SUPPLEMENTS: Critical Care Ultrasonography protocol

The diagnostic accuracy of clinical examination for estimating cardiac index in critically ill patients: the Simple Intensive Care Studies-I

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Content

General outline

Cardiac output and cardiac index will be measured using transthoracic echocardiography. For study purposes different researchers will be trained in the basics of transthoracic echocardiography by a cardiologist-intensivist. They will learn how to determine cardiac output by obtaining four different echocardiographic views and subsequent measurements.

Procedure

Transthoracic echocardiography will be performed at the bedside during the clinical examination with a mobile ultrasonic machine (General Electric Vivid-S6) with the use of the cardiac probe M3S of M4S with default cardiac imaging setting. The patient will be supine or in left lateral tilt (partly on the left). Physical assessment will be performed before examination. After the images have been acquired, cardiac output and cardiac index will be calculated and data will be saved on the hard disk. At a later time the images will be validated by an echocardiography technician or a cardiologist who will be blinded for all other measurements.

Views and images

Three or four standardized echographic views will be obtained in all patients:

1. Parasternal long axis view (PLAX);
2. parasternal short axis view (PSAX);
3. apical four chamber view (AP4CH);
4. apical five chamber view (AP5CH).

The PSAX view will only be obtained in case the PLAX does not provide a clear image of the aortic annulus. The views are described in more detail below.

Training

The medical research interns and Ph.D. students were trained by a cardiologist-intensivist, i.e. a consultant in both cardiology and intensive care medicine. These researchers were trained to obtain only specific CCUS variables to answer predefined research questions. An important part of the training focused on aligning the Doppler signal as parallel as possible through the left-ventricular outflow tract (LVOT), allowing a maximum angle of approximately 30 degrees. Researchers could contact one of the cardiologist-intensivists for advice when CCUS measurements appeared difficult to obtain. The first 20 CCUS measurements for each researcher were supervised. Researchers who had independently performed more than 50 CCUS measurements supported other researchers.

Data management

The echocardiographic images were saved on the internal hard disk of the echo Doppler machine. This is required for later validation. The images could be used for patient management as soon as data collection or the obtained images were supervised by a cardiologist. After the measurements, the measurements was entered in the data management system (OpenClinica). For validation, a USB drive or external hard drive was used to transfer images to the echolaboratory technician (Groningen Imaging Core Laboratory; www.g-icl.com) for external validation and anonymization. The anonymized images and measurements were stored on the central secure server of our department.

Parasternal long axis (PLAX)

The parasternal window is located next to the sternum, between the 3rd and 5th intercostal space.

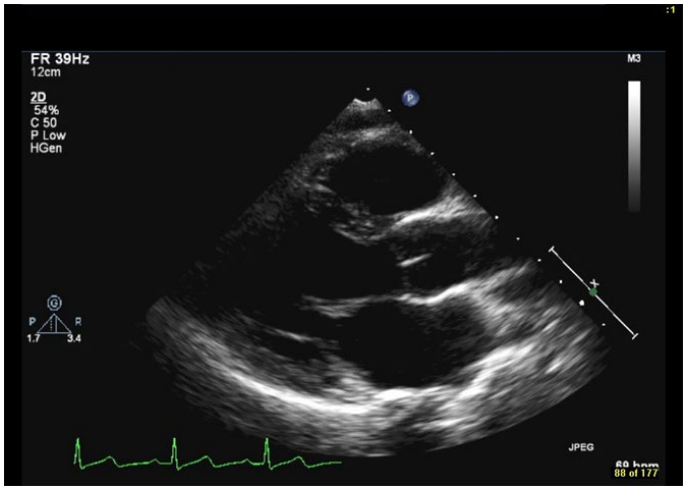

Fig 1. Parasternal long axis (PLAX)

Criteria of quality for a good view (**Fig. 1**):

- Minimized angle between ascending aorta and left ventricle;
- maximized width view of left ventricle;
- maximal opening of mitral valve (showing both anterior and posterior mitral valve leaflets, right- and noncoronary cusps of aortic valve;
- no papillary muscle in view.

The PLAX view is the primary view used to measure the left ventricular outflow tract (LVOT). An image will be saved for validation.

Parasternal short axis (PSAX)

This view will only be obtained in case the PLAX view does not provide a clear image of the LVOT. The PSAX view can be obtained on several levels. For study purposes it will be measured on the aortic, tricuspid and pulmonic valve level (**Fig. 2**). An image will be saved for validation.

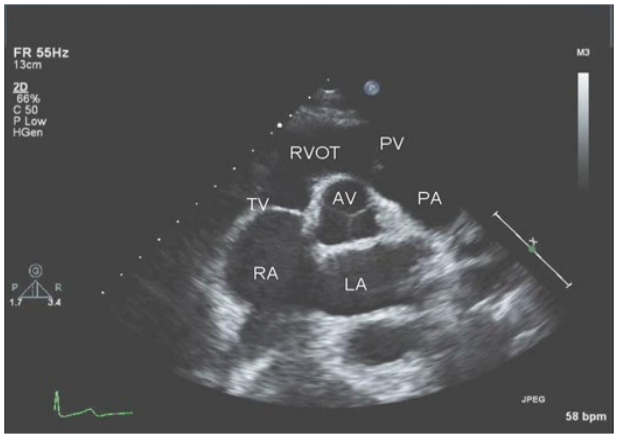

Fig 2. Parasternal short axis (PSAX)

Apical four and five chamber view (AP4CH and AP5CH)

The apical echographic window is located at the apex of the left ventricle (apical impulse).

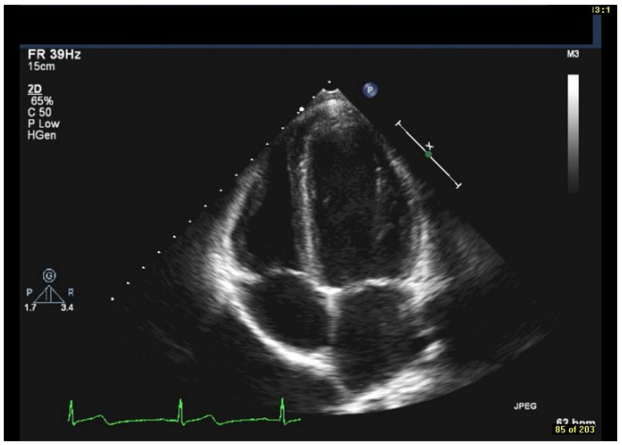

Fig 3. Apical four chamber view (AP4CH)

Criteria of quality for a good view (**Fig. 3, 4**):

- Maximized view of endocardial border;
- Frames per second > 40;
- the entire endocardium is within scan sector in *both end-diastole and end-systole*;
- avoid apical foreshortening.

From the four chamber view the probe will be tilted caudally to obtain the apical five chamber view. In the apical five chamber view the velocity time integral will be measured using the pulse wave Doppler signal from the LVOT. Of both views an image will be saved for validation.

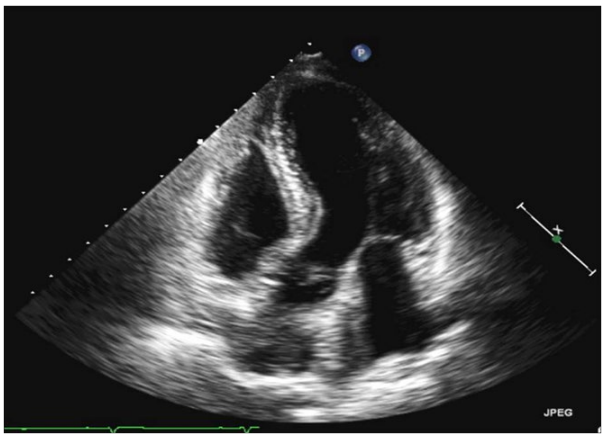

Fig 4. Apical five chamber view (AP5CH)

Measurements

Measuring the left ventricular outflow tract (LVOT)

The LVOT diameter changes very little through systole and diastole and is assumed to be constant and closely approximating a circle in shape. The LVOT diameter will be measured in 2D in the parasternal long axis view in systole (**Fig. 5**). If a clear image cannot be obtained through this view, the LVOT will be measured in the parasternal short axis or the AP5CH view.

The Groningen Imaging Core Laboratory ('corelab') assessed each echocardiographic image for the abovementioned criteria. When fulfilled, the corelab measured the LVOT-diameter in the PLAX image (Fig. 6). The LVOT-diameter was measured between the insertions of the aortic valve, in mid-systole which was assessed by mitral valve closure (a) followed by aortic valve opening (b) and after the QRS-complex on the electrocardiogram (c).

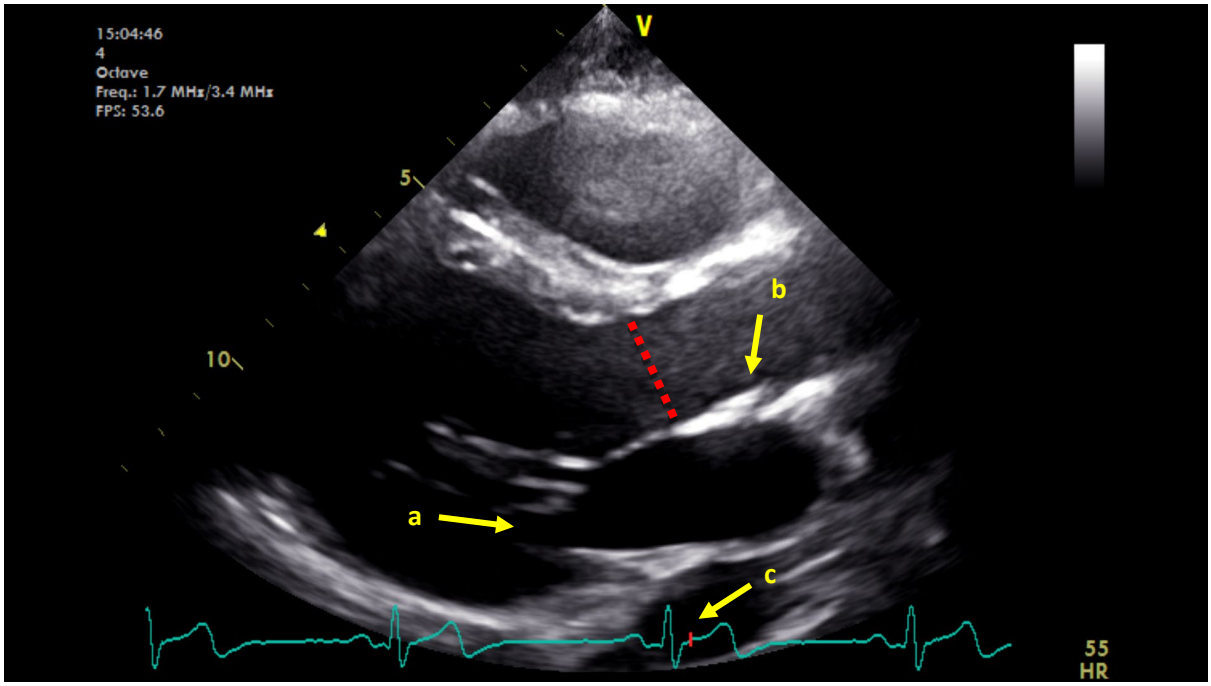

Fig. 5. Measurements of the LVOT diameter in the PLAX. a) closure of mitral valve, b) opening of aortic valve, c) timing on the electrocardiogram.

Measurement of the velocity time integral (VTI)

The LVOT velocity time integral (LVOT-VTI) provides information regarding blood flow velocity across the time period of systole and is in the units of cm. Typical values are close to 2 cm. Blood flow velocity will be measured just above the aortic valve in the apical five chamber view by using pulse wave Doppler (**Fig. 6**). The LVOT-VTI measurement was assessed by checking the placement of the Doppler signal (a; parallel with the LVOT) and presence of aortic closing (b). The velocity time integral will be traced out on the ultrasound machine. In case of an irregular rhythm such as atrial fibrillation, the average VTI of several beats will be used. Images of both measures will be saved for validation.

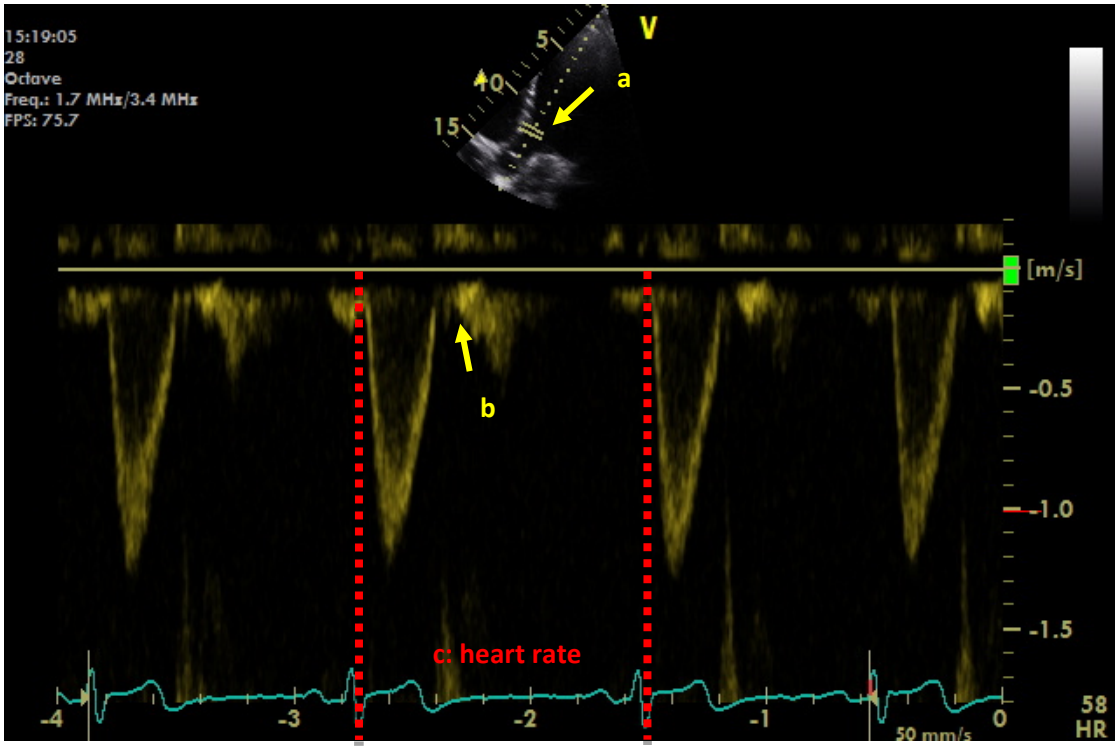

Fig. 6. Measurements of the LVOT-VTI in the AP5CH. a) angle and placement of Doppler signal, b) closure of aortic valve, c) heart rate measurement.

Calculating cardiac output and cardiac index

Cardiac output will be automatically calculated on the ultrasound machine after measuring the LVOT, VTI and heart rate (c). Cardiac index will be automatically derived using patient length and weight.