

Doppler echocardiography as a modern tool to diagnose and monitor non-cardiac surgical patients: does it improve outcome ?

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Abstract : Echocardiography and Doppler provide intra-operative and immediate insight when a haemodynamic deterioration occurs. Both morphological and haemodynamic features can be diagnosed instantly. Furthermore, this tool is used as a functional haemodynamic monitoring device offering on line information on systolic function, preload and afterload.

No clear data exist on improvement of outcome in non-cardiac surgery, but analogy to cardiac patients suggest strongly outcome can be advanced with echo-Doppler.

Key words : Echocardiography ; haemodynamic monitoring ; hypotension ; preload.

Echocardiography and Doppler is now accepted as an invaluable tool to assess cardiac compromised patients. Both morphology and function of all cardiac chambers, valves and major vessels can be evaluated in a physiological approach. Furthermore, haemodynamic monitoring, revealing ventricular function, insufficient preload or excessive afterloading conditions, is often fine-tuned utilizing Doppler echocardiography. In mechanically ventilated patients, in particular during surgical procedures, the non-invasive transthoracic mode is often unsatisfactory and impractical.

Since the advent of the transoesophageal approach, intra-operative monitoring and follow up became far easier. An increasing number of indications have been described not only in the cardiology practice, but in critically ill intra-operative and ICU patients. Although the transoesophageal approach is somewhat more invasive, it remains a safe technique (4).

The prognostic value of transoesophageal echo-Doppler follows actually from the many advantages on the morphological and functional haemodynamic plan. Most of the literature and research is confined to the peri-operative cardiac surgery setting. In non-cardiac surgery, limited information is available and will be summarized in the present review.

Indications and advantages of intra-operative echo-Doppler investigation.

With the technical advancement in mounting a two-dimensional transducer at the end of a flexible gastroscope, it is possible to acquire high standard imaging because of the close relationship between the oesophagus and the heart, the introduction of the different planes, and the advances of the technology itself, available on the transoesophageal probe (24, 31).

From a morphological point of view, intra-operative TOE is in particular useful in patients with suspicion of valvular lesions, endocarditis, thoracic aortic disease, intra-cardiac masses and exclusion of thrombi (e.g. in the left atrial appendage). Also, 'minor' cardiac lesions as atrial septum defect and patent foramen ovale can be diagnosed properly.

A functional approach allows assessment of ventricular and atrial function by combination of different techniques, as there are two-dimensional echocardiography, transmitral and pulmonary vein Doppler for the left and transtricuspid/caval vein Doppler for the right heart and finally myocardial Doppler imaging. In addition, the functional assessment of valvular lesions permits grading the severity of the insufficiency or/and stenosis. All these tools provide insight in functional haemodynamics, in conjunction with other rather invasively obtained data, on the condition that these data are to be integrated in the human mind and interpreted in a physiological approach (20). In this way, it is perfectly possible to get information on systolic and diastolic function of the ventricles, the actual preloading conditions and even afterload.

Table 1 summarizes the advantages and limitations of intra-operative TOE in non-cardiac surgical procedures.

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Table 1

Advantages and limitations of TOE in non-cardiac surgery

<p>Advantages :</p> <p>High standard quality imaging by the transoesophageal approach</p> <p>Less expensive than other cardiac imaging techniques</p> <p>Immediate information (within seconds)</p> <p>Bedside visualization, thus useful in not-transportable patients</p> <p>Direct insight in both right and left heart dynamics</p> <p>Limitations :</p> <p>Certain regions are not echogenic owing the presence of air-containing lungs (superior ascending aorta, initial part of aortic arch)</p> <p>Often different scanning images necessary before decision making</p> <p>Interfering pitfalls of the technique, owing physical properties of ultrasound : reverberations, artifacts, extraneous accessory low intensity beams</p> <p>Expensive, although often far less costly than other cardiac imaging techniques</p> <p>Need of (extensive) education for the caregiver</p>
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ECHO-DOPPLER DIAGNOSTIC TOOL

The unique combination of several echo-Doppler tools facilitates the correct interpretation of flows within a selected zone. These tools comprise :

- two-dimensional imaging, offering insight in morphology and function ;
- colour Doppler, exemplifying scattering and directions of flows, within the selected area ;
- Doppler, providing information on directions, intensity and duration of flows. Also, the morphology of the Doppler pattern itself can provide indications of the pathology present ;
- myocardial Doppler imaging, demonstrating the relative motion, direction and intensity of the investigated myocardial wall segment. In particular, this technique is useful when analyzing systolic and diastolic function of the left ventricle. Care should be taken that both systolic (1) and diastolic (30) characteristic Doppler waves are preload dependent.

Hence, correct interpretation could only be achieved when the physiological meaning is fully understood, applied and integrated within the knowledge of other data.

TECHNIQUE TO OBTAIN IMMEDIATE BEDSIDE HAEMODYNAMIC INFORMATION

Performing a complete echocardiogram offers a full picture of the heart as cardiac muscle and pump of the circulation. As with each other (invasive) haemodynamic monitoring tool, all tricks and flaws must be recognized to permit a comprehensive haemodynamic analysis of a haemodynamically unstable patient.

In a hypotensive patient, a quick investigation of cardiac function at the level of the short axis view permits to differentiate between a cardiac and a non-cardiac cause of hypotension (12, 21). A small left ventricle suggests hypovolaemia (vide infra) whereas a dilated barely contracting left ventricle needs inotropic support. A similar differentiation can be made with respect to the right ventricle. A normal right ventricle is depicted as a crescent shaped structure. A dilated right ventricle (i.e. right ventricular diameter > 0,6 diameter left ventricle) suggests either right ventricular myocardial ischaemia, volume or/and pressure overload (Fig. 1).

Further investigation with the four chamber view and more detailed colour Doppler analysis of the mitral and tricuspid valve will reveal degree of regurgitation. Aortic forward flows can be analyzed revealing details on stroke volume and contracting force. Typically, from a tricuspid regurgitant flow a pressure gradient can be assessed to calculate right ventricular systolic pressure.

a. Evaluation of systolic function

Both global left and right and regional systolic function can be assessed utilizing echocardiography and Doppler. In view of load dependency, different variables can be discriminated (3).

1. Global systolic function

Ejection fraction has always been the default approach of assessment of left ventricular systolic function (22). Echocardiography allows direct visualization of the fractional area contraction, which is the analogue of the ejection fraction, at the level of the short axis view. Stand still images at this level

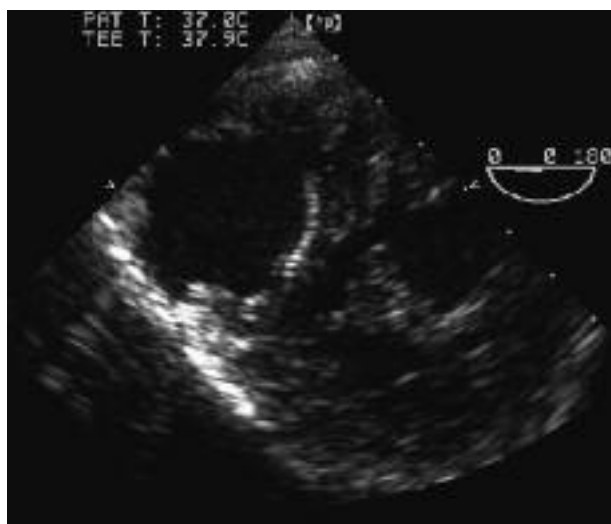


Fig. 1. — Short axis with the left (right side) and right (left side) ventricle. The right ventricle is enormously dilated following chronic pulmonary hypertension.

both at end-systole and end-diastole permits the estimation of left ventricular end-systolic and end-diastolic areas, respectively, from which the fractional area contraction can be calculated.

Another measure which can be readily obtained is cardiac output. Stroke volume can be calculated from the difference between both end-diastolic and end-systolic volumes or from the time velocity integral (which is the amount of cm one red blood cell is pushed forward with each beat).

Myocardial performance index is a variable of both systolic and diastolic function (28), which is however load dependent (10, 19, 20). The following formula reveals how to calculate this index :

$$(a - b) / b = (ICT + IRT) / ET$$

with ET, ejection time measured at the Doppler signal of the aortic flow ; ICT, isovolumic contraction time ; IRT, isovolumic relaxation time (Fig. 2).

Although this index has a prognostic power in cardiologic practice (5), intraoperatively it provides little supplementary information, especially in view of the load dependency.

Another more useful load-dependent variable, also intra-operatively, is the systolic velocity of the mitral annulus, assessed with tissue Doppler imaging. Velocities beneath 8 cm/s suggest decreased systolic function whereas velocities above 15 cm/s imply normal left ventricular systolic function. Both preload (1) and afterload (2) appear to have impact on the amplitude.

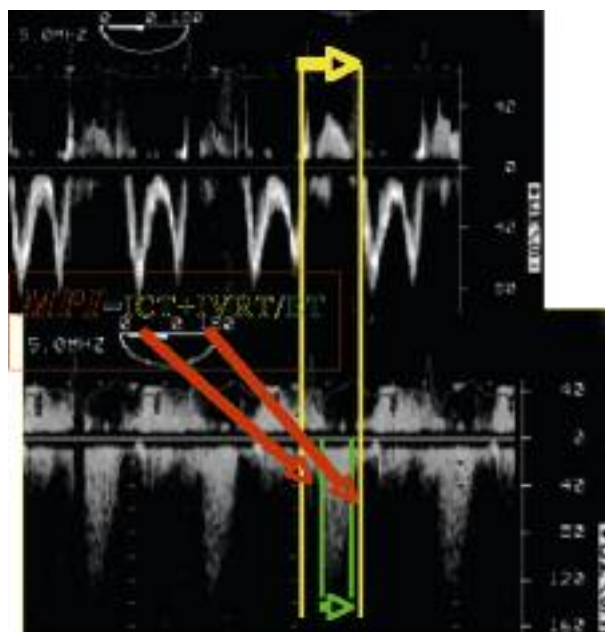


Fig. 2. — Myocardial performance index, as calculated from the Doppler variables.

Examples of load independent systolic function variables are the relationship of end-systolic meridoneal wall stress rate corrected mean velocity of fibre shortening (17), and end-systolic pressure dimension relationship (8).

2. Regional wall motion abnormalities

The direct visualization of the relative motion of the different wall segment provides an ideal window to detection of myocardial ischaemia, on the condition that no other interfering factors could occur and the regional wall motion abnormality is detected after previous normal motion of the questioned segment. These two conditions again suggest the difficulties which can be encountered when trying to detect myocardial ischaemia with echocardiography. Therefore, echocardiography is not the preferential tool to detect intra-operative myocardial ischaemia except when echocardiographers have the possibility to view constantly the echo-images in the different planes.

Colour coding of the respective motion of the segmental walls could help in discriminating the detection of myocardial ischaemia (9), albeit necessity of continuous monitoring is still present. Newer technologies are currently developed utilizing vector related technology.

b. Assessment of preload

Whenever a patient is hypotensive, preload is the first issue to be assessed. The simplest manner

to obtain this is the legs up test. By means of echocardiography, the legs up test has been utilized many times to evaluate optimal preloading conditions (16).

From a short axis view, left ventricular end-diastolic area can be easily appreciated. An area $< 5.5 \text{ cm}^2$ was shown to be associated with low preloading conditions (26). End-systolic obliteration is a sign of either low preload or high inotropic support, urging to decrease the dose (15). This measure, however, provides a static load variable, independent on heart-lung interactions.

Nowadays, often dynamic variables are used as they provide more insight in the optimisation of the preload. They are used in conjunction with mechanical ventilation and rely on the variation of intrathoracic pressures with ventilation. Both inferior (23) and superior caval vein (29) variations with ventilation can be utilized. Care should be taken that these variables only provide insight in right ventricular preload. Right ventricular failure could strongly interfere with the findings. Then, absence of ventilation induced variation of the caval vein diameter will not indicate optimal preload. Again, starting the echocardiographic investigation with the short axis view will already eliminate right ventricular failure.

Analogous to stroke volume variation and flow variation assessed with a Doppler device (25), variation of the stroke volume exemplified by variations of the time-velocity-integral (TVI) will demonstrate the same information (6, 27) (Fig. 3). However, a Doppler device, although easier to use, will not provide information on the morphology of the aortic valve, although the latter will interfere with the morphology of the Doppler signal. SLAMA *et al.* clearly demonstrate that in graded haemorrhagic shock, the variations of the TVI increased considerably, whereas retransfusion of the same amount of blood, relieved the TVI variations again (27).

Echo-Doppler of the myocardial tissue (low velocity – high amplitude waves) has been used since more than a decade to assess systolic and diastolic function (7). The relationship of the early filling flow velocity (E) across the mitral valve and the homologue at the level of the mitral annulus (E') has been related to pulmonary capillary wedge pressure and is thus an appealing variable of estimation of left ventricular filling pressures (14, 18).

All these variables can be utilized during an echocardiographic investigation, although they are not essential. Often, however, some of them are used to confirm findings, integrating them into a

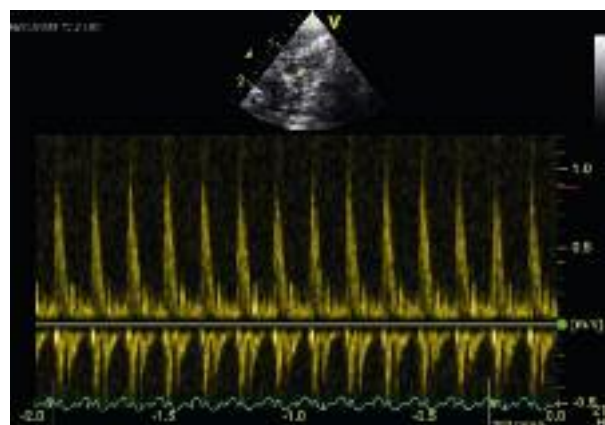


Fig. 3. — Systolic ventilation induced variation of flow, assessed at the level of the aortic valve.

larger number of haemodynamic non-invasive and invasive parameters.

c. Evaluation of afterload

Although relatively easy to identify afterload in an isolated muscle preparation, this variable is hard to define in the intact, beating heart. Several issues have to be considered: a distensible arterial tree acting as a visco-elastic system, the arterial tree as ventricular afterload with a non-pulsatile flow – rather a measure of vasomotor tone, the stress imposed on the ventricular wall during systole, incorporating both stress and geometric characteristics (11).

The reader is referred to review articles to have more in depth discussion on this topic (13, 17).

CONCLUSIONS

Intra-operative echocardiography provides immediate insight in the morphological and haemodynamic functional aspects of cardiac and circulation related issues. The most important advantage is that proper use will lead to direct action depending on the findings, even with limited number of views. Anaesthetists committed with daily management of haemodynamically unstable patients should be convinced to utilize echocardiography as primary diagnostic and monitoring tool.

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