REVIEW

Doppler echocardiography in shocked patients

Xavier Repessé[a,b], Laurent Bodson[a,b], and Antoine Vieillard-Baron[a,b]

Purpose of review

To reiterate the necessity of integrating echocardiography in the management of shocked patients and to propose a step-by-step functional evaluation of hemodynamics proven to optimize hemodynamic monitoring and to adapt the treatment.

Recent findings

Echocardiography has become the cornerstone to hemodynamic monitoring. By providing real-time images, echocardiography has the advantage over 'blind' technologies of an excellent diagnostic performance and of quick provision of information about the pathophysiology of circulatory failure. Critical care echocardiography (CCE) has been defined as echocardiography performed and interpreted by intensivists themselves, 7/7 and 24/24, at the bedside. Basic CCE is mainly a diagnostic approach, allowing quick and focused examination of cardiac function. Advanced CCE is the core of functional hemodynamic monitoring. It is based not only on transthoracic echocardiography but also strongly on transesophageal echocardiography, a very useful approach in ventilated patients. However, this monitoring is discontinuous. A single-use 72-h indwelling transesophageal probe was recently tested, allowing functional hemodynamic monitoring more continuously.

Summary

Echocardiography has become a hemodynamic monitoring technique used worldwide. It allows to make a quick and simple diagnosis of typical hemodynamic situations, by means of basic CCE, and also to achieve real functional hemodynamic monitoring, through advanced CCE.

Keywords

critical care echocardiography, functional hemodynamic monitoring, shock, transesophageal echocardiography

INTRODUCTION

Acute circulatory failure is a common situation encountered in critically ill patients that needs to be identified quickly to restore adequate tissue perfusion [1]. Of all hemodynamic monitoring devices, echocardiography is the only one that directly provides both morphological and functional information on the circulatory system [2,3]. Echocardiography, as developed in the ICU, is far away from the initial examinations performed by board-certified consultant cardiologists and started to be developed in the ICU in the middle of the 1980s when a few intensivists revolutionized its use from a static and quantitative point of view, as done by cardiologists, to a dynamic and more qualitative one adapted to hemodynamic monitoring.

For a decade, identification of the pathophysiology of hemodynamically compromised patients has become a crucial issue in improving their survival. The early goal-directed therapy protocol described more than 10 years ago [4] made physicians aware of the importance of time in shocked patients. In this context, echocardiography has become the cornerstone to hemodynamic monitoring [5▪]. By providing real-time images, echocardiography has the advantage over 'blind' technologies of an excellent diagnostic performance and of quick provision of information about the pathophysiology of circulatory failure [6]. This is especially true in sepsis where most mechanisms of shock are often associated. For instance, hypovolemia and left ventricular systolic dysfunction may occur

[a]Assistance Publique-Hôpitaux de Paris, University Hospital Ambroise Paré, Intensive Care Unit, Section Thorax-Vascular Disease-Abdomen-Metabolism, Boulogne-Billancourt and [b]Faculté de Médecine Paris Ile de France Ouest, University of Versailles Saint-Quentin en Yvelines, France

Correspondence to Antoine Vieillard-Baron, Intensive Care Unit, Section Thorax-Vascular Disease-Abdomen-Metabolism, University Hospital Ambroise Paré, 9, Avenue Charles-de-Gaulle, 92100 Boulogne-Billancourt, France. Tel: +33 1 49 09 59 03; fax: +33 1 49 09 58 92; e-mail: antoine.vieillard-baron@apr.aphp.fr

Curr Opin Crit Care 2013, 19:221–227

DOI:10.1097/MCC.0b013e3283602344

KEY POINTS

- Echocardiography has become the cornerstone to hemodynamic monitoring.
- Basic critical care echocardiography is a quick and focused examination of cardiac function, performed in patients with shock or acute respiratory failure admitted to the ICU.
- Advanced critical care echocardiography is the core of functional hemodynamic monitoring.

simultaneously. This is also true in an apparently 'simpler' situation, such as cardiogenic shock, wherein a distributive mechanism has been reported not to be unusual [7]. In these different clinical scenarios, it is difficult to assess hemodynamics accurately without echocardiography, which can evaluate each mechanism of shock independently of the others.

This review reiterates the necessity of integrating echocardiography in the management of shocked patients and proposes a step-by-step functional evaluation of hemodynamics based on our previous experience in this mainly qualitative field. This review also describes two different ways of using echocardiography in the critically ill patient (Table 1), depending on the intensivist's skills. The first mainly uses echocardiography as a diagnostic approach, and is named 'basic critical care echocardiography' (CCE) [8]. Physicians may by themselves identify 7/7, 24/24 gross hemodynamic abnormalities, such as profound hypovolemia, marked left ventricular systolic dysfunction, acute cor pulmonale (ACP) or cardiac tamponade. The second, named 'advanced CCE' [8], uses echocardiography as a true hemodynamic monitoring tool, although discontinuous, allowing intensivists to analyze and reanalyze cardiac function and fluid responsiveness according to changes in hemodynamic support, respiratory settings and the natural progression of the disease. Finally, we will conclude this review by suggesting some perspectives supported by technological improvements that render the hemodynamic monitoring driven by echocardiography more 'continuous' (or less discontinuous).

BASIC CRITICAL CARE ECHOCARDIOGRAPHY: A CRUCIAL PART OF THE CLINICAL EXAMINATION

CCE has been defined by the American College of Chest Physicians (ACCP) and the French Society of Intensive Care (SRLF) as echocardiography performed and interpreted by intensivists themselves, 7/7 and 24/24, at the bedside [8]. Basic CCE is a quick and focused examination of cardiac function, performed in patients with shock or acute respiratory failure admitted to the ICU (Table 1). This is mainly a diagnostic approach and the goal in shock is simply to routinely identify the mechanism, as cardiac tamponade, profound hypovolemia, ACP or severe left ventricular systolic dysfunction, leading to a prompt and adequate treatment. A hyperkinetic profile detected by basic CCE may also indicate a septic problem [9]. Transthoracic echocardiography (TTE) offers sufficient information for basic CCE, is totally noninvasive and is obviously more adapted to nonventilated patients. McLean

Table 1. Summaries of basic and advanced critical care echocardiography

	Basic CCE	Advanced CCE
Definition	Quick and focused examination of cardiac function	Repeated full functional hemodynamic evaluation
Goal	To diagnose a typical hemodynamic situation	To monitor hemodynamics
Method	Morphological	Functional
	Mainly transthoracic approach	Mainly transesophageal approach
Formation	Theoretical: 10 h	Theoretical: 40 h
	Practice: 30 supervised TTE	Practice: 150 TTE, 30–50 TEE
Questions to answer	(1) Is there severely depressed LV contractility?	(1) Is the depressed LV contractility related to cardiogenic shock or to septic cardiomyopathy?
	(2) Is there acute cor pulmonale?	(2) What is the impact of respiratory settings and prone position on the right ventricle?
	(3) Is there massive pericardial effusion?	(3) Is there a pattern of 'pretamponade' (collapse of the right atrium)?
	(4) Is there profound hypovolemia?	(4) Is the patient fluid-responsive?

CCE, critical care echocardiography; LV, left ventricular; TEE, transesophageal echocardiography; TTE, transthoracic echocardiography.

and Huang [10] recently developed the concept of a rapid and routine examination that provides a fast and accurate evaluation of shocked patients. This concept, called 'RACE', for Rapid Assessment by Cardiac Echocardiography, is a morphological 2D imaging and M-mode echocardiography designed to answer four basic questions: First, what is the left heart function? Second, what is the right heart function? Third, is there any evidence of pericardial effusion and cardiac tamponade? Fourth, what is the fluid status? [10]. In specific clinical settings, such as postcardiac and thoracic surgery, basic CCE may require transesophageal echocardiography (TEE) [11■■].

A large panel of international experts, representing the main international societies of critical care medicine, recently defined a training programme for the teaching of the skills needed to perform basic CCE [11■■]. They recommended a 10-h theoretical course, divided between lectures and didactic cases with image-based training [11■■,12,13]. For practice, they recommended at least 30 fully supervised TTE at the bedside in critical situations. A consensus was also obtained to proclaim that basic CCE should be included in the curriculum of all intensivists and that a specific certification is not required.

ADVANCED CRITICAL CARE ECHOCARDIOGRAPHY: THE CORE OF FUNCTIONAL HEMODYNAMIC MONITORING

Functional hemodynamic monitoring is a new approach to hemodynamic evaluation that is practical, qualitative and less invasive than the old approach mainly based on invasiveness and numbers. This was first illustrated in the management of fluids, wherein evaluation of preload dependency has supplanted evaluation of preload [14]. By its ability to evaluate cardiac function and preload dependency, echocardiography is perfectly adapted to this functional approach. In circulatory failure, the question is not to know precisely how much the cardiac output is but rather why this cardiac output is inadequate. The collaborative work between the ACCP and the SRLF has defined advanced CCE as the ability of intensivists to repeat full functional hemodynamic evaluation using echocardiography in severely ill patients [septic shock, acute respiratory distress syndrome (ARDS)] in different situations and at different times (Table 1). This monitoring is based not only on TTE but also strongly on TEE, a very useful approach in ventilated patients. As stated by the international experts, skills acquisition requires a course of 40 h with lectures and didactic cases, 150 supervised TTE and 50 TEE during a 1 to 2-year training programme [11■■]. Certification is mandatory.

We now present our practical approach based on a step-by-step echocardiographic evaluation proven to optimize hemodynamic monitoring and to adapt the treatment [15] (Table 2). In a recent multicenter study [16], we demonstrated that such an evaluation, using this protocol, required intensivists to perform at least 30 supervised TEE to be competent.

First step: evaluation of fluid responsiveness

For a long time, fluid challenge was the main 'test' used to determine the need for fluids. Given the deleterious effect of fluid overload, which increases duration of ventilation and worsens prognosis

Table 2. Step-by-step practical approach of hemodynamic monitoring

	Question	View			
First step	Fluid responsiveness	ΔSVC: TEE, long-axis view, 90°	No respiratory variation	Moderate respiratory variation (partial collapse)	Major respiratory variation (complete collapse)
		ΔIVC: TTE, Subcostal view	No respiratory variation	Moderate respiratory variation	Major respiratory variation
Second step	LV systolic function	LVFAC: LV short axis view, 0°	Normal	Moderately decreased	Severely decreased
		LV filling pressure: Pulsed-Doppler at the mitral valve	Nonelevated	Elevated	–
Third step	RV function	RV dilation: four chambers, 0°	No	Moderate	Severe
		Paradoxical septum: LV short-axis	No	Yes	–
Fourth step	Expertise	LV diastolic function (tissue-Doppler)	Normal	Moderately impaired	Severely impaired
		Valvulopathies	No	Moderate	Severe

ΔIVC, IVC distensibility index; LVFAC, left ventricular fractional area contraction; ΔSVC, SVC collapsibility index; TEE, transesophageal echocardiography; TTE, transthoracic echocardiography.

[17,18], and given that only half of patients actually respond to fluids after initial resuscitation [19], dynamic parameters based on heart–lung interactions have been proposed to predict the response to fluids.

In mechanically ventilated patients perfectly adapted to the ventilator, superior vena cava (SVC) collapsibility index has been proposed as a gauge of volume status [20]. It requires a transesophageal approach to obtain a long-axis view (90°) of the vessel, allowing a combination of two-dimensional mode and time-motion study. Collapsibility index is defined as maximal SVC diameter during expiration minus minimal diameter during inspiration divided by maximal diameter. A 'magic number' of 36% allows discrimination between fluid-responsive and fluid-unresponsive patients [20]. But we demonstrated that a simple qualitative approach was accurate enough to manage patients who may be classified, without any measurement, as having major, moderate or no SVC respiratory variations [15]. For patients in whom esophageal access is impossible or contraindicated, TTE can also be helpful in distinguishing between responsive and unresponsive patients. A subcostal view visualizes the inferior vena cava (IVC) and can be used to evaluate its distensibility index, calculated as maximal diameter in inspiration minus minimal diameter in expiration divided by minimal diameter [21]. The more the IVC is able to dilate during tidal ventilation, the greater the preload reserve and so the response to fluids [22▪].

In spontaneously breathing patients, respiratory variations of the vena cava cannot be used to predict fluid responsiveness [22▪]. In 'extreme' situations, a virtual IVC or a left ventricular end-systolic exclusion is useful. Passive leg raising has been proposed [23]. It requires measurement of left ventricular stroke volume before and during the maneuver, which is easily achievable by echocardiography.

Second step: evaluation of left ventricular systolic function

Whereas many echocardiographic parameters of left ventricular systolic function have been proposed [24], our pragmatic approach recommends evaluating such a function using the left ventricular fractional area contraction (LVFAC). LVFAC is obtained from a left ventricular short-axis view (parasternal or transgastric approach) and is the end-diastolic area minus the end-systolic area divided by the end-diastolic area. We previously reported that LVFAC was strongly related to left ventricular ejection fraction in a population of septic shock patients [25]. Interestingly, a quantitative approach is not mandatory and we also previously demonstrated that patients may be accurately classified by advanced CCE intensivists, without any measurement, as having a severely depressed, a moderately depressed or a normal left ventricular systolic function, just by use of the eye-balling method [15].

Two very different hemodynamic profiles may be distinguished in case of shock-related left ventricular systolic dysfunction. The first one is a profile of cardiogenic shock. In this situation, left ventricular filling pressure is elevated. When the left ventricle is dilated, this suggests a chronic injury of the left ventricle, as in chronic cardiomyopathy, whereas the absence of dilatation is suggestive of an acute injury, as seen, for instance, in fulminant myocarditis, acute myocardial infarction (a regional wall-motion abnormality is suggestive) or in some drug intoxication [26]. The second profile is a profile of septic cardiomyopathy. In this situation, the clinical context is of course different. But cardiac evaluation is also very suggestive: left ventricular filling pressure is normal or low, left ventricular hypokinesia is global and no significant left ventricular dilatation is observed [27]. Interestingly, repeated echocardiography may allow intensivists to unmask this left ventricular systolic dysfunction after correcting left ventricular afterload by norepinephrine.

Third step: evaluation of right ventricular systolic function

In critically ill patients, right ventricular systolic dysfunction is mainly due either to right ventricular ischemia or to acute increase in right ventricular afterload, a frequent situation, especially in mechanically ventilated patients [28]. In the latter situation, a pattern of ACP may be observed. This may occur not only in pulmonary embolism [29] but also in ARDS [30] or in sepsis [15]. A very simple message has to be promoted: a failed right ventricle, responsible for shock, is dilated. No right ventricular dilatation means no shock-related right ventricular dysfunction. So, the first evaluation considers the size of the right ventricle. A four-chamber view is required by a transthoracic or a transesophageal route. Dilatation is defined as a right ventricular/left ventricular end-diastolic area ratio of more than 0.6 [31]. We define the dilatation as moderate when the ratio is between 0.6 and 1 and as severe when the right ventricle is bigger than the left ventricle [32]. The second evaluation consists in looking for paradoxical septal motion. A left ventricular short-axis view is required. When occurring in systole, paradoxical septal motion reflects right ventricular systolic overload. The association of right ventricular dilatation with paradoxical septal motion defines ACP. In clinical practice, evaluation of the interventricular septal motion is qualitative: there is or there is not septal dyskinesia. However, advanced CCE intensivists may be able to quantify the septal dyskinesia by calculating the left ventricular systolic eccentricity index, which is the 'ratio of the length of two perpendicular minor-axis diameters, one of which bisected and was perpendicular to the interventricular septum' [33]. The normal value is 1 (the left ventricle is normally purely spherical) and the higher the value, the higher the right ventricular systolic overload with a left ventricle described as having a 'D-shape'. This could be used to compare the impact of different respiratory settings on the right ventricle, as proposed by Mekontso-Dessap *et al.* [34] in ARDS.

What differentiates basic and advanced CCE for evaluation of right ventricular function is the ability that advanced intensivists have to repeat echocardiographic evaluations (i.e. monitoring) and then to interpret right ventricular function accurately according to the treatment (with or without norepinephrine), the respiratory settings (high or low plateau pressure, high or low positive end-expiratory pressure) and the patient's position (supine or prone). Another difference is their ability to use pulsed-Doppler and then to record the right ventricular ejection flow. For instance, in a ventilated patient, a huge decrease in the Doppler signal during tidal ventilation at the level of the pulmonary valve reflects a significant decrease in right ventricular stroke volume due either to a preload or to an afterload effect of positive pressure ventilation.

Fourth step: a 'very advanced' evaluation

In certain situations, evaluation of left ventricular-diastolic function may be useful. This requires advanced CCE intensivists to be able to use pulsed-Doppler and tissue Doppler at the mitral level. Left ventricular diastolic dysfunction has been reported especially in two different situations: sepsis and weaning. In sepsis, recent data suggest that such dysfunction could be independently associated with a worse prognosis [35■■]. In weaning, we and others have demonstrated that left ventricular diastolic dysfunction occurs during a spontaneous breathing trial and could impact the success of such a procedure [36,37■]. It is likely that evaluation of left ventricular diastolic function in critically ill patients will develop in the future [38■].

Finally, advanced CCE intensivists are able to detect valvulopathies and to do the first evaluation of their grade, to enable discussion with an expert cardiologist. Some critical situations have to be recognized quickly and fully understood, such as papillary muscle rupture at the initial phase of an acute myocardial infarction.

OUTLOOK

For more than a decade, several studies have demonstrated the additional value of echocardiography in comparison with 'conventional' devices, thanks to immediate identification of the failing ventricle in low-flow states [39] and because of the inability of static parameters such as cardiac filling pressures to predict fluid responsiveness [40]. The two-fold advantage of instantaneously providing unparalleled information on volume status and cardiac function in septic patients has recently been demonstrated by Bouferrache *et al.* [41■■]. In this study, a poor agreement was reported in the early prescription of fluid loading and of inotropic support between TEE evaluation and the guidelines of the Surviving Sepsis Campaign (SSC). Echocardiography allowed fluid loading to be avoided in 14 patients despite a central venous pressure less than 12 mmHg. Echocardiography also helped physicians to prescribe inotropes in 14 patients, whereas SSC guidelines based on venous oxygen saturation would have recommended such treatment in only four patients [41■■].

Nevertheless, the main limitation of ultrasound techniques is their intermittent and operator-dependent characteristics. Of course, this intermittent examination can be repeated several times a day in order to achieve 'semi-continuous' monitoring in the most severely ill patients, but this is clearly difficult with the current echocardiography machines and probes, especially in large units. In our usual practice, we always recommend combining echocardiography with continuous invasive monitoring of blood pressure and with serial measurements of base deficit and lactate [41■■]. However, a single-use, 72-h indwelling transesophageal probe was recently tested [42■]. It may combine simplicity and pragmatism, allowing functional hemodynamic monitoring, as described above. The probe is designed to be left in place for 72 h in the patient to obtain the three standardized views that offer most of the basic hemodynamic information needed to identify the mechanisms of acute circulatory failure: the SVC view, although on a transverse axis, the left ventricular long-axis view and the left ventricular short-axis view by a transgastric approach. In a pilot study [42■] performed in 94 hemodynamically unstable patients, we recently demonstrated the hemodynamic capability and safety of this new probe. It is now necessary to study how to combine this new approach using the single-use probe with 'regular' echocardiographic examinations, and in which patients.

CONCLUSION

Over the past decades, echocardiography has become a hemodynamic monitoring technique used worldwide. It has the two-fold advantage of enabling morphological and functional evaluation, which allows intensivists to make a quick and simple diagnosis of typical hemodynamic situations, by means of basic CCE, and also to achieve real functional hemodynamic monitoring, through advanced CCE. The future of critical care ultrasound now lies in the dissemination of educational programs to spread knowledge of CCE and in the development of new miniaturized devices allowing more continuous monitoring.

Acknowledgements

None.

Conflicts of interest

There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:
▪ of special interest
▪▪ of outstanding interest
Additional references related to this topic can also be found in the Current World Literature section in this issue (p. 272).

1. Antonelli M, Levy M, Andrews PJ, *et al.* Hemodynamic monitoring in shock and implications for management. International Consensus Conference, Paris, France, 27–28 April 2006. Intensive Care Med 2007; 33:575–590.
2. Edler I, Hertz CH. The use of ultrasonic reflectoscope for the continuous recording of the movements of heart walls. Kungl Fysiogr Sallsk Lund Forh 1954; 24:40–58.
3. Feigenbaum H. Evolution of echocardiography. Circulation 1996; 93:1321–1327.
4. Rivers E, Nguyen B, Havstad S, *et al.* Early goal-directed therapy in the treatment of severe sepsis and septic shock. N Engl J Med 2001; 345:1368–1377.
5. ▪ Vincent JL, Rhodes A, Perel A, *et al.* Clinical review: update on hemodynamic monitoring – a consensus of 16. Crit Care 2011; 15:229.
This review provides a review of the available monitoring systems with their respective advantages and limitations in critically ill patients.
6. Price S, Nicol E, Gibson DG, Evans TW. Echocardiography in the critically ill: current and potential roles. Intensive Care Med 2006; 32:48–59.
7. Kohsaka S, Menon V, Lowe AM, *et al.* Systemic inflammatory response syndrome after acute myocardial infarction complicated by cardiogenic shock. Arch Intern Med 2005; 165:1643–1650.
8. Mayo PH, Beaulieu Y, Doelken P, *et al.* American College of Chest Physicians/La Société de Reanimation de Langue Française statement on competence in critical care ultrasonography. Chest 2009; 135:1050–1060.
9. Joseph MX, Disney PJ, Da Costa R, Hutchison SJ. Transthoracic echocardiography to identify or exclude cardiac cause of shock. Chest 2004; 126:1592–1597.
10. McLean A, Huang S. Critical care ultrasound manual. Churchill Livingstone: Elsevier; 2012.
11. ▪▪ International expert statement on training standards for critical care ultrasonography. Intensive Care Med 2011; 37:1077–1083.
This article defines minimal competencies required to achieve basic level and advanced level in CCE.
12. Manasia AR, Nagaraj HM, Kodali RB, *et al.* Feasibility and potential clinical utility of goal-directed transthoracic echocardiography performed by noncardiologist intensivists using a small hand-carried device (SonoHeart) in critically ill patients. J Cardiothorac Vasc Anesth 2005; 19:155–159.
13. Vignon P, Dugard A, Abraham J, *et al.* Focused training for goal-oriented hand-held echocardiography performed by noncardiologist residents in the intensive care unit. Intensive Care Med 2007; 33:1795–1799.
14. Pinsky MR, Payen D. Functional hemodynamic monitoring. Crit Care 2005; 9:566–572.
15. Vieillard-Baron A, Charron C, Chergui K, *et al.* Bedside echocardiographic evaluation of hemodynamics in sepsis: is a qualitative evaluation sufficient? Intensive Care Med 2006; 32:1547–1552.
16. Charron C, Vignon P, Prat G, *et al.* Number of supervised studies required to reach competence in advanced critical care transesophageal echocardiography. Intensive Care Med 2013. [Epub ahead of print]
17. Boyd JH, Forbes J, Nakada TA, *et al.* Fluid resuscitation in septic shock: a positive fluid balance and elevated central venous pressure are associated with increased mortality. Crit Care Med 2011; 39:259–265.
18. Wiedemann HP, Wheeler AP, Bernard GR, *et al.* Comparison of two fluid-management strategies in acute lung injury. N Engl J Med 2006; 354:2564–2575.
19. Michard F, Teboul JL. Predicting fluid responsiveness in ICU patients: a critical analysis of the evidence. Chest 2002; 121:2000–2008.
20. Vieillard-Baron A, Chergui K, Rabiller A, *et al.* Superior vena cava collapsibility as a gauge of volume status in ventilated septic patients. Intensive Care Med 2004; 30:1734–1739.
21. Barbier C, Loubieres Y, Schmit C, *et al.* Respiratory changes in inferior vena cava diameter are helpful in predicting fluid responsiveness in ventilated septic patients. Intensive Care Med 2004; 30:1740–1746.
22. ▪ Bodson L, Vieillard-Baron A. Respiratory variation in inferior vena cava diameter. Crit Care 2012; 16:181–183.
This editorial focuses on basic physiology to explain meaning of the respiratory variation of the IVC in spontaneously and mechanically ventilated patients.
23. Monnet X, Rienzo M, Osman D, *et al.* Passive leg raising predicts fluid responsiveness in the critically ill. Crit Care Med 2006; 34:1402–1407.
24. Kirkpatrick JN, Vannan MA, Narula J, Lang RM. Echocardiography in heart failure: applications, utility, and new horizons. J Am Coll Cardiol 2007; 50:381–396.
25. Vieillard Baron A, Schmitt JM, Beauchet A, *et al.* Early preload adaptation in septic shock? A transesophageal echocardiographic study. Anesthesiology 2001; 94:400–406.
26. Charron C, Mekontso-Dessap A, Chergui K, *et al.* Incidence, causes and prognosis of hypotension related to meprobamate poisoning. Intensive Care Med 2005; 31:1582–1586.
27. Jardin F, Valtier B, Beauchet A, *et al.* Invasive monitoring combined with two-dimensional echocardiographic study in septic shock. Intensive Care Med 1994; 20:550–554.
28. Piazza G, Goldhaber SZ. The acutely decompensated right ventricle: pathways for diagnosis and management. Chest 2005; 128:1836–1852.
29. Vieillard-Baron A, Page B, Augarde R, *et al.* Acute cor pulmonale in massive pulmonary embolism: incidence, echocardiographic pattern, clinical implications and recovery rate. Intensive Care Med 2001; 27:1481–1486.
30. Vieillard-Baron A, Schmitt JM, Augarde R, *et al.* Acute cor pulmonale in acute respiratory distress syndrome submitted to protective ventilation: incidence, clinical implications, and prognosis. Crit Care Med 2001; 29:1551–1555.
31. Jiang L, Levine RA, Weyman AE. Echocardiographic assessment of right ventricular volume and function. Echocardiography 1997; 14:189–206.
32. Jardin F, Dubourg O, Bourdarias JP. Echocardiographic pattern of acute cor pulmonale. Chest 1997; 111:209–217.
33. Ryan T, Petrovic O, Dillon JC, *et al.* An echocardiographic index for separation of right ventricular volume and pressure overload. J Am Coll Cardiol 1985; 5:918–927.
34. Mekontso-Dessap A, Charron C, Devaquet J, *et al.* Impact of acute hypercapnia and augmented positive end-expiratory pressure on right ventricle function in severe acute respiratory distress syndrome. Intensive Care Med 2009; 35:1850–1858.
35. ▪▪ Landesberg G, Gilon D, Meroz Y, *et al.* Diastolic dysfunction and mortality in severe sepsis and septic shock. Eur Heart J 2012; 33:895–903.
This article describes the high prevalence of left ventricular systolic and diastolic dysfunction among a large population of septic patients. It demonstrates that diastolic dysfunction represents a major predictor of mortality.
36. Caille V, Amiel JB, Charron C, *et al.* Echocardiography: a help in the weaning process. Crit Care 2010; 14:120–126.

37. Papanikolaou J, Makris D, Saranteas T, *et al.* New insights into weaning from
■ mechanical ventilation: left ventricular diastolic dysfunction is a key player. Intensive Care Med 2011; 37:1976–1985.
This study suggests an association between left ventricle diastolic dysfunction and weaning success in ventilated patients. An E/Ea ratio greater than 7.8 could help to identify patients at a high risk of weaning failure.
38. Saleh M, Vieillard-Baron A. On the role of left ventricular diastolic
■ function in the critically ill patient. Intensive Care Med 2012; 38:189–191.
This editorial brings out the crucial importance for the future of evaluating diastolic function in critically ill patients, in particular in sepsis and during the weaning process.
39. Vieillard-Baron A, Prin S, Chergui K, *et al.* Hemodynamic instability in sepsis: bedside assessment by Doppler echocardiography. Am J Respir Crit Care Med 2003; 168:1270–1276.
40. Cavallaro F, Sandroni C, Antonelli M. Functional hemodynamic monitoring and dynamic indices of fluid responsiveness. Minerva Anestesiol 2008; 74:123–135.
41. Bouferrache K, Amiel JB, Chimot L, *et al.* Initial resuscitation guided by the
■■ Surviving Sepsis Campaign recommendations and early echocardiographic assessment of hemodynamics in intensive care unit septic patients: a pilot study. Crit Care Med 2012; 40:2821–2827.
This article demonstrates the discrepancy between echocardiographic monitoring and the Surviving Sepsis Campaign guidelines for the management of patients with septic shock.
42. Vieillard-Baron A, Slama M, Mayo PH, *et al.* A pilot study concerning the safety
■ and clinical utility of a single-use 72-h indwelling transesophageal echocardiography probe. Intensive Care Med 2013. [Epub ahead of print]
This study describes a new miniaturized esophageal ultrasound device for semi-continuous hemodynamic monitoring in 94 ventilated patients.