8

ECHOCARDIOGRAPHY AND CARDIAC EMERGENCIES

Echocardiography is an important basic investigation in the management of cardiac emergencies. It provides useful information about cardiac structure and function to aid diagnosis and risk stratification. However, like all imaging modalities, it has both advantages and limitations. It is important to remember these limitations and treat the patient, not the echocardiogram, and to seek alternative strategies when appropriate or when clinical findings fail to tally with echocardiographic findings.

This chapter will discuss the uses, advantages and limitations of, indications for and alternatives to transthoracic and transoesophageal echo, and explain how to interpret the echo report, in general and in relation to each of the common cardiac emergencies.

Abbreviations used:

- TTE – transthoracic echocardiogram.
- TOE – transoesophageal echocardiogram.
- CT – computed tomography.
- MRI – magnetic resonance imaging.
- LA – left atrium.
- RA – right atrium.
- LV – left ventricle.
- RV – right ventricle.
- EF – ejection fraction.
- FS – fractional shortening.
- AS – aortic stenosis.

- MS – mitral stenosis.
- EOA – effective orifice area.
- AVG – aortic valve gradient.
- MVG – mitral valve gradient.
- TVG – tricuspid valve gradient.
- AR – aortic regurgitation.
- MR – mitral regurgitation.
- TR – tricuspid regurgitation.
- ASD – atrial septal defect.
- VSD – ventricular septal defect.

TRANSTHORACIC ECHOCARDIOGRAM (TTE)

Uses

Provides diagnostic information about structural abnormalities and their functional significance. TTE is useful for the assessment of:

- Atrial and ventricular size, shape and function.
- Myocardial thickness.
- Valve structure and function.
- Aortic root.
- Pericardial effusions.
- Intracardiac masses.
- Congenital and acquired heart defects, and connections between great vessels and the heart.
- In babies and small children, ascending aorta, aortic arch, proximal descending aorta and pulmonary artery up to the bifurcation may also be well visualized.
- Pulmonary artery pressure (may be estimated in the presence of tricuspid regurgitation and absence of pulmonary stenosis).

Advantages

- Portable – can bring equipment to sick patient rather than move patient to test facility.

- Does not limit access to sick patient for clinician, nurse or monitoring equipment.
- Can be performed in upright position in severely orthopnoeic patients.
- Non-invasive and safe – therefore also highly suitable as follow-up investigation.
- Relatively cheap.
- Widely available.

Limitations

- Image quality is dependent on operator skills, patient anatomy and position. Generally best in left lateral position. May be severely impaired by air between chest wall and heart, e.g. hyperinflated lungs in obstructive airways disease, patients on mechanical ventilator, pneumothorax, supine or right lateral position. Narrow rib spaces and obesity may also cause technical difficulty.
- Information is often qualitative rather than quantitative. Significant intra- and inter-observer variation when images suboptimal.
- Left atrial appendage and in adults, superior vena cava and majority of aorta and pulmonary arteries above valve/root level, cannot be imaged.
- Image quality generally inferior to transoesophageal echo.
- Limited capacity for differentiation between different types of tissues and fluids.

TRANSOESOPHAGEAL ECHOCARDIOGRAM (TOE)

Uses

- Like TTE, provides diagnostic information about structural abnormalities and their functional significance.
- Image quality better than TTE. Particularly useful when better resolution of detail is needed.

prosthetic valve dysfunction

- endocarditis (e.g. on valves, central venous lines, pacing leads) and its complications (e.g. annular abscess, fistulae)
- atrial septal defects (ASD)
- atrial masses

- inadequate TTE
- strong suspicion of cardiac pathology despite negative TTE
- Can also image additional structures not imaged by TTE:

  thoracic aorta, e.g. in aortic dissection/transection

  left atrial appendage, e.g. cardiac source of thromboemboli

  pulmonary artery up to the bifurcation

  superior vena cava
- Complements TTE; does not replace it. Rarely, if ever, indicated without prior TTE – unlike good TTE, views are often off-axis, reducing accuracy of assessment of chamber dimensions, myocardial thickness, left ventricular function, Doppler flow velocities and valve gradients (often underestimated).

Advantages

- Portable – can bring equipment to sick patient rather than move patient to test facility. Can be performed intra-operatively.
- Does not limit access to sick patient for clinician, nurse or monitoring equipment.
- Low risk procedure in patients who are relatively well.
- Relatively cheap.
- Image quality relatively independent of patient anatomy and position.

Limitations

- Most centres perform TOE under sedation due to patient intolerance of associated discomfort, or general anaesthesia in patients at high risk with sedation.
- Semi-invasive – risks low but potentially severe: regurgitation/vomiting with aspiration, oesophageal perforation in oesophageal pouch or abnormal oesophagus (e.g. neoplasia), bacteraemia.
- Information is often qualitative rather than quantitative.
- Limited capacity for differentiation between different types of tissues and fluids.
- Not possible to image section of aortic arch where it crosses left main bronchus due to interference from air/bronchus interface.

- Inferobasal wall and true apex sometimes difficult to image satisfactorily.

Requirements for TOE under sedation

- Patient fit for sedation – commonly used sedative: benzodiazepine, e.g. IV midazolam or diazepam. If not, need to consider TOE under general anaesthesia.
- Able to lie flat in left lateral position.
- Patient fasted for at least 4 h.
- Information about medications, drug abuse, alcohol excess, allergies. May interfere with ease of sedation. May require antibiotic prophylaxis (similar to simple gastroscopy) in high-risk patients (e.g. previous or suspected endocarditis, prosthetic valves).
- Suitable for blind oesophageal intubation. Oesophageal perforation unlikely – no significant dysphagia, no known oesophageal pouch or friable oesophageal wall (e.g. neoplasm). No major maxillofacial trauma.
- Intra-procedural safety measures available – oxygen, suction, monitoring (ECG, pulse, blood pressure, oxygen saturation), qualified assistant (preferably two).
- Suitable after-care till patient sufficiently awake. Avoid food or drink for 2 h after procedure if pharyngeal local anaesthetic spray used as control of swallowing may be affected.

COMMON INDICATIONS FOR ECHOCARDIOGRAPHY

Myocardial infarction

Especially if new murmurs, intractable heart failure and/or hypotension not obviously due to severe continuing ischaemia (chest pain, ECG changes).

- Echo may demonstrate impaired function in both ventricles but not their relative haemodynamic contributions. Clinical/ECG/chest X-ray assessment and pulmonary artery catheter pressure measurements may be more useful than echo in distinguishing between hypotension due to poor left ventricular function and hypotension due to acute right ventricular infarction.
- May have complications of post-infarct ventricular septal defect (figure 1), ruptured papillary muscle with severe acute mitral regurgitation,

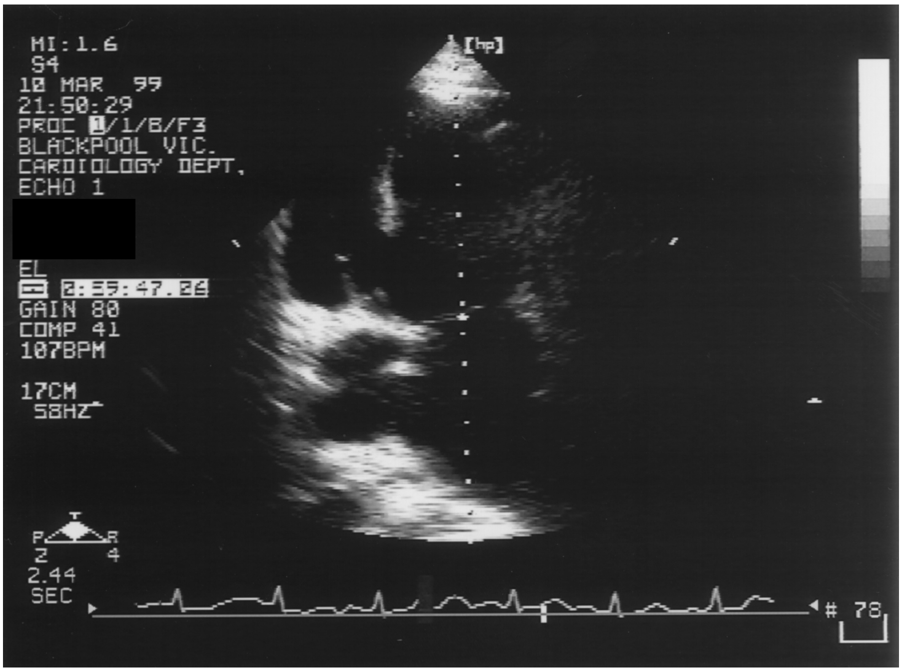

Figure 1 – TTE. Apical four-chamber view demonstrating a post-infract VSD.

rarely myocardial rupture with subacute cardiac tamponade (most arrest suddenly and die before investigation).

- Echo LVEF is calculated from linear measurements using the basic assumption of a truncated symmetrical ellipsoid shape. Substantial inaccuracies arise if images are suboptimal, resulting in errors subsequently magnified by multiplication during calculation, and/or if LV is asymmetrically impaired by regional myocardial infarction, when the basic assumptions about LV shape used in calculation no longer hold true.
- Subjective estimates by an experienced echocardiographer may be preferable. Moderate LV dysfunction generally equates to LVEF 30–40% (normal ≥ 50%). Qualitative echo assessment of LV contractility can be as effective as calculated LVEF in selecting patients who will benefit from ACE inhibitors (TRACE trial, wall motion index scoring).[1]
- LVEF is a load-dependent parameter and varies with prevailing haemodynamic conditions.

Note: should not rely heavily on LVEF alone as the indicator of LV dysfunction

- Other features are also very important. Large complete Q wave infarcts on ECG, especially anterior infarcts, widespread loss of R wave on ECG, large cardiac enzyme rises and clinical or radiographic heart failure all suggest need for ACE inhibitors, probably even if calculated LVEF does not meet trial criteria (e.g. big anterior infarct with echo LVEF 45%). Anterior infarction is also associated with higher incidence of LV thrombus (11%) than other sites (2%).

- MUGA radionuclide left ventriculography was used in SOLVD and SAVE trials. MUGA LVEF measurements are more reliable and reproducible than echo in the unselected population, but are still subject to 5–10% variation, are more time-consuming and costly, and involve radiation. Echo is usually adequate to guide clinical decisions.

- Anticoagulation[2] should be considered regardless of whether in sinus rhythm or atrial fibrillation to reduce stroke (SAVE trial) and cardiac mortality (SOLVD trial). Poor LV function is sufficient indication for anticoagulation[3] without demonstration of LV thrombus (figure 2).

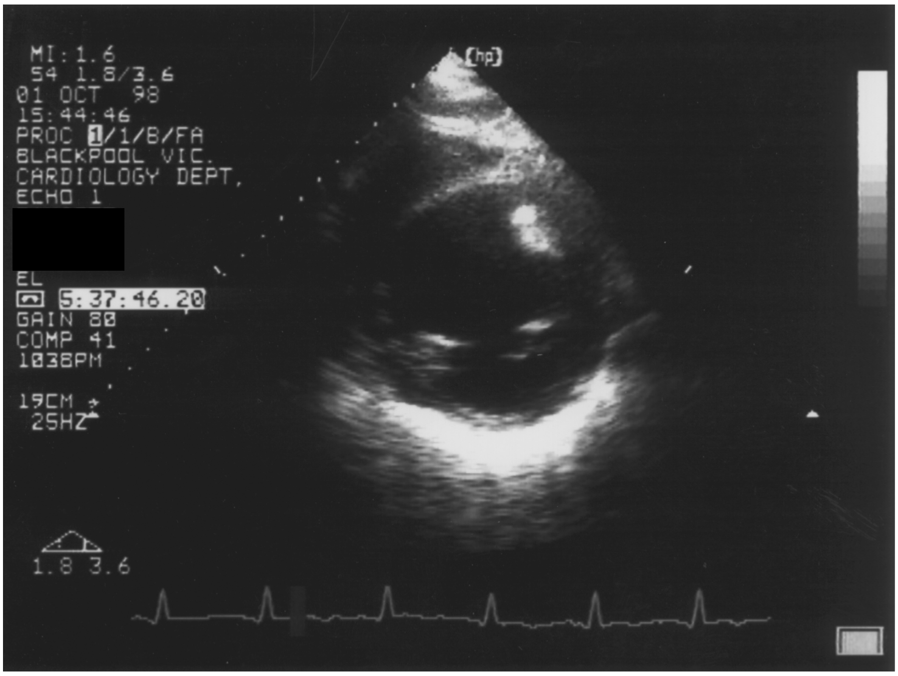

Figure 2 – TTE. Sagittal view of LV Mural thrombus.

Pulmonary oedema: heart failure

- Echo is particularly useful for diagnosis of significant systolic LV dysfunction, valve disease, dilated and hypertrophic cardiomyopathies. Mitral and aortic valve disease are commonest; isolated tricuspid disease the rarest. If TTE fails to confirm strong clinical suspicion of severe valve disease, especially prosthetic valve dysfunction, consider TOE.
- Diastolic LV dysfunction is difficult to assess. LV hypertrophy is a clue to hypertensive heart failure with preserved systolic function but diagnosis remains clinical.
- Pericardial constriction and restrictive cardiomyopathy are difficult to diagnose on echo. There may be no specific features. LV may appear mildly impaired. Pericardium is often echobright even when normal, and changes in thickness and calcification are often not detectable. Suspicion must be clinical (e.g. oedema out of proportion to degree of LV dysfunction) and confirmation of diagnosis sought by other means – cardiac catheter studies for intracardiac pressures, myocardial biopsy for amyloid, computed tomography (CT) or magnetic resonance imaging (MRI) for pericardial thickening and/or calcification.
- Isolated right heart failure may be primarily cardiac (e.g. previously undiagnosed large ASD) or more commonly, secondary (cor pulmonale, pulmonary embolism, rarely primary pulmonary hypertension). Right atrial and ventricular dilatation, tricuspid regurgitation and raised pulmonary pressures are the main echo findings. ASD may not be well imaged on TTE and may require TOE to confirm diagnosis and assess suitability for percutaneous device closure.

Endocarditis

- Main functions of echo are confirmation of diagnosis by demonstration of vegetations (figure 3), and assessment of extent and severity of infection and complications.
- TTE may be adequate to provide the diagnosis but is much less sensitive than TOE. Consequently, TOE has become a routine investigation for endocarditis, including TTE-proven endocarditis, and especially for prosthetic valve endocarditis.
- Extent of infection – number of valves affected, extent of valve infection, involvement of adjacent structures. Helps surgeon plan operation (e.g. mitral valve inspection as well as replacement of damaged aortic valve, mitral valve repair rather than replacement).
- Complications – severe valvular regurgitation. Annular abscess – may rupture to communicate with the circulation, become aneurysmal, form

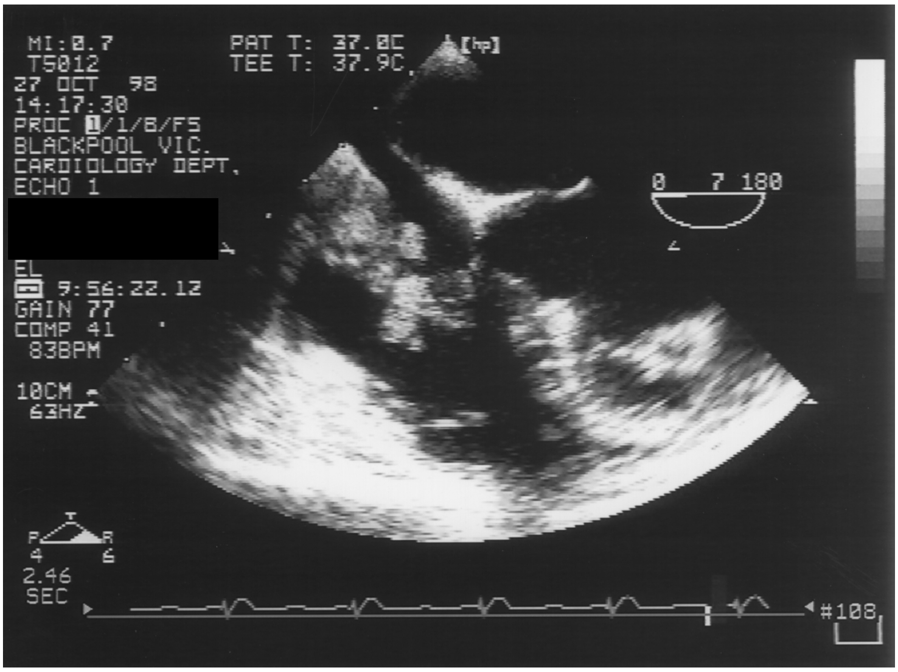

Figure 3 – TOE of endocarditis with large vegetation on pacing lead.

fistulae or rupture into pericardial space to cause haemopericardium and sudden death. Emboli.

- Echocardiographic indications for early surgery before completion of 6-week course of antibiotic therapy include worsening valvular regurgitation and enlarging abscesses which suggest failure of antibiotic therapy, unstable 'rocking' prosthetic valves at risk of complete dehiscence, and large and expanding aneurysms at high risk of rupture. There is some evidence that vegetations > 10 mm diameter have high risk of embolization but no conclusive evidence that surgery is indicated based on vegetation size alone.

Note: echo can never 100% exclude or confirm endocarditis. Vegetations may be too small to visualize. May be impossible to differentiate between new vegetations, old healed vegetations, thrombus (e.g. on pacing lead or prosthetic valve), calcific masses on degenerate valves and rare valve tumours. Diagnosis is ultimately clinical, albeit aided by echo.

Exertional syncope: ventricular arrhythmias

- Echo may be normal in ischaemic heart disease or show previous infarction, regional LV dysfunction or LV aneurysm formation.

- LV dysfunction is often global in dilated cardiomyopathies.
- Hypertrophic cardiomyopathy and aortic stenosis should be excluded by echo before provocative stress testing for malignant arrhythmias in patients with marked ECG changes of LV hypertrophy or suggestive clinical signs.
- Arrhythmogenic right ventricular dysplasia may be widespread with isolated RV dysfunction or localized/patchy with normal echo appearances.
- Echo is usually normal in right ventricular outflow tract ventricular tachycardia.

Atrial arrhythmias – atrial fibrillation, atrial flutter, atrial tachycardia

- Unexplained atrial arrhythmias may be the initial presenting feature of ischaemic heart disease, cardiomyopathy, valve disease especially mitral, and ASD.
- Atrial fibrillation and flutter predispose to left atrial (LA) thrombus and systemic thromboembolism.[4] Thrombo-embolic risks are reduced by adjusted-dose anticoagulation to an INR = 2.0–3.0. Risks are low (0.5% p.a.) in patients < 65 years with lone atrial fibrillation, similar to sinus rhythm (0.3% p.a.) and do not warrant anticoagulation.

Presence of clinical:

- past embolus
- heart failure
- hypertension
- diabetes mellitus
- atherosclerosis – coronary, peripheral or cerebrovascular
- and possibly age

and echocardiographic:

- TTE or TOE:
- LA diameter > 5 cm
- LV dysfunction
- LA or LV thrombus
- mitral stenosis
- mitral annular calcification

- TOE – dense LA or LV spontaneous echo contrast (implies sluggish blood flow)
- LA appendage thrombus
- low LA appendage peak flow velocities ≤ 20 cm/s
- complex aortic atheroma

risk factors are indications for anticoagulation. Clinical and TTE assessment are generally adequate to determine need for anticoagulation. TOE is not required routinely.

- Early DC cardioversion without ≥ 3 weeks of adequate prior anticoagulation may be preferable but not essential on clinical grounds. TOE may be used to exclude intracardiac thrombus before cardioversion.[5] TTE alone is inadequate (cannot image LA appendage). Note: exclusion of thrombus by echo does not obviate the need for peri- and post-cardioversion anticoagulation for atrial stunning.

Pericardial tamponade

- Pericardial tamponade is a clinical diagnosis.
- Echo can only diagnose a pericardial fluid collection (figure 4), demonstrate its size, distribution and suitability for safe pericardiocentesis via

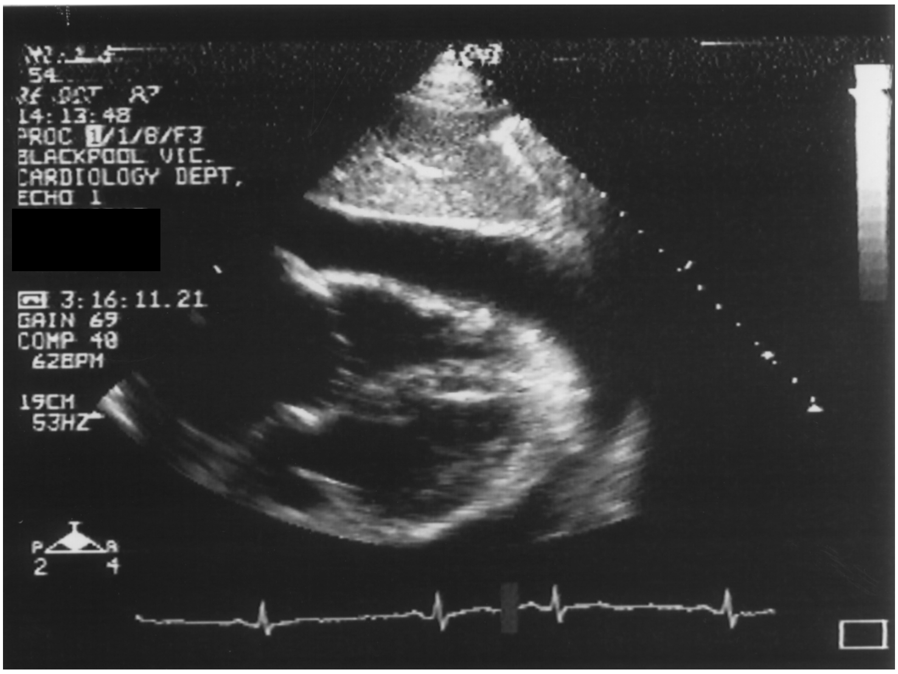

Figure 4 – TTE. Sub-costal view of pericardial effusion.

the subxiphisternal route, and provide evidence of haemodynamic effects but not their clinical significance. Right atrial and RV outflow tract diastolic collapse are non-specific and common even without clinical tamponade. Dilated inferior vena cava > 2 cm with > 50% inspiratory collapse, extensive RV collapse and > 40% inspiratory fall in early mitral inflow velocity suggest significant tamponade but may not always be present.

Major pulmonary embolism

- Diagnosis is largely clinical.
- Echo findings of RV dilatation/dysfunction and pulmonary hypertension with small/normal LV support the diagnosis but are not diagnostic. Diagnostic findings of mobile right heart thrombus or saddle embolus at the pulmonary bifurcation are rare and may require TOE.

Major chest trauma[6]

- Penetrating injury – echo finding of pericardial fluid collection suggests possible injury to the heart and warrants urgent surgical exploration.
- Blunt trauma and deceleration injuries, e.g. in road traffic accidents. The heart may hit the anterior chest wall resulting in myocardial contusions or anterior myocardial infarction due to trauma to left anterior descending artery. Distortion of the heart may result in valve leaflet or chordal rupture and significant valvular regurgitation. Descending aorta is relatively immobile and sudden shift of heart and aortic arch with sudden deceleration may result in aortic transection/rupture.
- TTE should be considered in all patients with major chest trauma. TOE is warranted where cardiac injury is suspected but TTE images inadequate (often the case in supine ventilated patients) and also where aortic injury is possible, unless alternative imaging modalities are used. TOE is frequently preferred to CT or MRI because it can be performed on the intensive care unit. There may be no murmurs with gross valvular regurgitation if flow is free and non-turbulent. LV contusions may be associated with only minor non-specific T-wave changes. Aortic transections may be silent initially, contained by haematoma with little bleeding and normal mediastinum on chest X-ray, but carry risk of acute rupture and sudden death.

Aortic dissection

- TTE may confirm diagnosis only if dissection involves the aortic root as ascending aorta and arch are usually poorly seen in adults. It may show the aortic dissection flap and possible complications – aortic valve involvement, aortic regurgitation, pericardial fluid collection (possible haemopericardium), cardiac tamponade, regional LV dysfunction or akinesia from coronary artery occlusion.

- Note: negative TTE does not exclude aortic dissection. Further investigation is necessary. TOE, dynamic contrast spiral CT, MRI and aortic angiography all have ≥ 95% sensitivity and specificity. TOE (figure 5) is frequently preferred in acute dissection as it can be performed on the intensive care unit. It will satisfactorily differentiate between dissections involving (Type A, emergency surgery is indicated) and not involving (Type B, conservative management if complications absent) the ascending aorta and identify the entry site for the surgeon. If complications involving the abdominal aorta are present (e.g. ischaemic leg), CT or MRI may be preferable as a single investigation that can also image the abdominal aorta as well. Current MRI scanners still limit access to patients, may interfere with monitoring and therapeutic equipment, and are more often used for chronic dissections and follow-up. Aortic angiography is generally not available in district general hospitals, carries an appreciable risk of catheter-related vascular damage, but can be combined with coronary angiography and might therefore be the

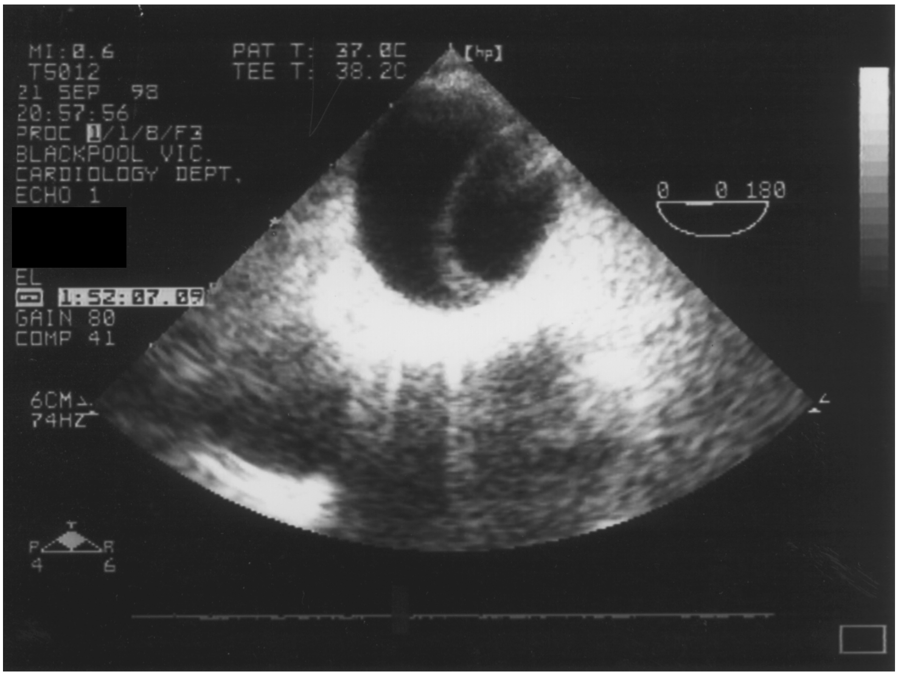

Figure 5 – TOE of type B aortic dissection.

technique of choice if concomitant severe ischaemic heart disease is suspected.

Interpretation of echo reports

Normal values

- LA diameter – 3–4 cm
- LV internal diameter – diastole 3.5–5.9 cm, systole 2.4–4.0 cm
- LV thickness:

  septum – 0.8–1.3 cm males, 0.7–1.0 cm females

  posterior wall – 0.8–1.1 cm males, 0.6–1.1 cm females
- LVEF – ≥ 50% (higher with severe MR/AR)
- FS – 28–44%

Systolic heart failure

Likely if:

- EF < 40%
- FS < 20%
- LV end systolic volume > 70 ml
- Extensive regional wall dysfunction
- Moderate-to-severe reduction in contractility

Possibly if:

- EF – 40–50%
- FS – 20–25%

Aortic stenosis (AS)

	Peak AVG (mmHg)	Mean AVG (mmHg)	EOA (cm^2)
Mild	15–30	<20	
Moderate	31–50	20–30	>1.0
Moderately severe	50–60	30–40	0.75–1.0
Severe	>60	>40	<0.75

Moderately severe and severe AS are haemodynamically significant and may warrant further investigation with a view to valve replacement.

- With poor LV function, valve gradient may be low and severity of stenosis underestimated. Low LV systolic pressures may result in peak AVG of only 30–40 mmHg despite severe AS. EOA by the continuity equation is a more accurate measure of severity in this situation.

Mitral stenosis

	EOA (cm^2)	Pressure half-time (ms)	Mean MVG (mmHg)
Mild	1.5–2.0	< 150	< 5
Moderate	1.0–1.5	150–200	5–10
Severe	< 1.0	> 200	> 10

- Echo findings of dilated right heart, impaired RV and pulmonary hypertension are indications for intervention even if relatively asymptomatic.
- Criteria for percutaneous valvotomy are:

  thickening confined mainly to leaflet tips; mobile anterior leaflet

  little chordal involvement

  no commissural calcification

  at most mild mitral regurgitation

  no LA thrombus (need TOE to rule out LA and LA appendage thrombus)

Aortic (AR) and mitral (MR) regurgitation

- AR and MR are assessed by width and depth of regurgitant jet on colour flow Doppler, strength and duration of pulsed wave Doppler signal in relation to distance from regurgitant valve, strength and duration of continuous wave Doppler signal. Pressure half-time is also useful in AR – AR is usually haemodynamically significant if pressure half-time < 400 ms. Severity of AR and MR may be underestimated if regurgitant jets are eccentric and difficult to image. If TTE findings do not tally with clinical findings of severe regurgitation, consider TOE.
- Severity is usually graded out of 4 and expressed as:

  Grade 1/4 or grade 1+ or mild regurgitation

  Grade 2/4 or grade 2+ or moderate regurgitation

  Grade 3/4 or grade 3+ or moderately severe regurgitation

  Grade 4/4 or grade 4+ or severe regurgitation

- Grades 3 (moderately severe) and 4 (severe) are haemodynamically significant and warrant assessment by a cardiologist. Surgery should be considered if there are clinical sequelae (breathlessness, heart failure) or features of deteriorating cardiac function (dilated LV, impaired LV contractility, and particularly with MR, pulmonary hypertension).
- Trivial or mild AR and MR are common as physiological regurgitation is increasing being detected with the aid of improved technology in normal people. In general, if the valve appears normal and there is no murmur, antibiotic prophylaxis is unnecessary.
- Mild-to-moderate MR is often associated with poor LV function, 'functional' in nature and associated with normal valves.

Tricuspid regurgitation (TR)

- Severity graded from 1 to 4, as for aortic and mitral regurgitation.
- Mild TR is detectable in most normal people.
- More severe TR is common in severe biventricular failure, mitral stenosis, cor pulmonale and any other cause of pulmonary hypertension.
- The peak systolic pressure gradient across the tricuspid valve (peak systolic TVG) can be calculated from the peak TR velocity. In the absence of pulmonary stenosis: peak pulmonary artery pressure = peak systolic TVG + right atrial pressure
- This is often simplified to: peak pulmonary artery pressure = peak systolic TVG + 10 mmHg. Note: in the presence of a very high JVP or CVP, right atrial pressure is significantly > 10 mmHg and pulmonary pressures may be significantly underestimated.

Further reading

Daniel WG, Mügge A. Transesophageal echocardiography. *N Engl J Med* 1995; **332**: 1268–79.

Feigenbaum H. *Echocardiography*, 5th edn, 1994. Philadelphia: Lea & Febiger.

Rimington H, Chambers J. *Echocardiography. A Practical Guide for Reporting*. Parthenon, 1998. Carnforth, UK

References

1. Køber L, Torp-Pedersen C, Carlsen J *et al.* An echocardiographic method for selecting high risk patients shortly after acute myocardial infarction, for inclusion in multi-centre studies (as used in the TRACE study). *Eur Heart J* 1994; **15**: 1616–20.

2. Al-Khadra AS, Salem DN, Rand WM *et al.* Warfarin anticoagulation and survival: a cohort analysis from the studies of left ventricular dysfunction. *J Am Coll Cardiol* 1998; **31**: 749–53.
3. Ciaccheri M, Castelli G, Cecchi F *et al.* Lack of correlation between intracavity thrombosis detected by cross-sectional echocardiography and systemic emboli in patients with dilated cardiomyopathy. *Br Heart J* 1989; **62**: 26–9.
4. Wheeldon NM. Atrial fibrillation and anticoagulant therapy. *Eur Heart J* 1995; **16**: 302–12.
5. Zabalgoitia M, Halperin JL, Pearce LA *et al.* Transesophageal echocardiographic correlates of clinical risk of thromboembolism in nonvalvular atrial fibrillation. Stroke Prevention in Atrial Fibrillation III Investigators. *J Am Coll Cardiol* 1998; **31**: 1622–6.
6. Chirillo F, Totis O, Cavarzerani A *et al.* Usefulness of transthoracic and transesophageal echocardiography in recognition and management of cardiovascular injuries after blunt chest trauma. *Heart* 1996; **75**: 301–6.