Early Goal-directed Therapy: A Role for Echocardiography

Jan Poelaert

ABSTRACT

Early goal-directed therapy has been implemented now several years. Various haemodynamic monitoring systems have been forwarded. The choice should be governed by interchangeability and consistency of data and ease of use at the bedside. The role of echocardiography has not been discussed in this respect. Advantages, shortcomings and flaws of cardiac ultrasound will be discussed.

Keywords: Transesophageal echocardiography, Ultrasound.

INTRODUCTION

Early goal-directed therapy (EGDT) has been introduced many years ago to implement a fast and effective manner to approach haemodynamic instability of the critically ill. Both pre-operative and intra-operative data suggest improved outcome after earlier and goaled treatment. Limitation of organ function comprising shortened admission in the hospital and usage of costly supportive therapies is one of the major advantages. In recent years, often relatively undemanding monitoring tools have been forwarded. Rivers et al demonstrated clearly that simple measures, such as ScvO2, assessed intermittently, as an early goal of haemodynamic monitoring, could help to adapt haemodynamic support of septic shock patients admitted in an emergency ward.1

Although the effectiveness of this relatively simple goal could not be discussed, it can be questioned whether this particular measure itself is the most appropriate choice in view of rapidly and efficiently optimizing failing haemodynamics in an unstable ICU patient.2 In fact, independent from used technique, careful follow-up of critically ill patients could already improve outcome. In other words, it is not excluded that other measures or/and techniques could help much more efficiently in attaining a considerable improvement of haemodynamics in critically ill patients.3 Furthermore, it could not be denied that readily available bedside technology permits immediate adaptation of the management of the critically ill. In addition, the technique used should be interchangeable and different interpreters must be able to decide similar consequences.

Few monitoring and diagnostic tools have such characteristics in view of completeness of information as echocardiography and Doppler, although some shortcomings have not to be neglected.

The purpose of this review is to discuss the advantages and shortcomings of echo-Doppler technology in the light of EGDT: Direct information obtained from a bedside echo-Doppler investigation should be able to guide the intensivist in the management of unstable haemodynamics. The final goal should be an improvement of outcome. The advantages of echo-Doppler imply a wide variety of haemodynamic variables, which could be most helpful in optimizing haemodynamics, appropriately interpreted. The most prominent benefit is of course the link between ultrasound data and interpretation of blood pressure signals, which are readily available in the critically ill.

SYSTOLIC FUNCTION

Echocardiography is explicitly the technique of choice to assess at the bedside global systolic function of both LV and RV. The short axis view (SAX) is the mainstay to start each echo-Doppler investigation.4,5 LV systolic function evaluation should include other imaging approaches, but the SAX provides already insight on global systolic function in a handsome way. Indeed, SAX combines visualisation of both LV and RV, permitting rapid evaluation of both ventricles with respect to systolic function and presence of dilatation, besides some other important physiological conditions, which will be described below.

Eye balling is the most frequently used technique but needs unequivocally large experience and a long learning curve to discriminate presence of regional wall motion abnormalities. However, in terms of discussing and comparison of data, it is important to obtain absolute data. Fractional area contraction (LVFAC) is the most frequently used variable. As loading changes are much more pronounced and frequently present in critically ill patients, care should be taken concerning load-dependency. Analysis of the motility of different wall segments and its related longitudinal strain offers a new opportunity to discriminate myocardial wall regions which are contracting less and more slowly.6 As most systolic function descriptors are load sensitive in clinical practice7,8 it is evident and imminent to implement correct load estimations.
PRELOAD ASSESSMENT

Essentially, preload is a static variable, describing loading conditions before muscular contraction is taking place. Invasive pressure estimation hardly can correctly assess preloading conditions in the most critically ill. With echo-Doppler various descriptors of loading conditions (Fig. 1) can be easily obtained. The LVEDA is a static variable of load: A value <5.5 cm²/m² BSA is very indicative for hypovolaemia.9

More importantly, dynamic load estimation provides more insight in the filling needs of a patient. Systolic ventilation induced pressure variation as well as stroke volume variation need invasive arterial pressure measurements.10-12 Stroke distance is obtained from a continuous wave Doppler signal across the aortic valve. Stroke distance across the aortic valve is the distance that one red blood cell is projected forward across that aortic valve with one ventricular contraction. With hypovolaemia, this stroke distance will vary with ventilation.13 Other dynamic load descriptors are inferior and superior caval vein diameter variation with mechanical ventilation.14,15 Whereas stroke distance at the level of the aortic valve is not useful in situations in which a left ventricular outflow obstruction is present (hyperdynamic left ventricular outflow obstruction,16 aortic stenosis, aortic obstructive disease)17 both inferior and superior caval vein diameter variation with mechanical ventilation relies strongly on normal right ventricular function.

Static descriptors of load can be used in a dynamic way by combining the SAX view with the legs up test. Care should be taken to obtain only the SAX view comprising both papillary muscles. If the LVEDA increases but LVFAC remains constant, the relative volume load counteracts hypovolaemia. Whenever, LVEDA increases concomitantly with a decline of LVFAC, fluid loading is not appropriate and should therefore be stopped. Care should be taken that the echocardiographer does not alter position of the probe, which is easier with a transoesophageal approach to visualise both papillary muscles.

FLOW ASSESSMENT

With the introduction of the pulmonary artery catheter, flow estimation became generally introduced. In view of ‘do not harm’, it seems logical that Doppler-echocardiography could replace in certain well-indicated areas and situations the pulmonary artery catheter, not in the least depending on the experience of the investigator. Indeed, all important features of haemodynamics could be provided by cardiac ultrasound, though in a discontinuous manner. Assessment of stroke distance across the aortic or pulmonary valve is a typical example of a Doppler mediated flow assessment in clinical practice to obtain cardiac output. From this variable, cardiac output can be achieved, although not essential in the haemodynamic assessment. Indeed, whereas estimation of cardiac output obliges the determination of an area through which the flow is running, the sole estimation of stroke distance itself provides already important and immediate information. Estimation of a diameter at the level of the pulmonary valve is sometimes difficult and obscured by interference of ventilated lungs. Therefore, restricting

![Image of Fig. 1: Various dynamic variables permitting estimation of presence of fluid responsiveness](image-url)
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The determination of stroke distance provides insight in the same characteristics: power or force of ventricular contraction, preloading condition and afterload state. A value of 0.18 to 0.22 m is normal in a human being. A low stroke distance provides similar information on these three major physiologic items, in particular when related to two-dimensional images of the LV. An increased stroke distance may be associated with high cardiac output (low sedation state) or the presence of a stenotic valve. In the latter case, the increased stroke distance is the sign of a restrictive outflow, not related with increased flow but rather with augmented pressure gradient across the valve. If a double envelope sign is present, still a stroke distance can be reliably measured.

In particular in those patients with unexplained cardiocirculatory shock, Doppler-echocardiography could play a major role in the rapid diagnosis and subsequent management of these patients. After stabilisation, as indicated in the Flow Chart 1, there is time enough to introduce a pulmonary artery catheter or other invasive haemodynamic monitoring to permit continuous follow-up of the initiated therapy and support. The indication area of a pulmonary artery catheter in this context, however, is relatively small. In addition, Doppler echocardiography often delivers the opportunity to finetune installed therapy and management guided by a pulmonary artery catheter. Since the introduction of non-invasive haemodynamic monitoring devices, based on finapres, beat-to-beat analysis and follow-up of systemic hypotension can be easily performed. However, pulmonary arterial hypertension with haemodynamic impact or a very restricted cardiac systolic function with hypotension and need for follow-up of SvO₂ are the good indications of pulmonary artery catheterisation in a second stage.

PRESSURE ASSESSMENT

Although estimation of right and left-sided cardiac chamber pressures has been promoted by many authors, consensus is present nowadays not to use Doppler echocardiography to estimate filling pressures. As suggested in the section of preload assessment, many other possibilities are available to approximate load.

Echo-Doppler should be utilised to estimate pressure gradients, whenever a stenotic area is present: a stenotic valve, a ventricular septal defect. In this respect, the modified Bernoulli equation provides the pressure gradient as:

\[ \Delta p = 4v^2 \]

where \( \Delta p \) is the pressure gradient and \( v \) the velocity assessed distally from the stenosis or regurgitation.

INTEGRATION IN A FLOW CHART FOR EGDT

All above-mentioned issues have to be wrapped up into one complete chart (see Flow Chart 1). Whenever, a patient with hypotension or shock is admitted to the ICU, cardiac ultrasound is warranted and some easy obtainable measures could be obtained. The basis is a transthoracic echo-Doppler investigation, to elucidate most prominent features of the hypotension/shock: global systolic ventricular function, presence of regional wall motion abnormalities, assessment of preload in a static manner (LVEDA) and exclusion of...
pericardial effusion. Is the LV characterised by a hypertrophic LV wall, chronic arterial hypertension or aortic valve stenosis must be excluded. Is the LV hypokinetic and/or dilated, further detailed investigation of the mitral valvular apparatus must be exerted. The reader is referred to review articles with respect to assessment of the mitral valvular apparatus. If this valve is indeed diseased, a close check up must be performed and continuous haemodynamic monitoring, including pulmonary arterial pressure, should be considered. In addition, optimisation of preload must be considered, e.g. by passive leg rising, in a sedated patient, or other measures, such as the caval index in sedated or awake patients. Care should be taken to aim for an augmentation of cardiac index with at least 10% to have a beneficial effect of filling. If the right ventricle is dilated, tricuspid regurgitation must be evaluated closely, in conjunction with measures to decrease RV afterload, such as bronchodilation, exclusion of atelectasis, and careful check of the ventilator settings. Also, pulmonary embolism must be excluded consequently. After the initial management with adjustment of ventilator settings, initiation of inodilators and further ICU management, a pulmonary artery catheter must be considered whenever, acute pulmonary arterial hypertension is present (CFR calculation of RVSP).

LIMITATIONS OF THE TECHNIQUE
Cardiac ultrasound offers no continuous monitoring. Therefore, whenever sustained haemodynamic monitoring is needed, the clinician should consider less or more invasive monitoring, but only after stabilization of the haemodynamically unstable patient. It should not be denied that measures, such as ScvO₂ are not available when Doppler-echocardiography is used, though this measure could be replaced by ScvO₂ in certain conditions. The interpretation entails a knowledgeable investigator, well-trained both in theoretical and practical issues in echo-Doppler. The latter implies ability to obtain the proper images and correct interpretation before haemodynamic management can start.

The transoesophageal approach is an invasive technique although with a low morbidity and mortality. The investigator should be aware of potential risks and hazards.

CONCLUSION
Doppler-echocardiography is a bedside technique allowing fast and complete evaluation of the cardiac haemodynamics in a critically ill patient. Early goal-directed management can be handled and supported utilising cardiac ultrasound. Also, this review stresses the importance to use this technology in the first line to stratify choice of and tailoring further haemodynamic monitoring.

REFERENCES
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ABOUT THE AUTHOR
Jan Poelaert
Head, Department of Anaesthesiology and Perioperative Medicine University Hospital of the Free University Brussels Laarbeeklaan 101, 1090 Brussels, Belgium, Phone: 3224778961 e-mail: jan.poelaert@uzbrussel.be