Echocardiography Performed by the Pulmonary/Critical Care Medicine Physician

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Echocardiography is a valuable and readily available diagnostic tool that is essential to the management of critically ill patients as well as in the diagnosis and treatment of respiratory diseases that are related to cardiopulmonary dysfunction. The pulmonary/critical care medicine (PCCM) clinician uses echocardiography information routinely, both obtaining and interpreting it themselves or as reported by consultant cardiologists. This article summarizes the inpatient and outpatient applications of echocardiography that are relevant to PCCM practice and their corresponding coding and reimbursement information.

**Critical Care Echocardiography**

Critical care echocardiography (CCE) as practiced by the PCCM specialist may be divided into two levels of competence: basic and advanced. Basic CCE is performed as a goal-directed examination using two-dimensional (2D) transthoracic echocardiography (TTE) or transesophageal echocardiography (TEE). It allows the intensivist to identify characteristic echocardiographic findings and to answer straightforward clinical questions. Intensivists may readily achieve competence in basic CCE. Competence in basic CCE is a very useful skill for every frontline intensivist to have in order to diagnose and guide management of the patient with cardiopulmonary failure. Some intensivists may decide to obtain further training in the field. Advanced CCE allows the intensivist to perform a comprehensive evaluation of cardiac anatomy and function including hemodynamic assessment using 2D TTE or TEE and Doppler echocardiography. Competence in advanced CCE requires a high level of skill in all aspects of image acquisition and interpretation. Compared to basic CCE, advanced level compe-
Diagnosis of Shock

Echocardiography allows rapid assessment and differentiation of the cause of shock. By obtaining a limited number of views (parasternal long- and short-axis mid-ventricular levels, apical four chamber, subcostal, and inferior vena cava [IVC]), the frontline intensivist with basic CCE skill level uses echocardiography in goal-directed fashion for qualitative assessment of left ventricular (LV) cavity size and function, right ventricular (RV) cavity size and function, identification of pericardial effusion, measurement of inferior vena cava (IVC) diameter with assessment of its respiratory variation, and qualitative assessment of valve function using color Doppler to assess for severe valvular regurgitation. With this information, the intensivist can categorize the cause of shock and decide on management strategy.

Competence in basic CCE does not include use of color or spectral Doppler for comprehensive assessment of valvular or hemodynamic function, definitive identification of isolated mild-to-moderate LV dysfunction, identification of specific segmental wall dysfunction, RV dysfunction in the absence of RV dilatation, or identification of abnormal or paradoxical interventricular septal motion pattern. The intensivist with basic level training must have knowledge as to when to identify an indeterminate result that may require consultation with a more advanced echocardiographer. We emphasize that competence in basic CCE is appropriate for most intensivists. Only a small proportion of intensivists may need to develop in competence in advanced CCE.

The intensivist who is competent in advanced CCE may perform a comprehensive assessment of cardiac anatomy and function using multiple views and Doppler assessment. Measurement of stroke volume and cardiac output using Doppler is a routine part of the advanced CCE examination, and allows the intensivist to quantitate hemodynamic function of the patient in shock. A pericardial effusion with systolic collapse of the right atrium, diastolic collapse of the RV, and mitral valve inflow decrease by 25% during inspiration (in spontaneously breathing patients) is consistent with tamponade physiology. Myocardial ischemia manifests with segmental wall motion abnormality, with different segments corresponding to specific coronary artery involvement. Ventricular rupture is diagnosed by color Doppler inspection of an ischemic segment, in association with pericardial effusion. Valvular abnormalities leading to shock include ruptured chordae or papillary muscle (mitral apparatus) or severe damage to the aortic valve resulting in a flail leaflet, both being associated with severe valvular regurgitation. Severe mitral or aortic valve stenosis may cause shock as a primary event, or complicate management of hemodynamic failure from other cause. Doppler analysis allows quantitative measurement of the severity of valvular stenosis and regurgitation. For example, the severity of aortic stenosis may be assessed qualitatively with 2D imaging by examining the aortic valve anatomy and motion. In addition, aortic valve area may be assessed quantitatively by the continuity principle using spectral Doppler analysis of the LV outflow tract (LVOT) and the aortic valve. Quantitative measurement of valve function is routine for the PCCM clinician trained in advanced level CCE. Acute RV myocardial infarction results in RV dilatation in association with decreased endomyocardial thickening of the RV free wall and the inferior wall of the LV. Acute cor pulmonale due to increased pulmonary vascular impedance (eg, acute pulmonary embolism, ARDS) is diagnosed by the presence of both RV dilatation (RV end-diastolic area/LV end-diastolic area > 1) and intraventricular septal dyskinesis. Vasodilatory shock (eg, sepsis)
can result in a LV of normal, decreased, or enlarged size depending on load conditions and contractile function. A decreased systemic vascular resistance can be identified using Abbas formula: mitral regurgitation peak velocity/LVOT velocity time integral < 0.2. Shock due to hyperdynamic LV function with LV intracavitary pressure gradient occurs in the hypotensive, hypovolemic patient who is overly diuresed while receiving inotropes. This entity presents with hyperdynamic LV function, a late peaking dagger-shaped intracavitary spectral Doppler signal that is usually found in mid-ventricle with higher peak velocity at the site of obstruction as compared with LVOT, and systolic anterior mitral valve leaflet motion. Finally, screening for rupture of an abdominal aortic aneurysm in a hypotensive patient can be rapidly achieved using the cardiac transducer.

**Assessment of Preload Responsiveness**

Volume resuscitation may not be indicated in all shock states, and may in some circumstances be harmful. Echocardiography allows assessment of whether volume replacement will improve cardiac output in patients with hemodynamic failure, thereby permitting the intensivist to avoid unnecessary and potentially harmful volume resuscitation.

Preload sensitivity may be tested in patients who are breathing spontaneously by using echocardiography to measure cardiac output response to passive leg raising. An increase in cardiac output > 10% in response to passive leg raising is the best bedside maneuver to determine responsiveness in nonintubated, hypotensive individuals. Qualitatively, an IVC diameter < 1 cm in a hypotensive patient generally indicates preload responsiveness.

Preload sensitivity may be tested in patients receiving mechanical ventilatory support providing the patient is not making any respiratory effort. Superior vena cava collapsibility > 30% measured with TEE, or IVC collapsibility > 20% (maximum diameter minus minimum diameter divided by their mean) correlates with volume responsiveness. Alternatively, an inspiratory increase in aortic flow velocity > 12% measured with Doppler echocardiography can also be utilized as a predictor of increased cardiac output following volume infusion. An inspiratory increase in stroke volume determined derived from Doppler measurement of velocity time integral is also useful in predicting preload responsiveness. Most techniques for determination of preload sensitivity use Doppler analysis and require competence in advanced CCE. For the intensivist who is competent in basic CCE, measurement of IVC size, respiratory variation in IVC size (on ventilatory support without respiratory effort), and pulmonary edema with preserved systolic function. Cardiac dysfunction as previously detailed and pulmonary edema with preserved systolic function (diastolic dysfunction) must always be considered in any individual presenting with acute respiratory distress. The same differential diagnosis applies to patients who cannot be liberated from mechanical ventilation.

**Rapid Response Team and Code Team Function**

Limited, real-time echo examination can change management during cardiopulmonary resuscitation: a large pericardial effusion, acute cor pulmonale, an intracavitary thrombus, a flail leaflet, or pulseless electrical activity with continued cardiac contractions but absent pulse or BP are diagnoses that can guide the team in planning emergency intervention. Echocardiography also may identify patients where continued cardiopulmonary resuscitation will not be successful.

**Monitoring**

Echocardiography has traditionally been viewed by the cardiologists as a tool for diagnosis. In fact, it is also a powerful monitoring tool. The frontline intensivist uses it to establish an initial diagnosis; and also in serial fashion to observe response to therapy, to follow the evolution of disease, and to search for new problems that may arise during the course of critical illness. Follow-up examinations are often goal directed or limited in scope. For example, preload responsiveness is not a one-time only assessment; echocardiography is repeated as many times as needed to assess further responsiveness during the course of the illness. If nothing else has changed, only IVC collapsibility may need to be estimated. The frequent occurrence of LV dysfunction with sepsis warrants serial echocardiography in order to guide use of inotropic agents and volume resuscitation, as well as to observe for improvement during the course of the illness. A single echocardiogram showing severe LV dysfunction in a patient with sepsis may result in the patient being labeled with this diagnosis indefinitely, whereas the intensivist is in an
ideal position to document complete recovery of LV function following the remission of sepsis. Finally, when acute cor pulmonale is present, echocardiography monitoring is useful to assess response to treatment and need for adjustment of therapeutic interventions.

Procedural Guidance

Echocardiography allows safe performance of pericardiocentesis. Callahan et al\(^\text{20}\) reported 1,127 serial echocardiography guided pericardiocenteses with a very low complication rate. Ultrasound-guided pericardiocentesis is so clearly superior to fluoroscopic guidance that the intensivist echocardiographer should develop proficiency in the procedure in order to improve patient safety.

Office-Based Echocardiography

General Respiratory Disorders

Evaluation of heart function is often a fundamental part of assessing and treating patients with respiratory disorders. Pulmonary and cardiac disorders are both common and frequently coexist. For example, a patient with an obstructive airway disorder may have coexisting systolic and/or diastolic LV dysfunction or unrecognized valvular heart disease. Another example is the patient with previous tuberculosis, fungal disease, or malignancy who has pericardial involvement. The presence of cor pulmonale in any patient with lung disease should trigger the search for potentially correctable causes: uncontrolled left heart or valvular disease, shunts, venous thromboembolic disease, sleep breathing disorders, or pulmonary vascular disease.

Pulmonary Arterial Hypertension

Echocardiography is the initial recommended test to screen for the presence of elevated pulmonary pressures. It assists in ruling out left heart disease, valvular disease, and intracardiac shunting as possible etiologies. There are pitfalls that need to be contemplated when interpreting echocardiographic data. For example, pulmonary artery systolic pressure measured by a modified Bernouilli equation (tricuspid regurgitation peak velocity\(^2 \times 4 + \text{right atrial pressure}\) may need to be adjusted for age, weight, and presence of systemic hypertension.\(^\text{21}\) Right atrial pressure is not often measured. A poorly performed Doppler study may underestimate the velocity of the tricuspid regurgitant (TR) jet, or even erroneously report mitral regurgitation velocity (very high) as the TR jet velocity. Alternatively, there may be no detectable tricuspid jet to measure systolic pulmonary artery pressure even with augmentation of the TR Doppler signal using injection of agitated saline solution. In this case, other findings may be used: pulmonary regurgitant jet allows estimation of both mean and pulmonary artery diastolic pressures. Right ventricular outflow tract acceleration time (RVOT) permits estimation of mean pulmonary artery pressure. Severely decreased RVOT acceleration time and/or acceleration time/ejection time ratio are almost never normal with pulmonary arterial hypertension (PAH). Some authors decline to label elevated pulmonary pressures as PAH unless there is evidence of elevated pulmonary vascular resistance (TR velocity/RVOT velocity time integral > 0.2).\(^\text{22}\) In other words, true PAH may exist only when there is an elevation of both measured pulmonary artery pressures and pulmonary vascular resistance. PAH secondary to lung disorders is an increasingly recognized problem: COPD, pulmonary fibrosis, eosinophilic granuloma, and sarcoidosis, for example, may result in PAH.

In addition to its utility in establishing the diagnosis of PAH, echocardiography is an excellent means of monitoring progression of disease and response to therapy. Beyond simple monitoring of pulmonary pressures, tricuspid annular systolic forward motion, myocardial performance index, tissue Doppler indexes, changes in right atrial size, changes in RV size and function, severity of TR, and changes in RV pressure during its isovolumic contraction period are indexes of right-sided function that may be useful in monitoring PAH. These measurements are within the capability of the PCCM clinician with interest in echocardiography. Standard echocardiography as performed by cardiologists does not generally focus on sophisticated evaluation of right-heart function. The PCCM clinician who has special interest in treatment of PAH may develop expertise in echocardiographic assessment of right-heart function.

Competence in Echocardiography

The American College of Chest Physicians is developing a statement defining competence in CCE. Until this is available, the PCCM clinician who seeks to establish competence in advanced echocardiography should follow the recommendations of the cardiology community that define competence in the field.\(^\text{23}\) Level 2 is equivalent to advanced level CCE and requires extensive training in echocardiography. Competence in basic level CCE does not have clear parallel to the levels defined by the cardiology societies. Specific standards of training required to achieve competence in CCE have not yet been
defined by the PCCM community. From a purely operational point of view, there is no regulatory barrier that prohibits any physician from performing and being reimbursed for echocardiography. Introducing office-based echocardiography into a practice is straightforward; it requires a machine and a PCCM clinician who is competent in echocardiography. Hospital-based echocardiography is more difficult because it requires that the PCCM clinician be credentialed to perform the procedure by the hospital. Credentialing is a local hospital-based issue with each hospital establishing its own requirements for credentialing. The PCCM clinician should anticipate resistance from their cardiology colleagues on this point. This resistance will not directly relate to competence, but rather to political and economic issues.

**Cost, Coding, and Reimbursement**

If echocardiography is performed in the hospital setting, all of the technical costs and the technical component reimbursement are absorbed by the institution. The clinician receives payment for the professional component of the procedure. In the private medical office, the equipment needs to be purchased, but the technical component becomes part of the revenue stream. Cost of equipment varies widely, depending on many factors. Portable machines are now available, with reduced cost and excellent capabilities. A recent generation portable, fully equipped echocardiograph with cardiac transducer can be purchased for approximately $40,000. The machine can also be used for chest ultrasonography. Applicable current procedural terminology codes with modifiers and updated reimbursements are listed in Table 1.24,25 If TTE is performed with contrast, separate contrast supply codes apply (not included). Medicare reimbursement rates may vary by geographic area, and we recommend the reader consults with his or her local Centers for Medicare and Medicaid Services carrier.

**How To Use Echocardiography**

**Hospital Setting**

Echocardiography is performed to characterize the cause of cardiorespiratory failure, to assess vol-

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**Table 1— Current Procedural Terminology Codes, Modifiers, and Medicare Reimbursement**

<table>
<thead>
<tr>
<th>Description</th>
<th>Current Procedural Terminology Code and Modifier</th>
<th>2008 Reimbursement, $</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTE, real-time with 2D image documentation with or without M-mode recording, complete</td>
<td>93307-26 (professional component) -TC</td>
<td>192</td>
</tr>
<tr>
<td>TTE, real-time with 2D image documentation with or without M-mode recording; follow-up or limited study</td>
<td>93308-26 -TC</td>
<td>114, 28, 87</td>
</tr>
<tr>
<td>Doppler echocardiography, pulsed wave and/or continuous wave with spectral display (list separately in addition to codes for echocardiographic imaging); complete</td>
<td>93320-26 -TC</td>
<td>85, 19, 66</td>
</tr>
<tr>
<td>Doppler echocardiography, pulsed wave and/or continuous wave with spectral display (list separately in addition to codes for echocardiographic imaging); follow-up or limited study</td>
<td>93321-26 -TC</td>
<td>42, 8, 34</td>
</tr>
<tr>
<td>Doppler echocardiography color flow velocity mapping (list separately in addition to codes for echocardiographic imaging)</td>
<td>93325-26 -TC</td>
<td>80, 4, 75</td>
</tr>
<tr>
<td>TEE real time with 2D image documentation (with or without M-mode recording); including probe placement, image acquisition, interpretation, and report</td>
<td>93312-26 -TC</td>
<td>316, 110, 205</td>
</tr>
<tr>
<td>Ultrasound B-scan and/or real time with image documentation; for abdominal aortic aneurysm screening</td>
<td>00398-26 -TC</td>
<td>115, 28, 87</td>
</tr>
<tr>
<td>Duplex scan of aorta, IVC, iliac vasculature, or bypass grafts; complete study</td>
<td>93978-26 -TC</td>
<td>239, 32, 207</td>
</tr>
<tr>
<td>Duplex scan of aorta, IVC, iliac vasculature or bypass grafts; unilateral or limited study</td>
<td>93979-26 -TC</td>
<td>166, 22, 144</td>
</tr>
</tbody>
</table>

*Reimbursement rates may vary by geographic area, and we recommend the reader consults with his or her local Centers for Medicare and Medicaid Services carrier. TC = technical component.
ume and pressor management, to monitor response to therapy, and to assist in pericardiocentesis. If TTE is performed, billing should include 93307, 93320 and 93325 codes. If TEE is performed, 93312 is the correct code. If the abdominal aorta is studied, G0389 is added. Most clinicians will perform screening with real-time sonography only. If Doppler interrogation of abdominal vessels is added, codes 93978 or 93979 should be added.

If an initial test was interpreted by a cardiologist or anesthesiologist, and the intensivist needs further information (eg, preload responsiveness, acute cor pulmonale response to therapy), a follow-up TTE study may be performed. Depending on how comprehensive the test is, appropriate codes include 93308, 93321, 93325 (eg, 2D imaging of LV/RV size, respiratory variation of LVOT spectral Doppler signal peak velocity and/or IVC) if a limited study is performed, or a comprehensive test altogether (93307, 93320, 93325) when a follow-up complete study is obtained. When appropriate, a new diagnosis or reason for the test is documented. There is no specific limitation to the number of tests that can be repeated, as long as the medical need for it is well documented.

If only the IVC is interrogated to assess preload responsiveness with no further cardiac assessment, the appropriate code is limited abdominal sonogram (76705). When echocardiography is performed during a code situation, the test is usually limited to a 2D study (93308). If color Doppler is included, then code 93325 applies. If 2D only is used to rule out a large pericardial effusion, code 93308 should be used. If TTE is performed with contrast, separate contrast supply codes apply (not included). Importantly, like with any other imaging modality, the PCCM echocardiographer needs to document images and interpretative report carefully and in a timely manner.

Office Setting

Unless limited for technical reasons, as in obese patients with inadequate acoustic windows, complete tests are routinely performed (93307, 93320, 93325).

CONCLUSION

CCE is a valuable diagnostic and monitoring technique. As performed by the PCCM clinician, it is different from standard consultative echocardiography. No other bedside tool provides the kind of information and assistance to the bedside critical care clinician. Bedside CCE allows the frontline intensivist to promptly evaluate the critically ill patient with cardiopulmonary failure in order to establish diagnosis and to guide management strategy. The same applies to outpatient echocardiography that addresses specific aspects of respiratory-related heart diseases with special emphasis on evaluation of right-heart function. Present reimbursement allows relatively rapid recuperation of the financial investment required to purchase the equipment both in the ICU and in the pulmonary office.

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