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Ten good reasons why everybody can and should perform cardiac ultrasound in the ICU

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Abstract

Critical care ultrasonography (CCUS) has been defined as an ultrasound evaluation of the heart, abdomen, pleura and lungs at the bedside by the intensivist, 24/7. Within CCUS, critical care echocardiography (CCE) is used to assess cardiac function and more generally haemodynamics. Experts in haemodynamics have published a 'consensus of 16' regarding an update on haemodynamic monitoring. They reported the ten key properties of an 'ideal' haemodynamic monitoring system, which perfectly match the ten good reasons we describe here for performing CCE in critically ill patients. Even though unfortunately no evidence-based medicine study is available to support this review, especially regarding CCE-related improvement of outcome, many clinical studies have demonstrated that CCE provides measurements of relevant, accurate, reproducible and interpretable variables, is easy to use, readily available, has a rapid response time, causes no harm, and is cost-effective.

Whether it is operator-independent is obviously more debatable and is discussed in this review. All these characteristics are arguments for the extensive use of CCE by intensivists. This is why experts in the field have recommended that a basic level of CCE should be included in the training of all intensivists.

Key words: critical care echocardiography, haemodynamic monitoring, shock

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Critical care ultrasonography (CCUS) has been defined as an ultrasound evaluation of the heart, abdomen, pleura and lungs at the bedside by the intensivist, 24/7 [1]. It has been recognised for many years, in collaborative publications and recommendations by international societies of intensive care medicine [2, 3] that general critical care ultrasonography (abdominal, vascular, pleural and lung evaluation), as well as critical care echocardiography (CCE, heart evaluation), is essential in modern intensive care units (ICUs). Furthermore, the inclusion of basic CCE in the curricula of all intensivists has been recommended [2].

Since most patients admitted to the ICU for cardiorespiratory compromise who die do so because of haemodynamic failure or fluid overload [4], haemodynamic monitoring is key to their management. Many devices are available for continuous or discontinuous haemodynamic monitoring. Repeated echocardiography has, in various situations such as septic shock, proven effective in determining the mechanisms of haemodynamic failure, such as hypovolemia, cardiac failure, or vasoplegia, or sometimes all three together [5].

This is why this review will exclusively focus on CCE and its ability to monitor haemodynamics, for which more data and clinical studies are probably available, even though general critical care ultrasonography is also of great importance.

In 2011, experts in haemodynamics published a 'consensus of 16' to update knowledge of haemodynamic monitoring [6], which emphasises the central role of echocardiography in managing a patient in shock. In the case of persistent haemodynamic instability, echocardiography is strongly recommended after a brief check for an obvious hypovolemic profile [6]. The experts also reported the

ten key properties of an 'ideal' haemodynamic monitoring system, which perfectly match what we consider to be ten good reasons for performing CCE in the ICU [6].

REASON 1: *MEASURES RELEVANT VARIABLES*

CCE plays a central role in functional haemodynamic monitoring [7]. Functional haemodynamic monitoring is a way to monitor haemodynamics more qualitatively, with fewer numbers, in contrast to what was done in the past with the pulmonary artery catheter, less invasively, and finally more centered on the appropriate treatment. A good illustration is the need for fluids. In the past, the main goal was to evaluate cardiac preload using pulmonary artery occlusion pressure or central venous pressure (CVP), neither of which is very relevant for fluid adaptation because of their well-known limitations [8].

With the functional haemodynamic monitoring approach, the goal now is to evaluate preload responsiveness, which echocardiography has been reported to predict well, using, as an example, vena cava respiratory variations [9] with good sensitivity and specificity. But CCE is also able to evaluate right heart function accurately [10], to detect acute cor pulmonale in different situations [11], and to recognise left ventricular (LV) dysfunction using the LV ejection fraction or its surrogate LV fractional area contraction [12]. All the potential causes of circulatory failure may be independently evaluated from the others, like direct visualisation of the cardiac chambers and heart function, in contrast to what can be done using other devices.

REASONS 2 AND 3: *PROVIDES ACCURATE AND REPRODUCIBLE MEASUREMENTS, IS OPERATOR-INDEPENDENT*

Whereas the first assertion is true, the second is debatable. As emphasised above, many echocardiographic parameters in critically ill patients have been reported to be accurate for evaluation of cardiac function and preload responsiveness. Reproducibility has also been studied for the usual echocardiographic parameters. Intra- and inter-observer variabilities of between 3 and 10% have been reported [5]. Logically, better image quality and acquisition result in better reproducibility. This is why in our view transoesophageal echocardiography (TEE) in mechanically ventilated patients is probably more accurate and reproducible, and less operator-dependent, than transthoracic echocardiography (TTE). This was indirectly suggested by two studies. The first, in critically ill surgical patients, showed that TEE is more efficient than TTE, especially in patients with significant weight gain (> 10%), with a chest tube or ventilated with a positive end-expiratory pressure higher than 15 cm H_2O [13]. The second, in 200 patients ventilated for acute respiratory distress syndrome, showed that TEE is more efficient than TTE in detecting acute cor pulmonale [14]. Provided that physicians are correctly trained, and that CCE is used as a qualitative approach (see Reason 1 above), we suggest that TEE may be considered as nearly operator-independent [15, 16].

REASON 4: *PROVIDES INTERPRETABLE DATA*

Since echocardiography directly visualises the cardiac chambers and ventricular contraction, parameters are by definition interpretable, provided image acquisition is adequate. In a clinical study of 128 transthoracic procedures, Vignon et al. reported quality that was good in 55% of cases, suboptimal in 23%, and poor in 22% [17]. In the event of TTE failure, TEE was very efficient [17]. In our experience, images recorded using a transoesophageal route are rarely uninterpretable. The respective advantages and disadvantages of TTE and TEE are summarised in a recent international consensus statement [3].

CCE visualises what is really happening, whereas recording of cardiac pressures is limited since they are subject to intrathoracic pressure, which complicates interpretation in certain situations. For instance, CVP depends more on changes in intrathoracic pressure than on haemodynamic changes in acute asthma and in acute exacerbation of chronic obstructive pulmonary disease, where there are large swings in intrathoracic pressure.

REASON 5: *IS EASY TO USE*

Compared to other devices for haemodynamic monitoring, echocardiography requires expertise and then training to acquire cognitive but also technical skills. From this point of view, echocardiography is not obviously easy to use. On the other hand, the global haemodynamic evaluation it allows and, unlike most other devices which focus mainly on cardiac output measurement, the balance it offers between interests and constraints, clearly favour echocardiography, even though no evidence-based medicine supports such an assertion.

CCE can be defined as basic or advanced [1]. Basic CCE, also called goal-directed echocardiography [18], is a procedure based on transthoracic echocardiography which allows a focused and rapid exam to diagnose obvious haemodynamic profiles, such as profound hypovolemia, severe LV systolic dysfunction, severe RV dilatation and extensive pericardial effusion [1]. Provided that appropriate skills acquisition is included in the training curriculum of all intensivists [2], one can say that basic CCE is (or will be) very easy to use. To acquire the necessary skills, a ten-hour course is recommended, divided into lectures and illustrative cases, plus at least 30 fully supervised TTE examinations in unstable patients [2].

Advanced CCE is quite different in that it allows a full haemodynamic evaluation [1]. Intensivists have to be com-

petent in the use of TTE and TEE in mechanically ventilated patients. It requires formal certification following a 40-hour course, 100 supervised TTE and 35 supervised TEE examinations [3]. Given these requirements, it is hard to maintain that advanced CCE is currently easy to use, but there are an increasing number of certification courses (local or international) open to intensivists.

REASON 6: *IS READILY AVAILABLE*

The recommendation is very clear: for CCE, the echocardiography machine has to be readily available, meaning in the ICU. Even though no recent survey has been done, one can nonetheless say that most ICUs now have one available 24/7. Similarly, TEE probe cleaning is better performed in the unit by the team itself.

REASON 7: *HAS A RAPID RESPONSE TIME*

In a recent multicentre study of the ability of 41 trainees to evaluate haemodynamics adequately in mechanically ventilated patients using TEE, Charron et al. reported that after six months and 31 ± 9 supervised TEE examinations per trainee, they were able to perform a full haemodynamic evaluation adequately in about 13 minutes [16]. Once again, this requires the machine and the oesophageal probe to be available in the ICU, as recommended.

Using the pulsed wave Doppler technique, echocardiography can also be used to calculate the LV stroke volume and then the cardiac output. Compared to other techniques, it clearly has a rapid response time since it enables real-time evaluation of the response to passive leg raising, as recommended [19].

REASON 8: *CAUSES NO HARM*

Even though the 16 experts in haemodynamics in their consensus reiterated in principle no. 10 for haemodynamic monitoring that "noninvasiveness is not the only issue", and absolutely not a goal per se, they also said that it is preferable to be less invasive when possible [6]. Whereas TTE is completely noninvasive, TEE can be considered as minimally invasive. When contraindications are strictly respected, side effects are few. In a large study of 2,508 TEE examinations, Hüttemann et al. [20] reported a 2.6% incidence of complications. Most of these complications could actually be considered minor and most occurred in spontaneously breathing patients. The most serious complication, oesophageal perforation, was mainly described in awake patients breathing spontaneously, with an incidence of around 1/2,500 procedures.

REASON 9: *IS COST-EFFECTIVE*

To the best of our knowledge, no formal medico-economic study has been performed to evaluate the cost-effectiveness of CCE compared to other haemodynamic devices in critically ill patients. Some studies indirectly suggest that, by limiting fluid overload, CCE may reduce the length of stay in the ICU and mortality compared to management using central venous pressure [5].

The cost of echocardiography machines has significantly decreased over time and new 'pocket' machines are now available at a very low price (< $10,000 US). Pocket echoscopic devices have proven efficient for basic CCE [21]. In general, compared to other haemodynamic devices, there are no costs for consumables once the machine has been bought. In an interesting study performed in critically ill surgical patients, Cook et al. tested the cost-effectiveness of three different scenarios [13].

In the first scenario, TTE was performed first, and if it was unhelpful TEE was done. The cost per patient was evaluated at $858 US. In the second scenario, TEE was routinely performed first. Here, the cost per patient was significantly lower, i.e. $677 US. Finally, in the third scenario, TTE was performed first in patients with a low risk of it failing, and TEE was done first in patients with a high risk of TTE failure. The cost per patient was $752 US.

REASON 10: *SHOULD PROVIDE INFORMATION THAT CAN BE USED TO GUIDE THERAPY*

This section alone could probably be a large review in itself because of the mass of available data and clinical studies. Therefore we will not strive to be exhaustive. Briefly, in the 1990s, many studies reported a therapeutic impact in 20–68% of cases when TEE was performed in addition to the rest of the haemodynamic evaluation [17, 22–24]. In these studies, TTE also had a significant therapeutic impact when adequate images were obtained. In a study in 2,508 critically ill patients, Hüttemann et al. [20] reported a therapeutic impact of TEE of 68.5% of cases. In close to half of the patients, the indication for TEE was haemodynamic instability [20]. More recently, Bouferrache et al. [25] reported a very simple therapeutic protocol based on TEE examination in mechanically ventilated patients with septic shock. In particular, they demonstrated their ability to diagnose and to correct step-by-step hypovolemia, septic cardiomyopathy and vasoplegia [25]. They also reported discrepancies between the TEE approach and the recommendations of the Surviving Sepsis Campaign. In particular, the SSC approach based on $S_{cv}O_2$ was reported to be inaccurate, compared to echocardiography, in identifying patients with severe LV systolic dysfunction [25].

CONCLUSION

Although no clear evidence-based medicine study has yet confirmed the ability of CCE to improve outcomes in critically ill patients, several observational studies support its

use as a true haemodynamic monitoring device. However, as also noted by the 'consensus of 16' experts in haemodynamics in their principle no. 1, no haemodynamic monitoring technique can by itself improve outcome [6]. We hope that this presentation, even though sometimes partial, of ten good reasons for using critical care echocardiography, will convince intensivists to seek training in, and to use, echocardiography at the bedside to optimise patient management.

References:

1. *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.
2. Expert round table on ultrasound in ICU: International expert statement on training standards for critical care ultrasonography. Intensive Care Med 2011; 37: 1077–1083.
3. Expert round table on ultrasound in ICU: International expert statement on training standards for advanced critical care echocardiography. Intensive Care Med 2014; 40: 654–666.
4. *Boyd JH, Forbes J, Nakada TA, Walley KR, Russell JA:* 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.
5. *Vieillard-Baron A, Prin S, Chergui K, Dubourg O, Jardin F:* Haemodynamic instability in sepsis: bedside assessment by Doppler echocardiography. Am J Respir Crit Care Med 2003; 168: 1270–1276.
6. *Vincent JL, Rhodes A, Perel A et al.:* Clinical review: Update on haemodynamic monitoring - a consensus of 16. Crit Care 2011; 15: 229.
7. *Pinsky MR, Payen D:* Functional haemodynamic monitoring. Crit Care 2005; 9: 566–572.
8. *Osman D, Ridel C, Ray P, Monnet X, Anguel N, Richard C, Teboul JL:* Cardiac filling pressures are not appropriate to predict haemodynamic response to volume challenge. Crit Care Med 2007, 35: 64–68.
9. *Charron C, Caille V, Jardin F, Vieillard-Baron A:* Echocardiographic measurement of fluid responsiveness. Curr Opin Crit Care 2006; 12: 249–254.
10. *Jardin F, Vieillard-Baron A:* Monitoring of right-sided heart function. Curr Opin Crit Care 2005; 11: 271–279.
11. *Vieillard-Baron A, Prin S, Chergui K, Dubourg O, Jardin F:* Echo-Doppler demonstration of acute cor pulmonale at the bedside in the medical intensive care unit. Am J Respir Crit Care Med 2002; 166: 1310–1319.
12. *Vieillard-Baron A, Caille V, Charron C, Belliard G, Page B, Jardin F:* Actual incidence of global left ventricular hypokinesia in adult septic shock. Crit Care Med 2008, 36: 1701–1716.
13. *Cook CH, Praba AC, Beery PR, Martin LC:* Transthoracic echocardiography is not cost-effective in critically ill surgical patients. J Trauma 2002; 52: 280–284.
14. *Lhéritier G, Legras A, Caille A et al.:* Prevalence and prognostic value of acute cor pulmonale and patent foramen ovale in ventilated patients with early acute respiratory distress syndrome. Intensive Care Med 2013, 39: 1734–1742.
15. *Vieillard-Baron A, Charron C, Chergui K, Peyrouset O, Jardin F:* Bedside echocardiographic evaluation of haemodynamics 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, 39: 1019–1024.
17. *Vignon P, Mentec H, Terré S, Gastinne H, Guéret P, Lemaire F:* Diagnostic accuracy and therapeutic impact of transthoracic and transesophageal echocardiography in mechanically ventilated patients in the ICU. Chest 1994; 106: 1829–1834.
18. *Repesé X, Charron C, Vieillard-Baron A:* Intensive care ultrasound: V. Goal-directed echocardiography. Ann Am Thorac Soc 2014; 11: 122–128.
19. *Teboul JL, Monnet X:* Prediction of volume responsiveness in critically ill patients with spontaneous breathing activity. Curr Opinion Crit Care 2008; 14: 334–339.
20. *Hüttemann E, Schelenz C, Kara F, Chatzinikolaou K, Reinhart K:* The use and safety of transesophageal echocardiography in the general ICU-a minireview. Acta Anaesthesiol Scand 2004; 48: 827–836.
21. *Biais M, Carrié C, Delaunay F, Morel N, Revel P, Janvier G:* Evaluation of a new pocket echoscopic device for focused cardiac ultrasonography in an emergency setting. Crit Care 2012; 16: R82.
22. *Heidenreich PA, Stainback RF, Redberg RF, Schiller NB, Cohen NH, Foster E:* Transesophageal echocardiography predicts mortality in critically ill patients with unexplained hypotension. J Am Coll Cardiol 1995; 26: 152–158.
23. *Polaert JI, Trouerbach J, De Buyzere M, Everaert J, Colardyn FA:* Evaluation of transesophageal echocardiography as a diagnostic and therapeutic aid in a critical care setting. Chest 1995; 107: 774–779.
24. *Slama MA, Novara A, Van de Putte P et al.:* Diagnostic and therapeutic implications of transesophageal echocardiography in medical ICU patients with unexplained shock, hypoxemia, or suspected endocarditis. Intensive Care Med 1996; 22: 916–922.
25. *Bouferrache K, Amiel JB, Chimot L et al.:* Initial resuscitation guided by the Surviving Sepsis Campaign recommendations and early echocardiographic assessment of haemodynamics in intensive care unit septic patients: a pilot study. Crit Care Med 2012; 40: 2821–2827.

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