# Transoesophageal echocardiography in cardiac anaesthesia

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## Abstract

Echocardiography is the most widely used minimally invasive investigation to diagnose heart disease. Transoesophageal echocardiography (TOE) was first introduced perioperatively in the 1980s and is now an important monitoring tool for patients undergoing cardiac surgery. Because of the close proximity of the oesophagus to the heart, TOE facilitates the acquisition of high-resolution images. The TOE probe is a multiplane transducer. This means that the image planes can be rotated from 0° to 180°, enabling three-dimensional (3D) assessment of the structure of interest. Intraoperative TOE has been shown to improve outcome in a variety of cardiac surgeries. The introduction of real-time 3D TOE has provided better diagnosis of the mechanism of certain valve pathologies. TOE has become an important investigation in the assessment of haemodynamic instability in the perioperative period because it allows rapid and accurate diagnosis.

**Keywords** Aortic stenosis; cardiac surgery; Doppler; mitral valve; transoesophageal echocardiography

**Royal College of Anaesthetists CPD Matrix:** 3G00

## Learning objectives

After reading this article, you should be able to:

- use the simplified Bernoulli equation to calculate transvalvular pressure gradients
- quantify the severity of aortic stenosis
- classify the mechanisms of mitral regurgitation

## Introduction

Over the past 15 years, transoesophageal echocardiography (TOE) has been established as the gold standard perioperative cardiac monitor in cardiac anaesthesia. The role of TOE has expanded from a diagnostic tool to an essential monitor, both intraoperatively and in the management of unstable postoperative patients in the critical care environment.

## Training and accreditation

Standardized training, assessment and accreditation for TOE operators are required to ensure competency in image acquisition and interpretation. The accreditation process is regulated by the British Society of Echocardiography and involves a written examination, interpretation of TOE images and submission of a logbook (see www.bsecho.org).

## Physics of ultrasound

Sound is a longitudinal, mechanical wave with areas of high pressure (compressions) and areas of low pressure (rarefactions). Ultrasound is defined as sound with a frequency greater than 20 kHz. Echocardiography machines typically emit ultrasound at a frequency of 2–10 MHz. The speed of ultrasound is determined solely by the medium through which the wave travels. The speed of sound in the heart is approximately 1540 m/s. Echocardiography machines produce pulses of ultrasound using the piezoelectric effect. A reflection occurs when there is a change in acoustic impedance between two media. The returning wave is received and processed by the machine to produce an image.

### Doppler

The frequency of a sound wave reflected by a moving object is different from the emitted frequency. This change in frequency is known as the 'frequency shift' or Doppler frequency. This principle is used to measure the velocity of red blood cells and myocardium in cardiac anaesthesia. The velocity of the moving object can be calculated from the Doppler equation:

$$v = \frac{cf_D}{2f_O \cos\theta}$$

where $v$ is the velocity of a moving object, $c$ is the speed of sound in soft tissue (1540 m/second), $f_D$ is the Doppler frequency, $f_O$ is the emitted frequency and cosθ is the correction for the angle of incidence.

The peak velocity of blood flow through a stenotic valve can then be used to calculate a pressure gradient across that valve, using the simplified Bernoulli equation:

$$\text{Pressure gradient} = 4v^2$$

Colour flow imaging makes the use of pulsed wave (PW) Doppler to create 'real-time' blood flow on a two-dimensional image.

## Indications for transoesophageal echocardiography

The indications and evidence for performing TOE were published by the American Society of Echocardiography (ASE)[1] and are shown in Box 1. The updated guidelines[2] recommend the use of intraoperative TOE in all open cardiac and thoracic aortic procedures. Class I indications are conditions in which TOE is shown to be useful and effective. Class II indications have conflicting evidence; in class IIa the weight of opinion is in favour of usefulness, whereas in class IIb efficacy is less well established. Class III indications have no supporting evidence that TOE is helpful.

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### Indications for transoesophageal echocardiography

Class I
- Evaluation of acute, life-threatening haemodynamic disturbances
- Surgical repair of valvular lesions, hypertrophic obstructive cardiomyopathy and aortic dissection
- Evaluation of complex valve replacements requiring coronary reimplantation
- Surgical repair of most congenital heart lesions that require cardiopulmonary bypass
- Surgical intervention for endocarditis when extension to perivalvular tissue is suspected
- Placement of intracardiac devices during port-access procedures
- Evaluation of pericardial window procedures in patients with posterior or loculated pericardial effusions

Class IIa
- Surgical procedures in patients at increased risk of myocardial ischaemia
- Evaluation of valve replacement, cardiac aneurysm repair, removal of cardiac tumours, intracardiac thrombectomy and pulmonary embolectomy
- Detection of air emboli during cardiotomy, heart transplant operations and upright neurosurgical procedures

Class IIb
- Evaluation of suspected cardiac trauma and anastomotic sites during lung transplantation
- Evaluation of regional myocardial function during off-pump coronary artery bypass graft procedures
- Evaluation of pericardiectomy and pericardial effusions
- Evaluation of myocardial perfusion or graft patency
- Assessment of residual duct flow after interruption of patent ductus arteriosus

Class III
- Surgical repair of uncomplicated secundum atrial septal defect

**Box 1**

### Relative contraindications to transoesophageal echocardiography

- Recent upper gastrointestinal surgery/radiotherapy
- Oesophageal tumour/varices/stricture
- Suspected cervical spine injury
- Atlanto-axial joint disease
- In an awake patient in whom hypertension and tachycardia are undesirable
- Large thoracic aortic aneurysm

**Box 2**

### Complications of transoesophageal echocardiography

- Dental injury
- Pharyngeal abrasion
- Odynophagia
- Recurrent laryngeal nerve injury
- Oesophageal perforation
- Upper gastrointestinal haemorrhage
- Endotracheal tube malposition
- Tachycardia/hypertension
- Equipment damage

**Box 3**

## Safety

Transoesophageal echocardiography is considered to be a semi-invasive monitor. The only absolute contraindications are patient refusal and the absence of an oesophagus. The relative contraindications are listed in Box 2. TOE has been shown to be a safe procedure,[3] with a serious complication rate of less than 1% (Box 3). The incidence of bacteraemia is quoted at less than 5%, with no serious sequelae reported. The routine use of prophylactic antibiotics for TOE is not recommended.

## Basic transoesophageal echocardiography views

The TOE probe is a modified gastroscope with an array of ultrasound crystals at the tip. It contains a multiplane transducer, which means that the transducer imaging sector can rotate through 180°(0° is horizontal and 90° is vertical). In 1999, the ASE published guidelines[4] for performing comprehensive intraoperative TOE. The ASE has identified 20 basic views to be performed in a systematic way to enable a complete examination to be performed. The ASE guidelines were further developed in 2013.[5]

There are four main positions for acquisition of images: upper oesophageal (25–30 cm at the teeth); mid-oesophageal (30–40 cm); transgastric (40–45 cm); and deep transgastric (45–50 cm). The images can be acquired in short axis (image plane is perpendicular to the length of the structure of interest) or long axis (image plane is parallel to the length of the structure of interest). The TOE probe can also be advanced or withdrawn, turned clockwise or anticlockwise, and the tip of the probe can be anteflexed (anteriorly) or retroflexed (posteriorly). Once the structure of interest is in the centre of the screen, the transducer image planes can be rotated from 0° to 180°, which allows full assessment of the structure of interest in all planes.

## Ventricular assessment

### Left ventricle

The normal left ventricle (LV) has an end-diastolic volume (LVEDV) of 70–100 ml. Approximately 40–60 ml is ejected during systole; this is the stroke volume (SV). The normal left ventricular ejection fraction (EF) is 60% and can be calculated by:

$$\mathrm{EF}\% = \left(\frac{\mathrm{SV}}{\mathrm{LVEDV}}\right) \times 100$$

The assessment of left ventricular function before and after cardiopulmonary bypass (CPB) is important as it will influence both anaesthetic and surgical management. The LV is often graded as good (EF >50%), moderate (EF 30–50%) or poor (EF <30%).




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