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Intensive care bedside echocardiography: true or a distant dream?

Ecocardiografia à beira do leito em terapia intensiva: uma realidade ou um sonho distante?

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ABSTRACT

During the last few years, technological development and acquired experience advanced and the echocardiogram has become an important and useful tool in intensive care unit environment. Data obtained from semi quantitative Doppler echocardiography (transthoracic and transesophageal) evaluation has contributed to an appropriate patient monitoring and management. Echocardiography as a diagnostic, prognostic and monitoring method for fluid responsiveness assessment has become available nowadays since hand-carried ultrasound devices are portable and cheaper. Adequate training and development of appropriateness criteria for use of echocardiography in intensive care unit may lead to a standard use as a bedside tool.

Keywords: Echocardiography; Intensive care; Heart arrest; Inservice training; Point-of-care systems

INTRODUCTION

In the last 10 years the systematic introduction of semi-continued echocardiography in intensive care units and in some services has made this method a valuable tool for severely ill patients management. Conditions where early diagnosis is sometimes decisive for a patient management, e.g. in cardiac tamponade and/or aortal dissecation, reiterate its implementation relevance and need.(1-2) Currently available equipments portability, and patient-focused training (point of care echocardiography) justify its use by intensivist physicians. Some recommendations suggested for its use are in chart 1.

Appropriate perfusion and optimized oxygen supply are the major intensive care objectives in circulatory dysfunction patients. Cardiac output (CO) is a variable closely related to venous return, which is defined as the difference between right atrium pressure and mean systemic filling pressure (MSFP). Consequently, the CO should be proportional to the blood flow arriving the heart, and, depending on the Frank-Starling curve patient's situation,(3) preload increase by a volume test may either increase or not the cardiac output. In hypovolemic conditions, probably the increased venous return will increase right ventricle preload, and consequently the left ventricle's, thus optmizing the systolic volume. This situation is said preload dependent, and the patient will be considered as a volume test responder. A frequent in-

Chart 1 – Intensive care echocardiogram uses

Indications	Echocardiography evaluation
Hemodynamic instability	Fluid-responsiveness evaluation
Ventricular functioning	Systolic and Diastolic ventricular function evaluation Systolic volume and cardiac output calculation Segmentar LV and RV analysis
Hypovolemia	Inferior vena cava collapsing ratio Right ventricular filling DVP-PSAP evaluation
Cardiac tamponade	RV diastolic collapse, and RA systolic Paradoxical ventricular septum movement Inspiratory right and left filling and aortal and pulmonary TVI variation
Pulmonary thromboembolism	RV dilation and dysfunction Pulmonary artery hypertension Direct RV and/or pulmonary trunk thrombus view
Severe valve dysfunction	Mitral incompetence (flow area, vena contracta, PISA) Mitral stenosis (PHT, transvalvar gradient, valve area) Aortal incompetence (vena contracta, PHT)Aortal stenosis (transvalvar gradient, valve area, continuity)Tricuspid incompetence (flow area)
Intracardiac shunts	Interatrial and interventricular defects Persistent ductus arteriosus Echo with microbubbles
Infective endocarditis	Vegetations, valve dysfunctions
Cardiorespiratory arrest	Pseudo PEA and PEA differentiation Differential CRA diagnosis CRA prognosis
Pacemaker positioning	Pacemaker location and implantation

LV – left ventricle; RV – right ventricle; RVP – right ventricle pressure; PASP – pulmonary artery systolic pressure; RA – right atrium; TVI – time velocity integral; PISA – Proximal Isovelocity Surface Area; PHT – Pressure Half-Time; PEA – pulseless electric activity; CRA - cardiorespiratory arrest.

tensive care question is knowing the patients' "volume status", and how to evaluate if tissue perfusion targeted therapeutic interventions are towards the right direction, i.e. if they are beneficial to the patient. With such questions, we perform CO monitoring as a valuable tool for critically ill patients evaluation. A fundamental aspect in these patients is the CO determination, which can't be reliably determined by physical examination. The Swan Ganz catheter remains as the current gold standard, however its use has been reduced based on the last two years published scientific evidence.(4) Thus, new non-invasive, safe, reliable and reproducible CO monitoring technologies, among them echocardiography, may mean considerable advantage on these patients management in comparison with the Swan Ganz catheter use.(5) Other non-invasive CO monitoring methods are listed on chart 2.

In addition to static measures evaluation, its implementation has allowed analyzing the systolic volume variation (dynamic respiratorycycle-related measurements), which is proportional to pulse-pressure (PP) and delta PP.(6-8) Another echocardiography tool is the possibility of estimating left ventricular filling pressure (LVFP), usually correlated with pulmonary wedge capilary pressure (PWCP), in the absence of significant valve changes, such as moderate to severe mitral valve incompetence. For this, the relationship between the trans-mitral (pulsed doppler) flow measure, positioned above the mitral valve closure (ventricular cavity), wave (E), i.e. rapid filling phase, and the tissue doppler (E') measure, positioned on the septal or lateral mitral ring is used. The E/E' <8 ratio predicts a LVFP < 12 mmHg; E/E' > 15 predicts LVFP > 18 mmHg, and intermediate values are in a grey zone.(9) Left atrium

Chart 2 – Non-invasive cardiac output monitoring methods

Methods	Advantages	Disadvantages
Esophageal doppler (CardioQ)	Tolerated with awaken patient Continued monitoring	Operator-dependent Probe can displace, changing accuracy
NICO (partial CO2 re-inhalation and measuring CO by indirect FICK technique	Minimally invasive Good CO accuracy	Needs OTI and MV MV changes may change CO Hemodynamic stability needed
Transesophageal echocardiogram	Good OC correlation with termodilution Fluid-responsiveness evaluation	Not tolerated by awaken patients Operator-dependent May cause esophageal injury
Thoracic electric bioimpedance	No vascular access needed	Electrode positioning subject to error
Pulse contour evaluation (Lidco, PiCCO, FloTrac)	Minimally invasive CO	Arterial curve artifacts may interphere on measures efficacy Anaysis prejudiced with arrhythmia

CO – cardiac output; OTI – orotracheal intubation; MV – mechanic ventilation; PiCCO - pulse contour cardiac output'; Lidco - lithium dilution cardiac output'; NICO – non invasive cardiac output.

pressure (LAP) may be estimated calculating the mitral regurgitation velocity integral in non-mitral valve disease patients. Practically, the non-invasive and validated gradient between left ventricle and left atrium is measured (4x peak mitral regurgitation velocity) in heart failure patients.[10]

Other echocardiographic measurements may help evaluating fluid-responsiveness, such as inferior cava vein distensibililty rate (ICVD), superior cava vein collapsing rate (SCVC), right ventricular systolic pressure (RVSP), right atrium pressure (RAP), and diastolic and end-systolic left ventricle area after volume infusion (Chart 3).

The echocardiogram dynamic both pressure and/or volume measurements advantages as compared to the static ones reside on that systolic and diastolic function, and valve changes, do not significantly interact with data interpretation, and thus with therapeutic choice. By inferior vena cava collapsing rate (IVCC), the inferior vena cava (IVC) diameter by subcostal echocardiographic section, aligning the cursor on mode M (motion) 2 cm from RA, we can estimate the right atrium pressure (Chart 4 and Figure 1).[9] Obviously there are situations where we can't evaluete RAP

Chart 3 – Static and dynamic echocardiogram hemodynamic variables

Echocardiography variable	Formula	Static/Dynamic parameter
ΔIVC (%)	IVC (Dmax – Dmin) / Dmin x 100	Dynamic
ΔSVC (%)	VCS (Dmax - Dmin) / Dmax x 100	Dynamic
Systolic volume (TEE)	LV exit way section area x VTIAo	Dynamic
ΔSystolic volume (TTE or TEE) + Passive leg raising	LV exit way section area x VTIAo, following lower limbs elevation maneuver	Dynamic
Left ventricle end-diastolic area	LE diastole planimetric area (transversal section)	Static
RVSP	4 x (Vmax IT)² + RAP	Static
Cardiac Output	(LV exit way section area x VTIAo) x heart rate	Static
LAP	LAP = 1.24 (E/E') + 1.9 4x mitral regurgitation peak velocity	Static
LVFP=PWCP	E/E' < 8 - LVFP < 12 mmHg E/E' >15 - LVFP >18 mmHg	Static

LV – left ventricle; IVC – inferior vena cava; SVC – superior vena cava; VTIAo – aortal time-velocity integral; PASP – pulmonary artery systolic pressure; TI – tricuspid incompetence; RVSP – right ventricle systolic pressure; RAP – right atrium pressure; ΔIVC(%) – inferior vena cava variation; ΔSVC (%) – superior vena cava variation; Dmax – maximal diameter; Dmin – minimal diameter; LAP – left atrium pressure; TTE – transthoracic echocardiogram; TEE – transesophageal echocardiogram; LAP – left atrium pressure; E – transmitral E wave; E' – mitral tissue Doppler wave; LVFP – left ventricle filling pressure; PWCP – pulmonary capillary wedge pressure; Vmax – maximal velocity.

by IVC respiratory phasic range, such as in case of right ventricle (RV) dysfunction and cardiac tamponade. Inferior vena cava is a predominantly extra-thoracic vessel (intra-abdominal) related with right heart chambers suffering amplitude variation according to the respiratory cycle and systolic volume. During spontaneous inspiration there is a reduced intra-thoracic pressure and increased venous return. Its amplitude variation is related with RAP measurement, however there are not yet literature evidences for its use as fluid-responsiveness index in spontaneous breathing or mechanicaly assisted ventilation patients.

Chart 4 – Inferior vena cava evaluation as hemodynamic index for spontaneously breathing patients

IVC size (cm)	Collapsing rate (%)	RAP (right atrium pressure)
<1.5 cm	100% collapsed	0-5 mmHg
1.5-2.5cm	>50% collapsed	5-10 mmHg
1.5-2.5cm	<50% collapsed	10-15 mmHg
>2.5cm	<50% collapsed	15-20 mmHg
>2.5cm	No change	>20 mmHg

IVC – inferior vena cava; RAP – right atrium pressure.
Source: Otto CM. Echocardiographic evaluation of left and right ventricular systolic function. In: Otto CM, editor. Textbook of clinical echocardiography. 2nd ed. Philadelphia: WB Saunders; 2000.

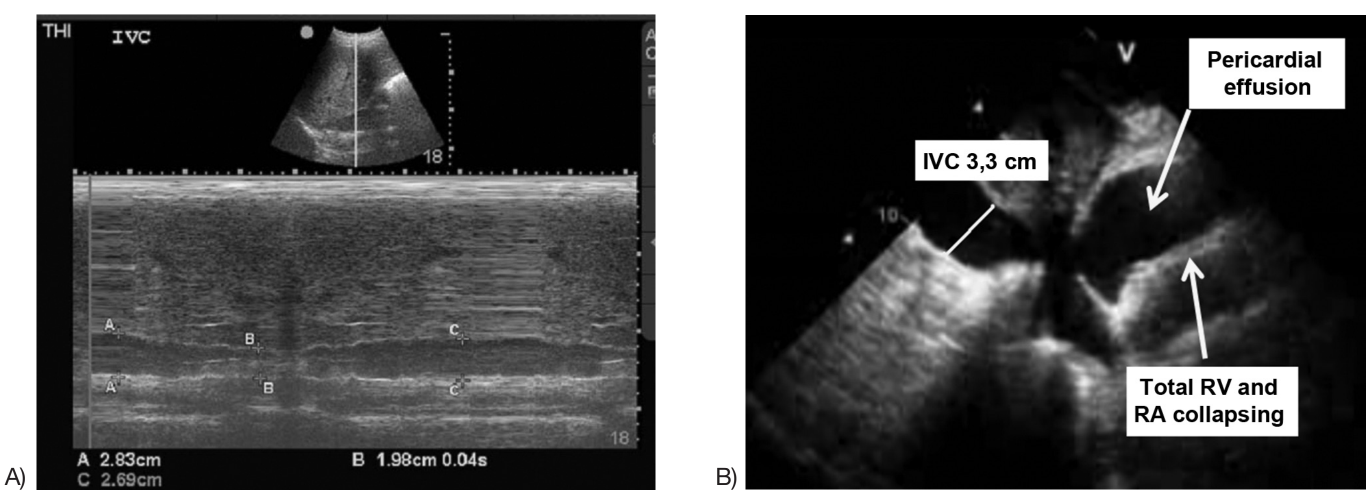
In mechanic ventilation patients, the IVC diameter variation is reversed, i.e., during the inspiratory phase there is increased intra-thoracic pressure and transference of pressures from the right atrium and, consequently, to the communicating vessels. In this case the vena cava has its diameter increased due to two main mechanisms:

1- RV preload reduction

2- RV increased post-load (positive pressure) associated with increased LV preload secondary to blood emptying from pulmonary bed and consequent systolic volume increase

This heart-lung coupling causes extra-thoracic vessels changes (both arterial and venous), which may represent volume replacement needs. In this situation, under mechanic ventilation, a percentage of inferior vena cava variation (%ΔIVC) and or superior (%ΔSVC) is used as parameter for volume infusion responsiveness and to identify them as either responders or non-responders.[11,12]

In practice we use a %ΔIVC cutoff value above 12% according to Feissel et al.[13] or above 18% according to Barbier et al.[14] Regarding the %ΔSVC,[15] we use a higher cutoff value equal to 36% in controlled mechanic ventilation patients for



A) B)

C)

$$\text{Inferior vena cava collapsing index (IVCCI\%) = estimate RAP} \quad \frac{\text{Maximal IVC diameter – minimal diameter}}{\text{Maximal IVC diameter}}$$

ICV – inferior vena cava.

Figure 1 – A) Inferior vena cava measuring, mode M, IVC 30% collapsed. B) IVC ingurgitated secondary to cardiac tamponade. C) Formula used for prediction of right atrial pressure in spontaneous breathing patients.

fluid-responsiveness determination.

Information from echocardiographic analysis should be always considered before the patient's clinical picture.

Recently, De Backer et al. Studied the respiratory rate (RR >30) interference on systolic volume evaluation in relation to dynamic indices. Their data showed that %ΔSVC had no respiratory rate interference, and is perhaps a more suitable parameter in this settings, such e.g., in patients with acute respiratory distress syndrome (ARDS) and/or relevant metabolic acidosis patients.[16]

The CO measurement may be performed using transthoracic echocardiography (TTE) by measuring the left ventricle exit way times the Doppler measured aortal valve time-velocity integral (VTIAo). The systolic volume found with this method is then multiplied times the heart rate, thus finding the CO.[17-18]

A growing set of evidence-based interventions is in place to guide intensive care clinical practice. As previously described, several and variable hemodynamic monitoring methods are available from echocardiogram. However, we show in the chart 5 the most consistent fluid-responsiveness related evidences, and their cutoff values.

In this context, several articles search for answers to help and study the fluid treatment effects in severely ill patients, with emphasis on echocardiography use. Despite Swan Ganz catheter use controversies, echocardiogram is a non-invasive test, easy to perform, with low morbidity and additional to other monitoring tools.[19] A point to be highlighted is that the previously described studies had retrospectively evaluated the predictive value of hemodynamic indices after volume administration, and not necessarily the clinical outcome, which should be evaluated in prospective, randomized and larger samples trials. Second, we should bear in mind that not necessarily a patient responsive to a volume test (%IVC 25%) actually needs fluid. A practical example would be an anesthetized patient with preserved microcirculation parameters and rated as volume-responder in who excessive hydration can entail venous-capillary congestion and increased morbidity.[20] This deserves reflection as the patient's global clinical status and use of bedside echocardiographic data. Hemodynamic echocardiographic information use confirms the hospital's efforts on safety monitoring and measuring of ICU options, which can be focused on the structure, process and health care results.[21]

Another much useful echocardiographic fashion in the intensive care setting is transesophageal echocardiography. Its indications and diagnostic accuracy are reported on chart 6.[22-24] In conditions,

Chart 5 – Dynamic echocardiographic fluid-responsiveness indices

Echo	Hemodynamic index	Objective	Formula	Cutoff value	Author/Year	Reference
TEE	Aortal peak velocity variation (delta Vpeak)	Aortal peak velocity during respiratory cycle	VpmaxAo-VpminAo/0,5 (VpmaxAo+VpminAo)	12%	Feissel M /Monnet X -2001	39
TEE	Superior vena cava collapsing rate	SVC variation during MV respiratory cycle	(maximal diameter – minimal diameter/maximal Demeter) x 100	36%	Vieillard- Baron A - 2004	15
TTE	Inferior vena cava distensibility rate	SVC variation during MV respiratory cycle	(maximal diameter – minimal diameter/ minimal diameter) x 100	12%/18% (median 15%)	Feissel M 2002 Barbier C 2004	13-14
TEE	PLR aortal blood flow variation	Difference between aortal flow velocity after PLR maneuver and baseline	Aortal flow (PLR) – baseline aortal flow	10%	Monnet X -2006	40
TTE	PLR systolic volume variation	Variation > 15% systolic volume after PLR maneuver and baseline	Ao LVEW section area (longitudinal axis) x VTIAo (apical)	12.5%	Lamia -2007	41

Echo – echocardiogram; TTE – transthoracic echocardiogram; TEE – transesophageal echocardiogram; PLR – passive leg raising; MV – mechanic ventilation; SVC – superior vena cava; LVEW – left ventricle exit way; VTIAo – time-aortal velocity integral; Vpeak – peak velocity; Max – maximal; Min – minimal; Ao – aortal.

e.g. during post heart surgery period, TEE is sometimes imperative due to difficult transthoracic images acquisition. The initial choice for transthoracic or transesophageal echocardiogram depends on the heart structure to be evaluated, as well as the clinical setting involved (surgical center, intensive care unit, pre-hospital).[25]

Chart 6 - Transthoracic and transesophageal echocardiogram characteristics and accuracy

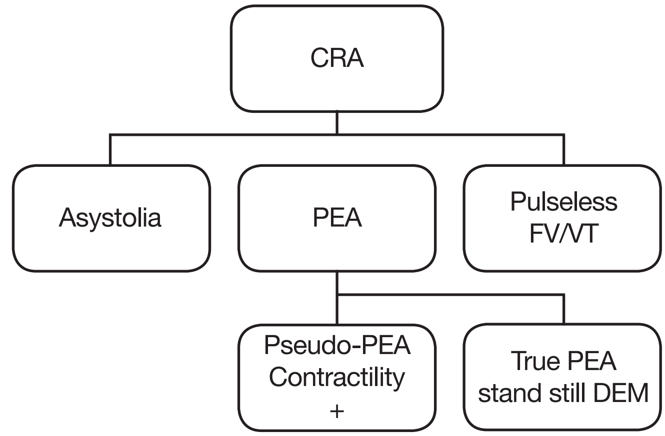
Indication	TTE	TEE
Aortal dissection	+	+++
Infective endocarditis evaluation	+	+++
Intracardiac thrombus	+	++
Prosthetic valve	+	++
Atrial apendix	+	+++
Obese patient	+	++
Emphysema patient	+	++
Hight PEEP MV	+	++
Surgery tubes or incisions	+-	+++
Post cardiac surgery period	+	+++

+ - less indicated; +++ - more indicated; +- - eventually indicated.

TTE – transthoracic echocardiography; TEE – transesophageal echocardiography; MV - mechanic ventilation; PEEP – positive end-expiratory pressure.

In the intensive care unit, an echocardiogram may be used as an ancillary method for cardiorespiratory arrest (CRA) differential diagnosis, specifically in pulseless electric activity (PEA) and asystolia, where spontaneous circulation return depends on reversion of the primary cause (hypovolemia, hypoxia, hiperkalemia, cardiac tamponade, pulmonary thromboembolism).

Particularly on PEA, with echocardiographic support, two forms were described: true PEA (no heart contractility associated to no pulse) and pseudo-PEA (myocardial contractility present, with no pulse) (Figure 2). This differentiation is important due to prognostic implications. The implementation of this new format during a CRA is being developed by well designed protocols, appropriate training and mainly, with no thoracic compressions interruptions.[26-28] Perhaps, the introduction of new technologies improve the extra-hospital and hospital survival, unchanged for three decades.[29,31] Blaivas et al.[32] evaluated 169 non-arrhythmic CRA patients (PEA asystolia) using echocardiogram during resuscitation maneuvers and demonstrated 100% mortality in patients with cardiac stand still.



CRA – cardiorespiratory arrest; PEA – pulseless electric activity; VF – ventricular fibrilation; VT – ventricular tachycardia; EMD – Eletric-mechanical dissociation.

Figure 2 – PEA rhythm dichotomization.

Other authors confirmed these findings, and suggested that echocardiogram cardiac stand still in non-arrhythmic CRA is, perhaps, enough to stop cardiopulmonary resuscitation efforts.[33,34] With an agile and more accurate clinical status benefiting from a particular intervention identification, maybe resuscitation odds may be significantly improved. So far we only have some echocardiogram use in CRA cases and series reports. Nevertheless this is a field to be explored with a perspective of future guidelines implementation. Another important echocardiogram monitoring and diagnosis related point is identifying its effectiveness and clinical feasibility with specific situations protocols, such as shock, CRA and sepsis. Based on these concepts, some studies mentioned in the text may be summarized on chart 7, evidencing its feasibility. Among the studies we highlight FEER and BEAT as promising and reproducible.

Training and education in intensive care echocardiography

Echocardiography systematization and training within the intensive care unit depends on solid guidelines and continued medical education implementation. The support of national and international associations is fundamental for these principles certification conduction. Currently, in France 90% of intensive care units have echocardiography training in a 2 years-long program. Another interesting fact is that in England, 90% of intraoperative TEE are conducted by anesthesiologists. This absolutely

Chart 7- Protocols using intensive care echocardiogram as diagnostic and therapeutic tools

Bedside echocardiogram protocols						
Protocol	Scenario	Objective	Variables	Results	Reference	Author/ Year
BEAT – Bedside echocardiographic assessment in trauma/critical care	Hemodynamic	TTE hemodynamic variables measuring	B= pump (cardiac index), E= pericardial effusion A= area or heart function T= tank, volume status (IVCI)	Good PAC and CVP correlation	18	Gunst M - 2008
Sepsis-Echo – Focused training for goal-oriented handheld echocardiography performed by noncardiologist residents in the ICU	Sepsis	Complement early therapy with echocardiogram	Measuring heart contractility and inferior vena cava variation in sepsis	Feasible and promising in sepsis settings	25	Vignon P - 2007
FEER – Focused echocardiographic evaluation in resuscitation management	CRA	Evaluation of non-arrhythmic CRA causes	Portable echocardiogram use for ruling out tamponade, hypervolemia, pneumothorax, pulmonary thromboembolism.	Reduce CRA time with appropriate treatment and management standardization during CRA.	26	Breitkreutz R - 2007

ICU – intensive care unit; IVCI – inferior vena cava index; TTE – transthoracic echocardiogram; TEE – transthoracic echocardiogram; PAC – pulmonary artery catheter; CVP – central venous pressure.

does not mean that the intensivist physician will replace echocardiographists in the ICU, but that will use this tool to respond specific and contextualized questions. Were recently published by the World Interactive Network Focused on Critical Ultrasound (WINFOCUS) recommendations on the use of echocardiography in the intensive care settings, and also by the British Echocardiography Society and American College of Chest Physicians and French Speaking Reanimation Society.[35-38] These guidelines recommend rational degrees of competency and training and how the echocardiogram should be performed. They propose three distinct levels of education, relating the echocardiography use in emergency conditions, as during CRA, and the need of requesting an expert evaluation when indicated and needed. The time to complete each phase depends on each institution's training, i.e., if there is a formal ICU echocardiography training during intensive medicine specialization, presence of preceptor echocardiography-expert cardiologists, and the ways of measuring students' performance based on different international associations' rules. WINFOCUS suggested a 2-year supervised training period, with at least 50 cases recorded yearly to achieve Level 2 competence (Chart 8). It is important highlighting the activity limits for different medical professionals, and the different horizons of echocardiography techniques use in intensive care and emergency settings. So far we have no Brazilian regulation on use of echocardiography for nonhabilitated medical professionals, according to the Brazilian Society of Cardiology Echocardiography Department (DEPECO/SBC).

Chart 8 – WINFOCUS[36] guidelines-based proposed intensive care echocardiography competence levels

Level 3	Echocardiography expert (invasive procedures, echocardiography investigator)
Level 2	Performs TEE and TTE, reference for Level 1, cardiovascular abnormalities diagnosis, possible investigation training
Level 1	Standard thoracic images acquisition (TEE, TTE), normal and abnormal recognition, need of an expert evaluation recognition, compare with other monitoring techniques
Emergency ECHO	TTE standard images acquisition, relating during CRA according to the ACLS algorithm, recognition for requesting expert evaluation.

CRA – cardiorespiratory arrest; TTE – transthoracic echocardiogram; TEE – transesophageal echocardiogram; ACLS – advanced cardio life support.
Source: Price S, Via G, Sloth E, Guarracino F, Breitkreutz R, Catena E, Talmor D; World Interactive Network Focused On Critical UltraSound ECHO-ICU Group. Echocardiography practice, training and accreditation in the intensive care: document for the World Interactive Network Focused on Critical Ultrasound (WINFOCUS). Cardiovasc Ultrasound. 2008;6:49.

FINAL COMMENTS

The use of echocardiography in the intensive care and emergency settings is nowadays real in some European countries and North American centers. Possibly in a near future we can have the same rational in Latin American intensive care and emergency centers, such as predicting fluid responsiveness in critical ill patient.[39-41] The both theoretical and practical qualifications and appropriate training are fundamental stones for this tool implementation. By scientific research and cooperation between both national and international medical associations, we can improve our daily practice, offering our patients better treatment and hoping our dream comes true.

RESUMO

Nos últimos anos, com o avanço tecnológico e a experiência adquirida, o ecocardiograma tem se tornado uma ferramenta importante e cada vez mais utilizada no ambiente de terapia intensiva. As informações obtidas, através da ecocardiografia transtorácica e da ecocardiografia transesofágica corroboraram com o monitoramento e o cuidado centrado no paciente. Seu papel como ferramenta de diagnóstico, prognóstico e monitoramento da resposta à infusão de fluidos (fluído-responsividade) tornaram-se disponíveis nos dias de hoje, em razão da portabilidade e diminuição dos custos na aquisição dos equipamentos. O treinamento adequado, assim como o desenvolvimento de diretrizes relacionadas à utilização do ecocardiograma na unidade de terapia intensiva, possibilitarão a padronização deste método assim como sua implementação à beira do leito.

Descritores: Ecocardiografia; Cuidados intensivos; Parada cardíaca; Capacitação em serviço; Sistemas automatizados de assistência junto ao leito

REFERENCES

1. Stamos TD, Soble JS. The use of echocardiography in the critical care setting. Crit Care Clin. 2001;17(2):253-70, v. Review.
2. Heidenreich PA. Transesophageal echocardiography (TEE) in the critical care patient. Cardiol Clin. 2000;18(4):789-805, ix.
3. Guyton AC, Lindsey AW, Abernathy B, Richardson T. Venous return at various right atrial pressures and the normal venous return curve. Am J Physiol; 1957;189(3):609-15.
4. Wiener RS, Welch HG. Trends in the use of the pulmonary artery catheter in the United States, 1993-2004. JAMA. 2007;298(4):423-9.
5. Hett DA, Jonas MM. Non-invasive cardiac output monitoring. Curr Anaesth Crit Care. 2003;14(4):187-91.
6. Jardin F, Valtier B, Beauchet A, Dubourg O, Bourdarias JP. Invasive monitoring combined with two-dimensional echocardiographic study in septic shock. Intensive Care Med. 1994;20(8):550-4.
7. Jardin F, Fourme T, Page B, Loubières Y, Vieillard-Baron A, Beauchet A, Bourdarias JP. Persistent preload defect in severe sepsis despite fluid loading: A longitudinal echocardiographic study in patients with septic shock. Chest. 1999;116(5):1354-9.
8. Michard F, Boussat S, Chemla D, Anguel N, Mercat A, Lecarpentier Y, et al. Relation between respiratory changes in arterial pulse pressure and fluid responsiveness in septic patients with acute circulatory failure. Am J Respir Crit Care Med. 2000;162(1):134-8.
9. Garcia MJ, Ares MA, Asher C, Rodriguez L, Vandervoort P, Thomas JD. An index of early left ventricular filling that combined with pulsed Doppler peak E velocity may estimate capillary wedge pressure. J Am Coll Cardiol. 1997;29(2):448-54.
10. Nagueh SF, Middleton KJ, Kopelen HA, Zoghbi WA, Quiñones MA. Doppler tissue imaging: a noninvasive technique for evaluation of left ventricular relaxation and estimation of filling pressures. J Am Coll Cardiol. 1997;30(6):1527-33.
11. Otto CM. Echocardiographic evaluation of left and right ventricular systolic function. In: Otto CM, editor. Textbook of clinical echocardiography. 2nd ed. Philadelphia: WB Saunders; 2000. p. 120–1.
12. Mitaka C, Nagura T, Sakanishi N, Tsunoda Y, Amaha K. Two-dimensional echocardiographic evaluation of inferior vena cava, right ventricle and left ventricle during positive-pressure ventilation with varying levels of positive end-expiratory pressure. Crit Care Med. 1989;17(3):205-10.
13. Feissel M, Michard F, Mangin I. Respiratory change in inferior vena cava diameter predict fluid responsiveness in septic shock (abstract). Am J Respir Crit Care Med. 2002;165(Suppl):A712.
14. Barbier C, Loubières Y, Schmit C, Hayon J, Ricôme JL, Jardin F, Vieillard-Baron A. Respiratory changes in inferior vena cava diameter are helpful in predicting fluid responsiveness in ventilated septic patients. Intensive Care Med. 2004;30(9):1740-6.
15. Vieillard-Baron A, Chergui K, Rabiller A, Peyrouset O, Page B, Beauchet A, Jardin F. Superior vena cava collapsibility as a gauge of volume status in ventilated septic patients. Intensive Care Med. 2004;30(9):1734-9.
16. De Backer D, Taccone FS, Holsten R, Ibrahimi F, Vincent JL. Influence of respiratory rate on stroke volume variation in mechanically ventilated patients. Anesthesiology. 2009;110(5):1092-7.
17. Huntsman LL, Stewart DK, Barnes SR, Franklin SB, Colocousis JS, Hessel EA. Noninvasive Doppler determina-

tion of cardiac output in man. Clinical validation. Circulation. 1983;67(3):593-602.
18. Gunst M, Ghaemmaghami V, Sperry J, Robinson M, O'Keeffe T, Friese R, Frankel H. Accuracy of cardiac function and volume status estimates using the bedside echocardiographic assessment in trauma/critical care. J Trauma. 2008;65(3):509-16.
19. Teboul JL, Monnet X. Prediction of volume responsiveness in critically ill patients with spontaneous breathing activity. Curr Opin Crit Care. 2008,14(3):334-9.
20. Michard F, Teboul JL. Predicting fluid responsiveness in ICU patients: a critical analysis of the evidence. Chest. 2002;121(6):2000-8.
21. Berenholtz SM, Pustavoitau A, Schwartz SJ, Pronovost PJ. How safe my intensive care unit? Methods for monitoring and measurement. Curr Opin Crit Care. 2007;13(6):703-8.
22. Moore AG, Eagle KA, Bruckman D, Moon BS, Malouf JF, Fattori R, et al. Choice of computed tomography, transesophageal echocardiography, magnetic resonance imaging, and aortography in acute aortic dissection: International Registry of Acute Aortic Dissection (IRAD). Am J Cardiol. 2002;89(10):1235-8.
23. Poelaert J, Goarin JP. Indications de l'échocardiographie Doppler chez les patients en état critique. In: Vignon P, Goarin JP, editors. Echocardiographie Doppler en réanimation, anesthesia et médecine d'urgence. Paris: Elsevier; 2002. p. 17-30.
24. Voga G, Bennett D, Matamis D, Rhodes A, for the Section of Cardiovascular Hemodynamics, ESICM. The use of echocardiography in European intensive care units [Abstract] Intensive Care Med. 2002; 28(Suppl 1):S18.
25. Vignon P, Dugard A, Abraham J, Belcour D, Gondran G, Pepino F, et al. Focused training for goal-oriented handheld echocardiography performed by noncardiologist residents in the intensive care unit. Intensive Care Med. 2007;33(10):1795-9.
26. Breitkreutz R, Walcher F, Seeger FH. Focused echocardiographic evaluation in resuscitation management: concept of an advanced life support-conformed algorithm. Crit Care Med. 2007;35(5 Suppl):S150-61.
27. Hernandez C, Shuler K, Hannan H, Sonyika C, Likourezos A, Marshall J. C.A.U.S.E.: Cardiac arrest ultrasound exam--a better approach to managing patients in primary non-arrhythmogenic cardiac arrest. Resuscitation. 2008;76(2):198-206.
28. Sloth E, Jakobsen CJ, Melsen NC, Ravn HB. The resuscitation guidelines in force-time for improvement towards causal therapy? Resuscitation. 2007;74(1):198-9.
29. International Liaison Committee on Resuscitation. 2005 International Consensus on Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care (ECC) Science With Treatment Recommendations. Circulation. 2005;112(22 Suppl):III-1–III-136.
30. American Heart Association in collaboration with International Liaison Committee on Resuscitation. Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2000;102(8 Suppl):I1–I384.
31. Standards for cardiopulmonary resuscitation (CPR) and emergency cardiac care (ECC). 3. Advanced life support. JAMA. 1974;227(7) Suppl:852-60.
32. Blaivas M, Fox JC. Outcome in cardiac arrest patients found to have cardiac standstill on the bedside emergency department echocardiogram. Acad Emerg Med. 2001;8(6):616-21.
33. Salen P, Melniker L, Chooljian C, Rose JS, Alteveer J, Reed J, Heller M. Does the presence or absence of sonographically identified cardiac activity predict resuscitation outcomes of cardiac arrest patients? Am J Emerg Med. 2005;23(4):459-62.
34. Salen P, O'Connor R, Sierzenski P, Passarello B, Pancu D, Melanson S, et al. Can cardiac sonography and capnography be used independently and in combination to predict resuscitation outcomes? Acad Emerg Med. 2001;8(6):610-5.
35. Fox K. A position statement: echocardiography in the critically ill. On behalf of a Collaborative Working Group of the British Society of Echocardiography (BSE). J Intensive Care Soc. 2008;9(2):197-8.
36. Price S, Via G, Sloth E, Guarracino F, Breitkreutz R, Catena E, Talmor D; World Interactive Network Focused On Critical UltraSound ECHO-ICU Group. Echocardiography practice, training and accreditation in the intensive care: document for the World Interactive Network Focused on Critical Ultrasound (WINFOCUS). Cardiovasc Ultrasound. 2008;6:49.
37. Boyd JH, Walley KR. The role of echocardiography in hemodynamic monitoring. Curr Opin Crit Care. 2009;15(3):239-43. Review.
38. Mayo PH, Beaulieu Y, Doelken P, Feller-Kopman D, Harrod C, Kaplan A, et al. American College of Chest Physicians/La Société de Réanimation de Langue Française statement on competence in critical care ultrasonography. Chest. 2009;135(4):1050-60.
39. Feissel M, Michard F, Mangin I, Ruyer O, Faller JP, Teboul JL. Respiratory changes in aortic blood velocity as an indicator of fluid responsiveness in ventilated patients with septic shock. Chest. 2001;119(3):867-73.
40. Monnet X, Rienzo M, Osman D, Anguel N, Richard C, Pinsky MR, Teboul JL. Passive leg raising predicts fluid responsiveness in the critically ill. Crit Care Med. 2006;34(5):1402-7.
41. Lamia B, Ochagavia A, Monnet X, Chemla D, Richard C, Teboul JL. Echocardiographic prediction of volume responsiveness in critically ill patients with spontaneously breathing activity. Intensive Care Med. 2007;33(7):1125-32.