sup>26</sup>

## Use of emergency echocardiography in different clinical settings

### Emergency room

Patients with cardiovascular emergencies are the most frequently seen in the emergency room. At this location, three scopes of emergency echocardiography can be recognized: diagnostic, symptom or sign-based, and resuscitative.

The first and most commonly utilized scope is 'diagnostic'. All acute cardiovascular conditions should be assessed with echo, including cardiogenic shock and other shocks of different causes, chest trauma, acute myocardial infarction and ischaemia, acute pulmonary embolism, cardiac tamponade, and aortic dissection.

The 'symptom or sign-based scope' implies the clarification of the cause of acute symptoms, like acute chest pain (e.g. differentiation between acute myocardial infarction and aortic dissection), dyspnoea (e.g. detection of myocardial ischaemia, acute pulmonary embolism, pericardial effusion, heart valve disease, cardiomyopathies), fever (e.g. detection of endocarditis, myocarditis, and pericarditis), neurological deficits (e.g. detection of cardiac sources of embolism, cardiac tumours, or aortic dissection), hypotension (e.g. detection of acute heart failure, cardiac tamponade, aortic stenosis, or hypertrophic obstructive cardiomyopathy), or cyanosis (e.g. detection of acute pulmonary embolism or severe shunts).

Finally, emergency echocardiography directly related to an acute 'resuscitation' is also possible in the emergency room. In this scenario, detection of pericardial effusion and tamponade, assessment of global and regional left-ventricular function, right-ventricular size, check of the central venous volume status and great vessels may be crucial for acute clinical decision making.

### Intensive care units

In the coronary care unit (CCU), intensive care unit (ICU), and the specialized post-operative cardiac surgery ICU, echocardiography is the basic imaging technique. In addition to the diagnostic, symptom or sign-based, and resuscitative categories, emergency echocardiography in CCU and ICU is established for procedure guidance, monitoring, and therapeutic control. Thus, echocardiography is used to evaluate regional and global left-ventricular function in patients with acute myocardial ischaemia/infarction (functional infarction size). It should detect and document the presence and haemodynamic significance of new pericardial effusion after percutaneous coronary interventions (PCI), electrophysiological procedures, and pacemaker/device implantations. It may also be used before primary PCI to identify infarct-related artery according to the location of asynergy, after elective PCI for detection of new asynergy indicating periprocedural infarction, after primary PCI to assess global and regional left-ventricular function or suspected early stent thrombosis, to detect complications after acute myocardial infarction (e.g. post-infarction ventricular septal defect, acute mitral regurgitation, and acute heart failure), as well as vegetations and/or abscess formation in suspected endocarditis.

In post-operative cardiac surgery, ICU echocardiography is important for the detection of early complications (e.g. vessel and bypass-graft occlusion, early prosthetic dysfunction or endocarditis, paracardiac bleeding, cardiac compression by haematoma, cardiac tamponade). In addition, pericardiocentesis and pleural drainage may be guided by echocardiography.

Since patients in ICUs are often put on mechanical ventilation and therefore have poor TTE images, TEE and contrast echocardiography should be used for better visualization of cardiac structures and assessment of left-ventricular function.<sup>17–20</sup>

## Operating room and catheterization laboratory

Emergency echocardiography is often used in the cardiac surgery operating room and catheterization laboratory in the presence of acute complications.

Detailed recommendations for the use and reporting of perioperative TEE have been published recently.<sup>27–29</sup> In a number of countries, intra-operative echocardiography is performed by the anaesthesiologists with special training and accreditation in TEE.

In the catheterization laboratory, echocardiography is used for the detection and documentation of acute severe complications (e.g. perforation of coronary arteries or myocardium with consecutive pericardial haemorrhage and tamponade) and assessment of device position and function in periprocedural cardiogenic shock.

## Bedside, ambulance, outside of the hospital

The portable echo machines and new pocket-size imaging devices enable the application of emergency echocardiography in almost all scenarios. In this context, it is mandatory to differentiate between echocardiography performed at bedside, in ambulance, and/or outside of the hospital with pocket-size devices and portable echo machines, and complete high-end echocardiography performed in an echo laboratory, which typically should follow.

## Recommendations for the use of echocardiography in cardiac and cardiac-like emergencies

A summary of the recommendations for the use of echocardiography in cardiac and cardiac-like emergencies according to their clinical presentation is given in *Table 7*. Of note, these conditions are serious, often life-threatening and might have more than one initial clinical presentation. One should be aware that not all possible clinical situations are included in the list. Detailed description of clinical and echocardiographic signs of specific causes of cardiac emergencies is beyond the scope of this text and can be found elsewhere.<sup>4</sup>

Listed recommendations are based on available data from the literature and current practical guidelines, and reflect the consensus opinion of the members of this writing committee. The intention was to outline the clinical situations where echocardiography may provide crucial or important additional information for

establishing the diagnosis, decision making, and/or guidance patient management. Listed recommendations are not intended to limit attending physicians who are encouraged to use echocardiography in cardiac emergencies according to their own clinical judgement in all situations that they personally believe to be appropriate or the best for their patients. However, we do believe that listed recommendations represent a rational approach for the use of echocardiography in the emergency settings, which is likely to be translated into significant benefit in the decision-making process.

## Performing and reporting of emergency echocardiography

### ‘ABCD’ approach

In order to reduce diagnostic errors, the ‘ABCD approach’ is proposed (*Table 8*).<sup>30</sup> It summarizes mental and practical steps that should be followed in order to handle real-life challenges that may lead to misdiagnosis and misinterpretation.

### Emergency echocardiography service

Although excellent emergency echocardiographic assessment can be provided by trained professionals without having a formally organized service, a structured service will result in better patient care in the long run and more efficient utilization of human and technical resources.

Key issues in establishing successful emergency echocardiography service are team work, supervision, and quality control. Depending on human resources (number and profile of professionals involved in emergency echocardiography programme), available equipment (number and type of the echocardiographic machines), locations in the institution needed to be covered (i.e. emergency department, ICU, CCU, cath lab, operating room, bedside), and availability of specifically dedicated resources, information system, and/or local network, organization, and implementation of such a service will vary considerably between institutions. Therefore, it would be difficult to propose universal guidance for the most appropriate way to organize it.

However, this committee believes that emergency echocardiography service should have the following characteristics:

- 24 h availability of a physician with independent operator level of competence in emergency echocardiography;
- Efficient second opinion/consultative or on-call service for special echocardiographic techniques, provided by the physician with an expert operator level in emergency echocardiography;
- Team work (professional help, consultations, regular reviewing of cases after the acute situation);
- Continuous supervision, provided by the physician with expert operator level in emergency echocardiography; supervision is strongly recommended for all emergency echocardiographic cases performed either by cardiologists or non-cardiologists, and is mandatory for sonographers and fellows. Ideally, the main supervisor should be a cardiologist with advanced level of expertise in echocardiography according to EAE

**Table 7** Summary of recommendations for the use of echocardiography in cardiac and cardiac-like emergencies

Emergency clinical presentations	Causes <sup>a</sup>	Echocardiography recommended <sup>b,c</sup>	Echocardiography not recommended <sup>f</sup>
Acute chest pain	Frequent: ACS, AoD, PE, MP, Ptx Less frequent: ADHF, T, AVR/PVD	<ol style="list-style-type: none"> <li>1. Evaluation of acute chest pain in patients with suspected myocardial ischaemia/infarction and non-diagnostic ECG and cardiac enzymes, and when resting echocardiogram can be performed during the pain.</li> <li>2. Evaluation of acute chest pain in patients with known underlying cardiac disease (valvular, pericardial, or primary myocardial disease).</li> <li>3. Evaluation of patients with chest pain and haemodynamic instability unresponsive to simple therapeutic measures.</li> <li>4. Evaluation of chest pain in patients with suspected acute aortic syndromes, pulmonary embolism, myopericarditis, and Takotsubo cardiomyopathy.</li> <li>5. As an initial imaging modality for diagnosis of suspected aortic dissection in the emergency setting.</li> <li>6. Guiding the therapeutic approach in patients with known pulmonary embolism (e.g. thrombectomy and thrombolytics).</li> <li>7. In patients with suspected pericardial disease, including effusion, constriction, or effusive-constrictive process.</li> <li>8. In patients with suspected bleeding in the pericardial space (e.g. trauma, perforation)</li> <li>9. Guidance and monitoring of pericardiocentesis.</li> </ol>	<ol style="list-style-type: none"> <li>1. Evaluation of chest pain when non-cardiac aetiology is apparent.</li> <li>2. Evaluation of chest pain in patients with confirmed diagnosis of myocardial ischaemia/infarction.</li> <li>3. In patients with suspected pulmonary embolism to establish or rule-out the diagnosis.</li> <li>4. As an elective diagnostic strategy in haemodynamically stable, normotensive patients with suspected pulmonary embolism.</li> </ol>
Acute dyspnoea	Frequent: ADHF, PE, T, AVR/PVD, ACS Less frequent: AoD, PTx, MP	<ol style="list-style-type: none"> <li>1. Distinguishing cardiac vs. non-cardiac aetiology of dyspnoea in patients in whom clinical and laboratory findings are ambiguous.</li> <li>2. Assessment of left-ventricular size, shape, and global and regional function in patients with suspected clinical diagnosis of heart failure.</li> <li>3. Detection of echocardiographic signs of tamponade.</li> <li>4. Detection of acute valvular regurgitation and/or prosthetic valve dysfunction.</li> <li>5. Detection of suspected complication of myocardial ischaemia/infarction, including but not limited to acute mitral regurgitation, ventricular septal defect, free-wall rupture/tamponade, right-ventricular involvement, heart failure.</li> </ol>	
Haemodynamic instability/shock	Frequent: ADHF, T, AVR/PVD, PE, ACS Less frequent: AoD, PTx, MP	<ol style="list-style-type: none"> <li>1. For differential diagnosis of the cause of hypotension or shock, by detecting cardiac or non-cardiac aetiologies.</li> <li>2. Rapid identification of pericardial effusion, left-ventricular or right-ventricular dysfunction, and acute valvular dysfunction.</li> <li>3. Rapid assessment of intravascular volume status.</li> </ol>	In patients suffering from shock of apparently non-cardiac aetiology (e.g. anaphylactic, neurogenic, haemorrhagic, etc.).
New murmur	Frequent: AVR/PVD, ACS, AoD Less frequent: MP, ADHF, PE	<ol style="list-style-type: none"> <li>1. In patients with cardiac murmurs and symptoms or signs of or suggestive of heart failure, myocardial ischaemia/infarction, syncope, thromboembolism, infective endocarditis, or clinical evidence of structural heart disease.</li> <li>2. Detection of valvular vegetations, indicating infective endocarditis.</li> </ol>	

Continued



**Table 7 Continued**

Emergency clinical presentations	Causes <sup>a</sup>	Echocardiography recommended <sup>b,c</sup>	Echocardiography not recommended <sup>c</sup>
Chest trauma	Frequent: T, AoD, PTx Less frequent: ACS, AVR/PVD	Detection of pericardial effusion, myocardial contusion or laceration, regional wall motion abnormalities, acute valvular regurgitation, and aortic dissection in patients with severe deceleration injury or chest trauma.	Routine evaluation in the setting of mild chest trauma with no electrocardiographic changes or biomarker elevation.
Cardiac arrest/CPR	Frequent: ACS, PE, T Less frequent: AoD, MP, AVR/PVD, PTx	Identification of the (unexpected) cause of cardiac arrest in order to guide CPR (e.g. tamponade, pulmonary embolism, hypovolemic heart, hypertrophic cardiomyopathy).	As a routine procedure during CPR, or if it interferes with CPR.

ACS, acute coronary syndrome; ADHF, acute decompensated heart failure; AoD, aortic dissection; AVR/PVD, acute valvular regurgitation/prosthetic valve dysfunction; CPR, cardiopulmonary resuscitation; MP, myopericarditis; PE, acute pulmonary embolism; PTx, pneumothorax; T, cardiac tamponade.

<sup>a</sup>In case of chest trauma, consequences are listed, not causes.

<sup>b</sup>TEE is indicated when TTE study is non-diagnostic.

<sup>c</sup>Recommendations related to specific conditions are applicable for all emergency clinical presentations they may have; after initial recommendation, they are not repeated in subsequent emergency clinical presentation sections in the table.

**Table 8 'ABCD approach' in performing emergency echocardiography**

A <b>A</b> wareness	<ul style="list-style-type: none"> <li>• Fight against routine</li> <li>• Think beyond apparent explanations</li> </ul>
B <b>B</b> e Suspicious	<ul style="list-style-type: none"> <li>• Referral diagnosis may be misleading</li> <li>• Never trust, confirm</li> </ul>
C <b>C</b> omprehensiveness	<ul style="list-style-type: none"> <li>• Do as complete examination as suitable</li> <li>• Careful interpretation</li> </ul>
D <b>D</b> ouble R <sup>a</sup>	<ul style="list-style-type: none"> <li>• The study should be recorded and reviewed</li> <li>• Team work is crucial</li> </ul>

<sup>a</sup>Record and Review.

recommendations.<sup>1</sup> However, supervision can also be accomplished through teamwork;

- Quality control (systematic detecting, handling and correcting of errors).<sup>1</sup>

Ideally, the echocardiography laboratory which serves as a core of emergency echocardiography service should be accredited in TTE and TEE.<sup>8</sup> Comprehensive programme with teaching courses of basic and advanced TTE, TEE, and contrast echocardiography should be organized through the laboratory, as well as additional training (Tables 3–5) for cardiologists and non-cardiologists involved in emergency cardiac care.

Emergency echocardiography service logistic and decision-making process can be considerably improved in hospitals with high-end ultrasound systems, by implementation of network-server-work stations and/or web-based solutions, allowing permanent audio-visual connection from the location where examination is performed to the supervisor laboratory with a cardiologist

with advanced level of expertise in echocardiography according to EAE recommendations.<sup>1</sup> The consultation via network connections enables a nearly immediate discussion with the most competent colleagues in the hospital, with direct visualization of the echocardiographic images, which may improve interpretation of the findings and adjust decision making.

### Emergency echocardiographic study report

The emergency echocardiographic study report should be in line with the basic format recently recommended by the EAE.<sup>7</sup> However, since the time for producing report is often extremely limited, an initial, preliminary report focused on critical findings and integrated into decision-making process may be issued. Whenever the result of the study indicates the need for urgent treatment, the physician who is in charge for the patient must be directly informed. Detailed, more complete, final report must follow soon after the patient is transferred/referred for further diagnostic or therapeutic procedure.

### Focused peri-resuscitation and critical care echocardiography

Recently, a number of protocols for basic focused echo examinations in the emergency or critical care situations have been developed. Focused echocardiography has been used to identify pericardial effusion, to differentiate between pericardial effusion and the enlargement of cardiac cavities, to estimate global left-ventricular function, and to differentiate true pulseless activity from profound hypovolaemia.<sup>31,32</sup> The focused cardiac studies can be combined with other focused emergency ultrasound examinations, such as focused aortic, chest or abdominal ultrasound. These protocols aim to enable individuals, after limited training, to identify critical cardiac pathologies.

Focused Echocardiography in Emergency Life Support (FEEL) is a limited echo protocol that can be performed by operators with minimal training during emergency life support and aims to identify true asystole, tamponade, and other catastrophic states.<sup>33</sup> Studies have shown that the findings may alter management of critically ill patients, including decisions on cessation or prolongation of resuscitation.<sup>34</sup> Training contains 'E' learning, a 1-day practical course and 50 supervised scans.<sup>35</sup>

Focused Assessed Transthoracic Echocardiography (FATE) is performed from four transthoracic positions, to obtain subcostal, parasternal, and apical views of the heart, as well as the left and right pleural views. Images are acquired in critically ill patients, in a fast sequence, with the following aims: to exclude obvious cardiac pathology, to assess wall thickness and dimensions of heart chambers, to assess ventricular pump function, to visualize pleura on both sides, and, finally, to relate obtained information to the clinical context. As proposed, screening for significant cardiac pathology and assessment of volume status and pump function can be made quickly by non-cardiologists, after completing a very short, intensive training protocol (typically, one and a half day course contains of 6 h of theory and interactive cases, and 6 h of practical hands-on training). The protocol was shown to contribute positively to decision making when used for cardiopulmonary monitoring in the ICU in almost all examined patients.<sup>36</sup>

Focused Assessment with Sonography for Trauma (FAST) is a focused, goal-directed, sonographic examination of the abdomen in patients with signs of shock or suspicion of abdominal injury. FAST utilizes subxyphoid images to view the heart, as an extension of clinical examination, with a goal to detect the presence of haemopericardium and haemoperitoneum. It has been shown that life-saving decisions can be made fast only by detecting free fluid collection in body cavities.<sup>37</sup>

The concept of focused point-of-care image acquisition using ultrasound in clinical practice has been actively promoted by the World Interactive Network Focused On Critical Ultrasound (WINFOCUS),<sup>38</sup> aiming to support education, training, and research related to the application of this concept in 'critical' scenarios in- and out-of-the-hospital. This concept is applied also to cardiovascular emergencies through organizing worldwide courses based on the FEEL and FAST protocols. Availability of high-quality pocket-size imaging devices, growing interest of wide range of clinicians dealing with medical emergencies, and restricted human and/or technical resources at all locations where these emergencies may occur, make these initiatives valuable for clinical practice, which have been recognized and addressed recently by relevant professional societies.<sup>39</sup>

Currently, we are witnessing an increased trend towards the performance of focused echocardiographic studies by non-cardiologists. It can be hardly argued that even focused echocardiographic examinations may provide key clinical information. However, they should be used wisely and cautiously, since this inherently limited approach carries a high risk of failing to detect important findings, as well as the risk of misinterpretation of restricted data set and/or deficiency of clinical experience and competence in emergency cardiac care of the operator. Therefore, while it is acknowledged that simple and fast cardiovascular

ultrasound procedures may be helpful in many cases, the EACVI's role is to strongly advocate systematic training in echocardiography and emergency echocardiography according to the recommendations stated.

## Pocket-size imaging devices

A choice of inexpensive, miniaturized, pocket-size imaging devices is available in the market, offering diagnostic-quality two-dimensional and, in part, colour-Doppler imaging in real-time. It is likely that many non-cardiologists and cardiologists with insufficient formal training will use them to extend the physical examination and improve their diagnostic accuracy.

This important issue has been addressed recently in detail in the 'EAE position statement on the use of pocket-size imaging devices'.<sup>40</sup> Briefly, it is stated that the image quality is usually sufficient for the fast initial screening in an emergency setting and to complement a physical examination in the coronary and ICU, offering qualitative evaluation of left- and right-ventricular function, pericardial and/or pleural effusion, B-lines in lungs as a sign of extravascular lung water, size and respiratory changes of inferior vena cava, extent of calcification and motion of aortic cusps, and valve regurgitation (based on colour-Doppler, if available).<sup>41,42</sup> Since examinations with current pocket-size imaging devices, due to technical limitations, cannot replace a complete echocardiogram, they can only be reported as a complement to physical examination.

## Medico-legal issues

Since diagnostic errors are likely to occur in the emergency settings, medical professionals should be fully aware of potential medico-legal consequences.

Most importantly, all emergency cases should be performed using adequate echocardiographic machines and well and retrievably documented, including the images and data obtained. Stored images/cineloops can be later used for reviewing the case, but also as a document to provide evidence of the findings in the acute setting. Reports should always reflect the recorded findings that have been interpreted, approved, and signed by the individuals with adequate formal education.

Finally, every effort should be made to obtain informed consent for potentially hazardous procedures (e.g. TEE, contrast echo) from the patient or the family, whenever applicable. Exceptions should be strictly limited to life-threatening situations.

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