The Role of Echocardiography in the Evaluation of AHF

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Acute heart failure (AHF) is a complex multifactorial syndrome with diverse primary and secondary causes, different phenotypic pathways of progression, and varied responses to therapies. Careful evaluation of patients presenting with AHF symptoms is essential to initiating prompt, appropriate therapy. The presentations in this session addressed the role of echocardiography in the diagnosis and evaluation of AHF.

IMAGING DIAGNOSIS OF AHF

Echocardiography can be a powerful tool for diagnosing and monitoring patients with AHF. However, there are many challenges in the imaging diagnosis of heart failure in the acute setting. Susanna Price, MD, Royal Brompton College, London, United Kingdom, discussed the diagnostic challenges, potential pitfalls, and a systematic approach to the diagnosis of AHF.

The use of transthoracic echocardiography (TTE) or transesophageal echocardiography to diagnose AHF may be determined by the patient characteristics and the underlying cause of AHF. Any findings must be interpreted in the specific clinical context, including arrest or peri-arrest, chest pain, acute dyspnea, shock, deterioration in the intensive care unit (ICU), and failure to wean from mechanical ventilation. The recent recommendations of the European Association of Cardiovascular Imaging and the Acute Cardiovascular Care Association [Lancelotti P et al. *Eur Heart J Acute Cardiovasc Care*. 2014] on the use of echocardiography in acute cardiovascular (CV) care describe conditions associated with AHF symptoms that can be diagnosed with echocardiography (Table 1).

In addition to helping to clarify the underlying cause of AHF, echocardiography can be used in the cardiac arrest/peri-arrest setting to determine the presence or absence of cardiac activity for prognosis after resuscitation [Salen P et al. *Am J Emerg Med*. 2005]; exclude potentially treatable causes such as tamponade, myocardial insufficiency, and hypovolemia; and guide interventions [Bocka JJ et al. *Ann Emerg Med*. 1988]. According to the 2010 resuscitation guidelines

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Table 1. Specific Conditions Associated With Acute Heart Failure Symptoms That Can Be Diagnosed With Echocardiography

Symptom/Feature	Condition
Chest pain	Acute coronary syndrome Myocarditis Pulmonary embolism Takotsubo Dissection and acute aortic syndromes
Acute dyspnea	Ventricular dysfunction Cardiomyopathies Respiratory pathology
Shock	Sepsis or systemic inflammation response syndrome–related cardiomyopathy Complicating acute myocardial infarction Severe, acute valve disease
Trauma	Blunt and penetrating chest injuries

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Source: Lancelotti P et al. *Eur Heart J Acute Cardiovasc Care*. 2014.

Table 2. Echocardiography Considerations in Diagnosis of Acute Heart Failure Caused by Mitral and Aortic Regurgitation

Mitral Regurgitation	Aortic Regurgitation
Hyperdynamic LV in context of AHF, shock, or pulmonary edema	VC > 6 mm or EROA ≥30 mm² indicates severe aortic regurgitation
Color Doppler may be misleading	PHT < 200 ms and holodiastolic flow reversal (> 20 cm/s) are helpful but exercise caution in: (1) very high LV end-diastolic pressure and (2) aortic dissection with flap truncating the aortic regurgitation jet
Measurements of VC and PISA method recommended but not always feasible	Premature diastolic opening of AV and premature closure of MV with diastolic mitral regurgitation associated with catastrophic regurgitation
VC > 7 mm or EROA ≥40 mm² indicates severe mitral regurgitation	High LAP suggested by short IVRT, very short E deceleration time; LUS may confirm interstitial edema
Modest mitral regurgitation volume acutely into small noncompliant LA may cause severe pulmonary congestion and systemic hypotension	In patients receiving mechanical circulatory support, even mild aortic regurgitation may lead to catastrophic progressive LV dilatation

AHF, acute heart failure; AV, aortic valve; EROA, effective regurgitation orifice area; IVRT, isovolumetric relaxation time; LA, left atrium; LAP, left atrial pressure; LUS, lung ultrasound; LV, left ventricle; MV, mitral valve; PHT, pressure half-time; PISA, proximal isovelocity surface area; VC, vena contracta.

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from the International Consensus on Cardiopulmonary Resuscitation [*Circulation.* 2010], ultrasound can help identify reversible causes of cardiac arrest, but only if used appropriately so as to minimize interruptions to chest compression. The guidelines recommend using a subxiphoid probe position. By placing the probe just before chest compressions are paused for a planned rhythm assessment, a well-trained operator can obtain views within 10 seconds.

Shock due to left ventricular (LV) dysfunction is the leading cause of mortality in patients with acute myocardial infarction (AMI). The admission ejection fraction (EF) does not correlate with the long-term outcome. Inotropic agents, sedating drugs, and positive pressure ventilation may significantly alter contractility, potentially confounding the association with EF and long-term outcomes. Parameters to assess left atrial pressure (LAP) may be challenging in the ICU. Isolated right ventricular (RV) infarction is unusual but RV failure secondary to respiratory disease is much more common. Acute cor pulmonale is associated with increased ICU mortality in patients with acute respiratory distress syndrome. Echocardiography findings can be inconsistent with respect to biventricular involvement, elevated LAP, and elevated pulmonary artery diastolic pressure.

Characterizing severe valve disease can be complex in patients with AHF. Considerations for echocardiography in the diagnosis of AHF due to mitral and aortic regurgitation are listed in Table 2.

According to Dr Price, the first principles in diagnostic imaging for the acutely/critically unwell patient with AHF are to help clarify the underlying diagnosis, to provide information as to the adequacy of the patient's cardiac output, and to assist in therapeutic decision making. If cardiac output is inadequate and/or venous pressure is excessive, corrective circulatory manipulations should be undertaken to optimize hemodynamics on either the right or left side. Mechanical circulatory support may be needed for patients with persistent inadequate cardiac output.

In summary, AHF is a syndrome, not a diagnosis. Failure to diagnose and treat the underlying cause results in a poor prognosis. After excluding obvious diagnoses, the less apparent causes of inadequate cardiac output or high venous pressure should be considered. Timely diagnosis of ineffective therapies and prompt referral for advanced therapies may be life-saving.

LUS IN AHF

Luna Gargani, MD, Institute of Clinical Physiology, Pisa, Italy, discussed the use of ultrasound imaging of the lungs in patients with AHF. Lung ultrasound (LUS) has recently emerged as a new technique for the evaluation of pulmonary conditions [Moore CL, Copel JA. *N Eng J Med.* 2011]. In a lung full of air, there is a high acoustic mismatch between the lung and the surrounding tissue, causing ultrasound to be reflected back. However, in cases where an exudate, fibrous tissue, or other substance displaces the air, ultrasound can penetrate the lung. For example, in interstitial edema, the ultrasound image shows B-lines, which are discrete laser-like vertical hyperechoic reverberation artifacts arising from the pleural line. The less air that is present in the lung, the more B-lines that will be observed. With extreme air loss, artifacts are no longer seen and the pulmonary parenchyma is directly visualized.

Table 3. Features Distinguishing Etiology of Interstitial Syndrome by Lung Ultrasound

	Acute Cardiogenic Pulmonary Edema	Chronic Heart Failure	Acute Lung Injury/Acute Respiratory Distress Syndrome	Pulmonary Fibrosis
Clinical setting	Acute	Chronic	Acute	Chronic
B-lines number	++++	+/++/+++	++++	+/++/+++
B-lines distribution	Multiple, diffuse, bilateral (white lung)	Multiple, diffuse, bilateral; following dependent regions (black and white lung)	Nonhomogeneous distribution; presence of spared areas	More frequently posterior at lung bases
Other lung ultrasound signs	Pleural effusion	Pleural effusion	Pleural effusion; subpleural alterations; various size parenchymal consolidations	Pleural thickening
Echocardiogram	Abnormal	Abnormal	Likely normal	Likely normal

Adapted from Gargani L. Lung ultrasound: a new tool for the cardiologist. *Cardiovasc Ultrasound*. 2011;9:6.

LUS is important for assessing pulmonary congestion in AHF because of the association between pulmonary congestion and poor prognosis [Fonarow GC, Weber JE. *Clin Cardiol*. 2004]. Pulmonary edema can be distinguished from chronic obstructive pulmonary disease by the presence of B-lines on LUS. Additionally, the B-lines have been correlated with natriuretic peptides, which are useful in the differential diagnosis of cardiac dyspnea from noncardiac dyspnea [Gargani L et al. *Eur J Heart Fail.* 2008].

LUS can be performed with any 2D scanner, including pocket-size devices with the patient in the near-supine, supine, sitting, or standing position. The absence of diffuse, bilateral multiple B-lines excludes pulmonary edema of cardiac origin with 100% negative predictive value [Neskovic AN et al. *Eur Heart J.* 2012]. LUS is used primarily during admission as a point-of-care technique [Gargani L, Volpicelli G. *Cardiovasc Ultrasound.* 2014] and is effective for the diagnosis and monitoring of pulmonary congestion in AHF patients in this setting [Volpicelli G et al. *Am J Emerg Med.* 2008].

The presence of comet-tail B-lines has prognostic value, as shown in an analysis of patients with AHF [Gargani L et al. EuroEcho. 2011]. Patients with <5 B-lines had a significantly higher event-free survival rate vs those with ≥ 30 B-lines ($P<.001$).

B-lines are a nonspecific sign of interstitial syndrome but their distribution and other LUS features can distinguish acute cardiogenic pulmonary edema from other interstitial syndromes (Table 3).

PCE IS A MUST

AHF is categorized according to hemodynamic type, based on LVEF and volume status. Therefore, immediate hemodynamic assessment is essential for prompt initiation of appropriate therapy. In this presentation, Nuno Cardim, MD, Hospital da Luz, Lisbon, Portugal, discussed the emergency echocardiographic evaluation of patients with symptoms of AHF.

Invasive hemodynamic assessment procedures are associated with complications. On the other hand, echocardiographic evaluation is quick and noninvasive. Echocardiography can be performed at the patient's bedside to provide information on cardiac function, intravascular volume, preload, contractility, and afterload. Preload measurements are well validated and more accurate than those obtained from pulmonary artery catheters. A study of 799 patients at their first admission for AHF showed that those evaluated with echocardiography had a significantly lower mortality rate at 36 months than patients evaluated without echocardiography (HR, 0.61; 95% CI, 0.48 to 0.78; $P<.001$) [Tribouilloy C et al. *Arch Cardiovasc Dis.* 2008]. Studies of patients evaluated with TTE in the ICU have demonstrated changes in diagnosis and management but no difference in patient outcomes [Orme RM et al. *Br J Anaesth.* 2009; Stanko LK et al. *Anaesth Intensive Care.* 2005].

Point-of-care echocardiography (PCE) with focused cardiac ultrasound (FoCUS) should be distinguished from comprehensive echocardiographic studies. FoCUS involves limited CV examination with ultrasound as an adjunct to the physical examination to obtain specific ultrasonic signs representing a narrow list of potential diagnostic data in a specific setting, using a predefined image acquisition protocol with the minimum and most efficient echocardiographic views. Comprehensive echocardiography and point-of-care FoCUS are compared in Table 4.

PCE is performed and interpreted by the healthcare provider in real time, directly correlating information with clinical data, without an intermediary imaging consultant [Marum S, Price S. *Curr Cardiol Rev.* 2011]. The result is an early diagnosis and immediate therapy, without the risk of

Table 4. Point-of-Care Focused Cardiac Ultrasound Compared With Comprehensive Echocardiography

Comprehensive Echocardiography	FoCUS
Comprehensive	Point of care
Full study of heart morphology and function	Standardized but restricted scanning protocol
Full operator training in echocardiography	Operator training in FoCUS (not necessarily echocardiography)
Fully equipped echocardiography machines	Often handheld devices Operator responsible for decision making and therapy

FoCUS, focused cardiac ultrasound.

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Source: Neskovic AN et al. *Eur Heart J*. 2014.

Table 5. Assessment of Key Parameters With FoCUS-POC

Parameter	FoCUS Features/Uses
Volume status	Clear initial therapeutic pathway Greater accuracy than clinical examination and Swan-Ganz catheterization Technically easy to learn Suited to day-by-day and bedside assessment Use RAP taking into account IVC dimensions and respiratory variation May also use LV filling pressures (E/A and E/e') IVC > 20 mm predicts RAP > 10 and PCWP > 17 with 83% and 81% accuracy, respectively [Blair JE et al. *Am J Cardiol.* 2009] IVC dimensions plus E/e' similar accuracy to BNP [Goonewardena SN et al. *J Cardiac Fail.* 2010]
Left ventricular function	Cornerstone of FoCUS-POC Good correlation with hemodynamic CO and CI Easy to learn with minimal training Major diagnostic and therapeutic impact: Normal LV function: volume or vasopressors Abnormal LV function: inotropes or vasodilators SV and CO important in addition to EF—may have low SV with high EF
Pericardial effusion	Important in differential diagnosis of AHF Identification and dimensions easy Echocardiographic assessment of tamponade more difficult Tamponade primarily a clinical diagnosis

BNP, B-type natriuretic peptide; CI, cardiac index; CO, cardiac output; EF, ejection fraction; FoCUS-POC, focused cardiac ultrasound point-of-care; IVC, inferior vena cava; LV, left ventricle; PCWP, pulmonary capillary wedge pressure; RAP, right atrial pressure; SV, stroke volume.

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transporting acutely ill patients to other hospital departments. Disadvantages of PCE include the lack of continuous monitoring and the inability to acquire all of the classic echocardiographic views in some patients. PCE usually is equivalent to FoCUS but using the term focused cardiac ultrasound point-of-care (FoCUS-POC) instead of PCE stresses its difference from emergency echocardiography, which is a comprehensive, full echocardiographic study.

FoCUS-POC provides immediate guidance for therapeutic management. Key parameters that can be assessed with FoCUS-POC include volume status, ventricular function, and pericardial effusion (Table 5).

According to Prof Cardim, FoCUS-POC is essential for the evaluation of patients with AHF, especially when complete echocardiography is not available. LV function and volume status are the minimum data needed for early diagnosis and immediate therapy. However, the FoCUS key points must not be forgotten: identify basic but critical cardiac pathology; FoCUS may provide sufficient information for mostly qualitative, gross assessment of morphology and function; and FoCUS should be used wisely, but cautiously, with awareness of its relevant limitations. Education and training on FoCUS are necessary, as are supervision, quality control, and reporting.