Echocardiography

Mohamed S Anwar

Patrick H Gibson

Abstract

Although computed tomography and magnetic resonance imaging have an important role, echocardiography remains the primary modality for imaging cardiac structure and function. This article aims to explain echocardiography from a non-cardiologist perspective, describing a standard imaging protocol including the use of colour and spectral Doppler methods. This incorporates assessment of left and right ventricular systolic function, valve structure and function, and other useful haemodynamic indices. More advanced techniques include trans-oesophageal echo, contrast echo, three-dimensional and strain imaging, and these have broadened the scope and utility of echocardiography in recent years.

Keywords Contrast echocardiography; diastolic function; Doppler ultrasound; echocardiography; trans-oesophageal echocardiography; ventricular function

Key points

- Echocardiography is a highly versatile imaging modality that provides extensive anatomical, functional and haemodynamic information
- A variety of ultrasound techniques are routinely applied, including two-dimensional imaging, and colour and spectral Doppler, which can be supplemented with more advanced techniques
- Several different methods exist to assess left ventricular function, including visual estimation, calculation of ejection fraction with or without ultrasound contrast, myocardial 'tissue' Doppler and novel measures such as strain imaging
- Trans-oesophageal imaging is more invasive but provides diagnostic clarity in some circumstances and lends itself to the three-dimensional representation of cardiac structure

Introduction

Echocardiography is the most widely available imaging modality for assessment of cardiac structure and function. It has several advantages, including portability that facilitates its use in any setting, for example emergency department, intensive care unit or operating theatre. Instant imaging means that immediate diagnosis can be life-saving in an acutely compromised patient. Excellent temporal and spatial resolution allows accurate assessment of valve pathology. Importantly, echocardiography does not employ ionizing radiation.

Recent progress has been equivalent in other modalities including cardiac computed tomography for non-invasive imaging of coronary arteries. Magnetic resonance imaging (MRI) provides a gold standard assessment of ventricular function and can demonstrate myocardial scarring or oedema. However, the additional resources required for these forms of tomographic imaging mean that echocardiography will remain the primary imaging modality in cardiology for the foreseeable future.

Ultrasound physics

Modern echocardiography scanning probes have evolved to incorporate a grid of densely packed piezo-electric transducers known as a 'phased array', with the scan head small enough to image between the ribs. When stimulated electrically in rapid sequence, the transducers emit a steerable beam of high-frequency ultrasound (2—12 MHz). The beam is reflected at tissue interfaces within the heart, mainly boundaries between blood, myocardium and valve structures. Reflected waves are also detected by the probe, which interpolates the relation of these boundaries by the time taken for the waves to return. By sweeping the beam very rapidly back and forward along a line, a fan-shaped imaging plane is generated. This sweep is continually repeated at high frequency (e.g. 40 times per second), resulting in apparently seamless two-dimensional (2D) moving images of the heart.

Doppler ultrasound

The addition of Doppler ultrasound allows measurement of the velocity of blood cells or myocardium. This is based on measurement of the 'frequency shift' of ultrasound waves reflected by a moving object — increasing frequency if moving towards the probe, and decreasing frequency if moving away. The extent of the frequency shift is determined by the velocity relative to the probe. This information can be applied in different ways.[1]

Colour Doppler

Colour Doppler provides a visual representation of blood flow within the heart. A 'colour box' is applied to the 2D image and located in the area of interest. By convention, a superimposed red colour indicates flow towards the transducer, and blue indicates flow away. Higher velocities can be made to stand out in green, which provides ready visualization of turbulent blood flow, for example caused by valvular regurgitation.

Spectral Doppler

More detailed interrogation of flow is performed using spectral Doppler imaging, which provides a graphic representation of blood velocity along a selected line, specified by a cursor placed within the imaging field. Flow at a particular point along the cursor can be measured using pulsed waves (PW Doppler), for example at the mitral valve inflow or in the left ventricular outflow. However, because of limitations in discriminating the location of these

***Mohamed S Anwar** MB ChB MRCP is a Cardiology Trainee and Clinical Research Fellow at the University of Edinburgh, UK. Competing interests: none declared.*

***Patrick H Gibson** BM BCh MD FRCP is a Consultant Cardiologist at the Western General Hospital and Royal Infirmary of Edinburgh, UK. Competing interests: none declared.*

Please cite this article in press as: Anwar MS, Gibson PH, Echocardiography, Medicine (2018), https://doi.org/10.1016/j.mpmed.2018.05.006

reflected pulses, this is only useful with relatively low-velocity flow. Higher velocities require a continuous Doppler signal (continuous wave (CW)), which interrogates blood flow along the entire length of the cursor. For both forms of spectral Doppler, flow is displayed graphically, with time along the *x*-axis and velocity along the *y*-axis. By convention, flow towards the probe is displayed above the baseline, and flow away displayed below the baseline (Figure 1). PW Doppler can also be used to assess myocardial velocity at a specified location, known as 'tissue Doppler'.

Haemodynamic application

Using simplified fluid dynamics, the pressure gradient (P) can be approximated using a modified Bernoulli equation, $P = 4v^2$, where v is the velocity of blood measured by Doppler ultrasonography. This has important applications in echocardiography. For example, CW Doppler measures of blood flow through the aortic valve are used to calculate peak and mean gradients, and establish severity of aortic stenosis. Likewise, inflow velocities can be used to measure trans-mitral pressure gradients, and assess severity of mitral stenosis.

The velocity of a jet of tricuspid regurgitation reflects the pressure difference between the right ventricle (RV) and atrium; knowledge of systolic pressure in the RV provides a surrogate assessment of pulmonary arterial pressure. Thus, a large amount of useful haemodynamic information can routinely be acquired.

Standard imaging protocol

Most routine transthoracic echocardiography is performed by specialist cardiac physiologists, who may report independently. The patient lies on their left side, displacing the heart from the midline, and rib spacing is increased by raising the left arm. Electrocardiogram monitoring allows digital capture of 2D images, which can be played continuously on a loop.

Parasternal views

Initial views are obtained from the upper left sternal edge with the probe aligned with the long axis of the heart. The RV is seen anteriorly, and the left ventricle (LV) posteriorly along with the mitral valve, left atrium, left ventricular outflow and aortic valve (Figure 2). LV dimensions can be measured in systole and diastole. Mitral and aortic valve motion is inspected, and colour Doppler used to assess valve regurgitation. By angling the probe inferiorly, the RV inflow (including tricuspid valve) is seen. Rotating the probe clockwise provides an orthogonal view allowing the heart to be inspected at different levels in the short axis. Initially, the aortic valve is seen *en face*, circumscribed clockwise by the tricuspid valve, RV outflow, pulmonary valve

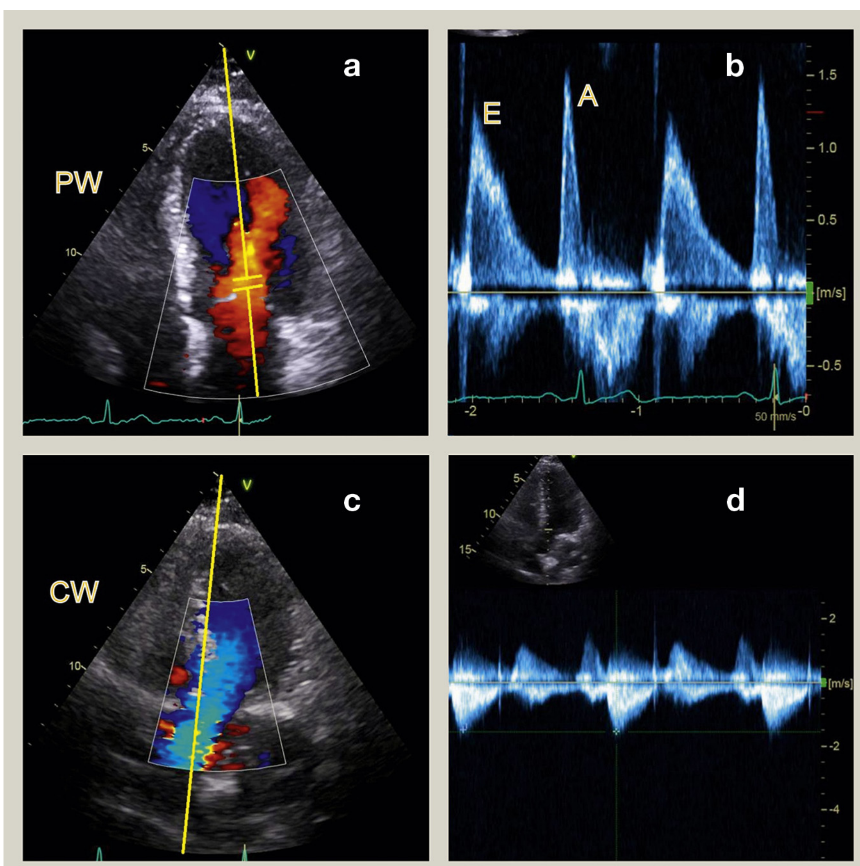

Figure 1 Colour and spectral Doppler in transthoracic echocardiography. (**a**) Colour Doppler image showing the mitral inflow coded red. The cursor is aligned to the inflow and the 'sample volume' placed at the leaflets specifying the location for pulsed wave (PW) Doppler assessment. (**b**) Early (E) and atrial (A) components of the mitral inflow are shown above the baseline. (**c**) Colour Doppler image showing left ventricular outflow coded blue, with the cursor aligned for continuous wave Doppler. (**d**) Aortic outflow is represented below the baseline as flow is away from the probe. The maximum velocity is <2.0 metres/second.

Please cite this article in press as: Anwar MS, Gibson PH, Echocardiography, Medicine (2018), https://doi.org/10.1016/j.mpmed.2018.05.006