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Assessment of fluid responsiveness in patients under spontaneous breathing activity

Avaliação da responsividade a volume em pacientes sob ventilação espontânea

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ABSTRACT

To assess fluid responsiveness in patients under spontaneous breathing activity ventilation remains a challenge for intensive care physicians. Much of the knowledge on heart-lung interactions and dynamic indexes of fluid responsiveness may not be useful for these patients. Historically, the most frequently used variables to guide fluid responsiveness on this population have been the static preload indexes. However, more recently, dynamic indexes from less invasive devices are being often used, even though their usefulness on spontaneously-breathing subjects remains controversial. The purpose of this article was to review evidences on the assessment of fluid responsiveness in patients under spontaneous ventilation. A search in literature showed poor evidence for use of static variables, such as filling pressures and ventricular end-diastolic volumes. Dynamic indexes, such as pulse pressure variation and other indexes had not been appropriately tested during spontaneous ventilation. Favorable results were found with central venous pressure variation and with transthoracic echocardiography or transesophageal Doppler dynamic indexes, especially when associated to passive lower limb elevation. We conclude that although central venous pressure variation and echocardiography variables could aid bedside clinicians in assessing fluid responsiveness during spontaneous ventilation, more studies on this subject are definitely required

Keywords: Fluid shifts; Fluid therapy/methods; Blood volume determination/methods; Stroke volume; Tidal volume; Hemodynamic

INTRODUCTION

One of the most frequent interventions in an intensive care setting is fluid replacement. Recent trials emphasize that excessive volume, given unnecessarily, may be harmful to the patient, and that assessment of volume responsiveness is fundamental for intensivists.[1,2]

Volume responsiveness may be defined as increased systolic volume (SV) with consequent increased cardiac output (CO) from an established volume infusion which would provide better oxygen supply to the tissue. However, this response to volume testing will only take place when both ventricles operate in the ascending phase of the Frank-Starling curve, i.e., in a preload dependence status.[3]

In the last decade, with improved knowledge and practical application of physiology and heart-lung interaction,[4-6] along with critical patient monitoring techniques, new volume responsiveness assessment methods were described, called dynamic methods. Described as such are pulse pressure variation (PPV),[7] systolic pressure variation (SPV),[8] systolic volume variation (SVV),[9] in addition to techniques using echocardiography to evaluate superior and inferior vena cava collapsibility.[10] The dynamic evaluation methods have good accuracy to predict fluid responsiveness, with much higher predictive values than static measurements.[11] However, an important limitation of these methods is that indexes and measurements were validated for specific groups of patients under sedation and volume controlled mechanical ventilation, with no respiratory effort and no arrhythmias. Other studies that tried to reproduce these results in different settings, did not reach the same results.[12-14]

In spontaneous breathing patients, or in those under mechanical ventilation with respiratory effort, fluid responsiveness assessment still requires additional studies,[15,16] as the current intensive care trend is to maintain the patient with the mildest sedation and weaning from mechanical ventilation as soon as possible.[17]

This review aims to summarize the main evidences on fluid responsiveness assessment in the spontaneous breathing patient, didactically dividing the static measurement studies from those with dynamic methods.

METHODS

A search was conducted in the Pubmed database using the key words: fluid responsiveness, spontaneous breathing, preload and echocardiography. Articles in english deemed relevant for this review were selected.

STATIC VARIABLES

This item will describe the main evidences of fluid responsiveness in spontaneous breathing patients as assessed by central venous pressure (CVP), pulmonary wedge pressure (PWP), right ventricular end-diastolic volume (RVEDV) and left ventricle end-diastolic volume (LVEDV).

Central Venous Pressure

CVP is the pressure measured in the right atrium or superior vena cava by a central or pulmonary artery catheter, and is one of the most assessed hemodynamic parameters in an intensive care unit (ICU).[18] The Surviving Sepsis Campaign,[19] a standardization of care to the septic patient based on the study by Rivers et al.,[20] recommend that, in the initial management of severe sepsis and septic shock patient, CVP be used as an hemodynamic parameter of volume resuscitation.

Michard & Teboul[11] in a review of fluid responsiveness in the ICU evaluated five CVP-related studies. Although this analysis involved both patients under spontaneous breathing and under mechanical ventilation, only two of the five studies had a relationship between low CVP values before volume testing and fluid responsiveness.[21,22]

A recent systematic review on CVP selected twenty four trials with total 830 patients, also with a mixed population (spontaneous and mechanical ventilation) concluding that no satisfactory data were available for use of CVP as fluid responsiveness parameter.[23]

A single study performed with healthy patients under spontaneous breathing [22] also failed to establish a relationship between CVP baseline value and fluid responsiveness. These authors could not establish any relation between baseline CVP and volume indexes.

Pulmonary artery wedge pressure

PAWP is measured by a pulmonary artery catheter and tends to reflect left atrial pressure. For a long time it was used as a volume marker. However, recent studies showed that PAWP is a poor predictor of fluid responsiveness and failed to establish a relation between the baseline value and responsiveness to volume expansion.[11,14] Furthermore, in these studies the population was not comprised only of spontaneous breathing patients, but included a majority of mechanical ventilation patients.

Kumar et al.,[24] also evaluated the PAWP value in healthy spontaneous breathing patients, and also in this group no relation between initial PAWP and fluid responsiveness was found, nor a relationship to RVEDV or systolic volume.

Ventricular end-diastolic volumes

With development of the pulmonary artery catheter and the possibility of checking the ventricular end-diastolic volume, RVEDV measurement was believed to become useful to predict the hemodynamic response after a volume expansion. However, few studies were able to correlate baseline RVEDV values and fluid responsiveness. Only two trials, conducted by the same group, were able to establish a relation between the initial value and considerable CO increase.[25,26] According to these studies, a baseline RVEDV value lower than 90 mL/m^2 was associated with increased chance of responsiveness with 64% accuracy, while values above 138 mL/m^2 were related to a 100% failure of response. Criticism to these trials comes from the use of mixed populations and also due to a considerable gap between the values 90-138 mL/m^2, where responsiveness to a volume ratio could not be established.

RVEDV analysis by pulmonary artery catheter and cardiac scintigraphy[21] did not show a relationship between baseline values and the fluid responsiveness prediction. A recent literature review also failed to find any study favorable to RVEDV use for volume responsiveness evaluation.[15]

DYNAMIC VARIABLES

When assessing dynamic volume responsiveness in spontaneous breathing patients, evidences related to CVP variation (ΔCVP), PPV and methods using transthoracic echocardiogram and esophageal doppler will be reviewed.

Central venous pressure variation

The first studies testing the hypothesis of ΔCVP to predict volume response in spontaneous breathing patients were issued in the nineties by Magder et al.[27,28] The rationale is that patients with sufficient inspiratory capacity to cause a 2 mmHg reduction of PAWP drop and presenting, in this respiratory cycle, a CVP variation decreasing more than 1 mmHg would be in a state of preload dependence and therefore would be fluid responsive. The authors showed that a CVP decrease of more than 1 mmHg has a 77% positive predictive value (PPV) and 81% negative predictive value (NPV) in the identification of responsive patients. In this trial, patients were in the immediate postoperative period of heart surgery, and under spontaneous breathing or were ventilator disconnected for ΔCVP measurement. Furthermore, they were monitored by the pulmonary artery catheter. Only patients with sufficient inspiratory capacity to cause a PWCP decrease above 2 mmHg were included.

However a recent study tried to reproduce the above mentioned findings, with different results.[29] The population studied was under spontaneous breathing or under mechanical ventilation with support pressure, and the authors assessed CVP, PAWP, ΔCVP and PPV. Surprisingly, ΔCVP was less accurate than CVP. In this study a high specificity was seen for volume responsive subjects when CVP was below 5 mmHg.

Noteworthy are some issues justifying the different results among studies.[30] 1. The last study did not check the patients' inspiratory capacity; 2. The patients could make a respiratory effort, confounding ΔCVP assessment; 3. CVP measurement was made at the middle axillary line, different from the first study where these measurements were performed at a point 5 cm below the sternum, which may bring about an up to 3 mmHg difference on mean CVP value; 4. Assessment of the CVP value may have been performed at a non-appropriate point of its curve.

Pulse pressure variation

The role of PPV for predicting volume responsiveness in spontaneous breathing patients is not yet fully understood. Although current data show that this is not a good parameter for volume replacement in this group of patients, three studies on the subject are noteworthy.[29,31,32]

Monnet et al.,[31] evaluated the ability of PPV to predict fluid responsiveness in two groups, one with controlled mechanical ventilation and the other with spontaneous breathing or respiratory effort. PPV was compared to aortic blood flow variation and passive lower limb elevation (PLLE) and 500 mL saline infusion, to confirm results of volume responsiveness. Among spontaneous breathing and sinus rhythm patients, PLLE maneuver for PPV assessment had a specificity of 75% and specificity of 46% , results below those of aortic blood flow variation.

Another study evaluated PPV in patients under pressure support ventilation or ventilation with a face mask, showing a PPV predictive value below CVP and PAWP.[29]

The third and more recent study evaluated 32 spontaneous breathing patients. Findings were better than the previous, with a sensitivity of 63% and a specificity of 92% for PPV above 12%. When testing PPV after a forced respiratory cycle, the PPV cutoff value increased to 33%, while accuracy was significantly decreased. Noteworthy, the responsiveness criterion was an increase of over 15% in the cardiac index (CI), identified by calculating variables reached from aortic transthoracic echocardiography Doppler analysis.[32]

ECHOCARDIOGRAPHY AND ESOPHAGEAL DOPPLER VARIABLES

Echocardiography is used in ICU for morphologic heart evaluation informing aspects of chambers and valves in addition to systolic and diastolic functions.

There is a growing interest in this method for volume dynamic and volume responsiveness assessments.[10] This test may be conducted by a transesophageal method, using Doppler installed in the esophageal region, and capture aortic flow velocity (AFV), or a transthoracic echocardiogram with data such as diameter, aortic area (AA) and aortic velocity-time integral (VTI), allowing to calculate SV by the formula: SV = VTI x AA.[33] Echocardiography can also be used for volume evaluation by the superior and inferior vena cava diameter variation indexes, however these are only validated for mechanical ventilation patients.[10]

Esophageal Doppler

A rapid diagnosis is fundamental in the ICU, and echocardiography is a very useful tool in this setting. As it is easily performed and not invasive, transthoracic echocardiography is the most widely used method. However, in up to 40% of the cases it fails to obtainr appropriate images and data, mainly in obese patients, those with chest wall deformities, subcutaneous emphysema, surgical drains and wounds. Esophageal doppler allows good quality register of aortic flow velocity along the descending thoracic aorta based on a nomogram (taking into account weight, height and age) for aortic area estimation, allowing CO calculation. The probe may remain for some days and allows instant CO measurements.[34] Dark & Singer validated the esophageal doppler as a reliable CO monitoring method for critically ill patients.[35]

An important study that used esophageal Doppler to assess fluid responsiveness, considered that an AFV increase above 10% induced by PLLE could predict fluid responsiveness with a sensitivity of 97% and a specificity of 94%. These sensitivity and specificity values are higher when compared to PPV in the same patient group.[31] However, in spontaneous breathing patients, this method is often not feasible due to the probe size, extremely uncomfortable for many patients.

Transthoracic Echocardiogram

When assessing fluid responsiveness by transthoracic echocardiography, two studies are worthy of mention.[36,37] In these, PLLE was also evaluated as for induction of sufficient hemodynamic changes in the evaluated parameters.

Lamia et al.[36] evaluated 24 spontaneous breathing patients, 14 of them under pressure support ventilation. In this study the authors, in addition to transthoracic echocardiography assessment regarding SV changes after PLLE, further studied the role of changes in measurements such as left ventricle end-diastolic area versus a volume expansion. The PLLE effect predicts an index of SV above 15% with 77% sensitivity and 100% specificity. However, analysis of other indexes did not disclose satisfactory values.

The second transthoracic echocardiography study also assessed PLLE effect on SV and CO changes and the ability to detect these changes by transthoracic echocardiography. Thirty four patients were recruited, all under spontaneous breathing. A patient was considered responsive if PLLE was able to promote a 12% change on SV or CO. Results of SV changes were a sensitivity of 69% and a specificity of 89% , while for CO change sensitivity was 63% and specificity 89%, practically showing equivalence of these variables.[37]

COMMENTS

Identification of volume responsive patients is difficult, especially in those under spontaneous breathing. It is estimated that 40 to 72% of patients have increased SV when faced with volume expansion.[11] On the other hand, critical patients receiving excessive fluids, unnecessary at late resuscitation animation stage, may have potentially preventable clinical complications.[38,39]

Many fluid responsiveness studies were performed in patients under sedation and controlled mechanical ventilation, so dynamic volume assessment parameters are only accurately validated for this population.[7-11] Few studies focused on volume assessment in spontaneous breathing patients.

This review corroborates other studies and reviews,[11,15,16] showing that static measurements of pressures or volumes, are not good predictors of fluid responsiveness and should not be used.

Regarding dynamic evaluation methods, PPV is much less accurate when results are compared to those of controlled mechanical ventilation patients,[8,29,31,32] although a study found satisfactory results when patients made no respiratory effort.[32]

Based on Magder studies,[27,28,30] ΔCVP continues to be the dynamic method with best outcomes, although the paper by Heenen[29] shows conflicting data. The technical differences between the Magder and Heenen studies must be remembered, also that measurements according to the Magder,[27,30] technique may be a method useful to assess volume in spontaneous breathing patients. However, procedures described in the first study cannot be carried out at bedside, since not all patients have a sufficient inspiration to cause a 2 mmHg PWCP decrease. Many patients, especially those with acute respiratory distress cannot be disconnected from the ventilator for measurement.

The use of echocardiography as a fluid responsiveness assessment method appears to be promising, mainly when associated with PLLE. PLLE is advantageous because it allows dynamic assessment, avoiding unnecessary fluid infusion. Both esophageal Doppler and transthoracic echocardiography appear to be useful tools, accurate for volume assessment in critically ill patients, with the additional advantage that transthoracic echocardiography is non-invasive. The greatest obstacle for these methods is that these devices are not available full time for many ICUs and they require an appropriately trained operator.[40]

Thus we can conclude that fluid responsiveness assessment in spontaneous breathing patients calls for additional studies, and that current evidence shows that static parameters should be avoided. Furthermore, best results were found with ΔCVP evaluation and with dynamic variables found with echocardiography or esophageal doppler. Based on these data, we suggest an algorithm for volume assessment in spontaneous breathing patients (Figure 1). However, before questioning whether the patient is or not fluid responsive, perhaps it would be more relevant to question if the patient effectively needs volume. Sometimes less can be better.

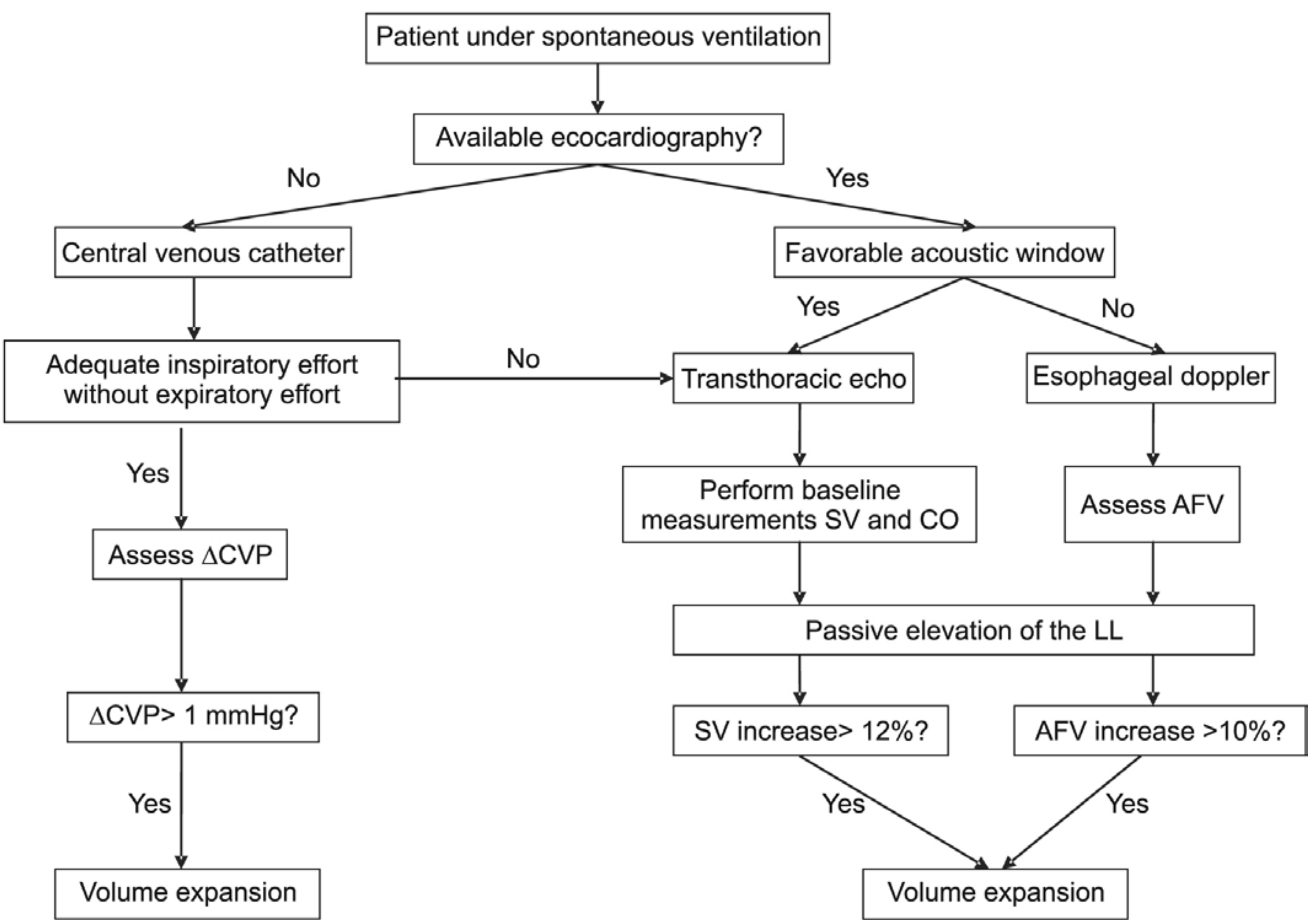

Figure 1- Algorithm for volume responsiveness for the spontaneous breathing patient.

*The ΔCVP should be assessed in an adequate inspiration of the respiratory cycle, without respiratory effort. In patients with a significant expiratory effort, this method is less accurate and not recommended.

ΔCVP – Central venous pressure variation; SV -systolic volume; AFV – aortic flow velocity; CO - cardiac output; LL - lower limbs.

RESUMO

A avaliação da responsividade a volume no paciente em ventilação espontânea representa um desafio para o intensivista. A maior parte dos conhecimentos adquiridos sobre interação coração-pulmão e o cálculo de índices dinâmicos de responsividade a fluidos podem não ser adequados para essa avaliação. Historicamente, as variáveis mais frequentemente utilizadas para guiar a responsividade a volume têm sido as medidas estáticas de pré-carga. Mais recentemente, índices dinâmicos obtidos por dispositivos menos invasivos têm sido mais usados, apesar de sua eficácia para esse fim em pacientes em ventilação espontânea ainda não ter sido adequadamente estabelecida. O objetivo deste estudo foi revisar as principais evidências sobre a avaliação da responsividade a volume nos pacientes em ventilação espontânea. A pesquisa na literatura demonstrou escassez nas evidências para utilização de medidas estáticas da volemia como as pressões de enchimento e o volume diastólico final dos ventrículos. Medidas dinâmicas como variação da pressão de pulso e outros índices também não foram adequadamente testados durante a ventilação espontânea. Resultados favoráveis foram obtidos com a variação dinâmica da pressão venosa central e com parâmetros dinâmicos que utilizam o ecocardiograma transtorácico ou doppler esofágico associado à elevação passiva dos membros inferiores. Conclui-se que embora a variação da pressão venosa central e variáveis obtidas com o ecocardiograma transtorácico ou doppler esofágico possam ser úteis na avaliação da responsividade a volume em pacientes sob ventilação espontânea, definitivamente são necessários mais estudos neste grupo de pacientes.

Descritores: Deslocamentos de fluídos; Hidratação/métodos; Determinação do volume sanguíneo/métodos; Volume sistólico; Volume de ventilação pulmonar; Hemodinâmica

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