

Suggested Reading List and Syllabus

- The European Association of Echocardiography Education Committee will run a teaching course in October which will provide preparation for the exam.
- The syllabus is set by the Accreditation Committee of the European Association of Echocardiography and is presented as a guide to candidates
- The reading list is provided by the Education Subcommittee of the European Association of Echocardiography

There are many excellent books on echo and just some examples are listed below. In addition to those listed there are many small basic texts which are a useful introduction to the subject.

Authoritative textbooks:

A.E.Weyman, Principles and Practice of Echocardiography, 2nd ed. 1994 Lea & Febiger

H.Feigenbaum, Echocardiography, 5th ed.1994 Lea & Febiger

JRTC Roelandt, NG Pandian. Multiplane transesophageal echocardiography. Churchill Livingstone 1996

Otto C. The Practice of Clinical Echocardiography. 2nd ed. Philadelphia: W. B. Saunders 2002.

Marwick TH. Stress Echocardiography: Its Role in the Diagnosis and Evaluation of Coronary Artery Disease (Book with CD-ROM) Kluwer 2003

Useful review articles:

Wranne B, Baumgartner H, Flachskampf FA, Hasenkam M, Pinto F. Stenotic lesions (editorial). Heart 1996; 75 (Suppl.2);36-42. Downloadable from <http://heart.bmjournals.com/supplements.shtml>

M Enriquez-Sarano,C Tribouilloy.Quantitation of mitral regurgitation: rationale, approach, and interpretation in clinical practice.Heart 2002; 88 (Suppl 4): iv1-iv3. Downloadable from <http://heart.bmjournals.com/supplements.shtml>

S Y Ho Anatomy of the mitral valve. Heart 2002; 88 (Suppl 4): iv5-iv10. Downloadable from <http://heart.bmjournals.com/supplements.shtml>

T Irvine, X K Li, D J Sahn, A Kenny. Assessment of mitral regurgitation. Heart 2002; 88 (Suppl 4): iv11-iv19. Downloadable from <http://heart.bmjournals.com/supplements.shtml>

D Pellerin, S Brecker, and C Veyrat. Degenerative mitral valve disease with emphasis on mitral valve prolapse. *Heart* 2002; 88 (Suppl 4): iv20-iv28. Downloadable from <http://heart.bmjournals.com/supplements.shtml>

Flachskampf FA, Decoodt P, Fraser AG, Daniel WG, Roelandt JRTC. Recommendations for performing transesophageal echocardiography. *Eur J Echocardiography* 2001;2;8-21. Downloadable from www.escardio.org

Gardin JM, Adams DB, Douglas PS, Feigenbaum H, Forst DH, Fraser AG, Grayburn PA, Katz AS, Keller AM, Kerber RE, Khandheria BK, Klein AL, Lang RM, Pierard LA, Quinones MA, Schnittger I; American Society of Echocardiography. Recommendations for a standardized report for adult transthoracic echocardiography: a report from the American Society of Echocardiography's Nomenclature and Standards Committee and Task Force for a Standardized Echocardiography Report. *J Am Soc Echocardiogr.* 2002 Mar;15(3):275-90. Downloadable from www.asecho.org

Zoghbi WA, Enriquez-Sarano M, Foster E, Grayburn PA, Kraft CD, Levine RA, Nihoyannopoulos P, Otto CM, Quinones MA, Rakowski H, Stewart WJ, Waggoner A, Weissman NJ. Recommendations for Evaluation of the Severity of Native Valvular Regurgitation with Two-dimensional and Doppler Echocardiography. *J Am Soc Echocardiogr* 2003;16:777-802. Downloadable from <http://www.asecho.org/freepdf/valvularregurg.pdf>

Cheitlin MD, Armstrong WF, Aurigemma GP, Beller GA, Bierman FZ, Davis JL, Douglas PS, Faxon DP, Gillam LD, Kimball TR, Kussmaul WG, Pearlman AS, Philbrick JT, Rakowski H, Thys DM. ACC/AHA/ASE 2003 guideline update for the clinical application of echocardiography—summary article: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (ACC/AHA/ASE Committee to Update the 1997 Guidelines on the Clinical Application of Echocardiography). *Circulation.*2003 http://www.acc.org/clinical/guidelines/echo/summary_article.pdf

Syllabus

GENERAL

General Concepts

The place of echocardiography

Clinical role of echocardiography and Doppler

- Information that echocardiography can, and cannot provide
- 'Ruling out' pathology (sensitivity, specificity & Baye's theorem)
- Likelihood of findings influencing patient management
- Undesirable outcomes: inaction while waiting for results, clinical 'red herrings'

Indications for echocardiography

Competing and complementary technology

- Cardiac catheterisation
- X-ray ventriculography and coronary angiography
- contrast C-T
- Magnetic resonance imaging
- Nuclear Cardiology

Service Provision

Advantages/disadvantages of technician-led versus physician-led service

Costs: fixed and variable

Provision and indication for specialised techniques, e.g. TOE. Stress echo, Contrast echo

Availability and access

Controlling workload

Training & motivation of staff

Audit, Quality Control, Clinical Governance

Relationship with patients

Explaining the procedure in terms relevant to the particular patient

Respect for patients' dignity and cultural backgrounds

Relationships with colleagues.

Handling requests for information about the study findings

Reporting and Documentation

Standard methods & terminology

Distinction between Technical and Clinical reports

Responsibility for reporting

Medico-legal considerations (Data Protection Act)

Imaging Physics & Instrumentation

Concepts and Terminology

Concept of compression waves

Definitions: frequency, wavelength, propagation velocity

Units of measurement: Hz and MHz, Decibel

Comparison of Ultrasound with audible sound.

Propagation of ultrasound through tissues

Speed of sound in different body tissues.

Frequency range used for diagnostic imaging

Distinction between specular reflection and backscatter

Principles of attenuation and scattering

Ultrasound Transducers

- Piezo-electric effect
- General concepts of transducer construction
- Characteristics of the ultrasound beam: Near (Fresnel) & Far (Fraunhofer) zones, side lobes
- Beam steering methods: mechanical & electronic
- Focusing methods, including multiple transmit focusing

Imaging physics

- Factors affecting choice of imaging frequency: typical practical values for adults & children
- Broad-band imaging
- Harmonic imaging
- B mode and M Mode methods.
- Scanning speed limitations, relationships between pulse repetition frequency, frame rate, lines per frame, field of view, depth to be imaged.
- Concept of Parallel Processing and its influence on frame rate and image quality
- Effect on evaluation of rapid motion, temporal resolution.
- Grey scale and dynamic range
- Measurement and optimisation of Resolution: axial, azimuthal and elevation
- Lateral resolution and grating artefacts
- Reverberation artefacts
- Limiting factors for detecting small targets

Echo Instrumentation

- Function of machine controls: Transmit power; overall gain; time gain compensation; reject, logarithmic compression,
- Signal processing, dynamic range, pre-processing; post processing
- Optimisation of imaging parameters, including transducer frequency, scan angle, gamma correction, spatial and temporal smoothing

Optimising Images

- Use of gel (infection risk from transducer, operator)
- Positioning of the subject
- Standard views: Parasternal, apical (4, 5 and 2-chamber), subcostal, suprasternal, right parasternal), long and short axis
- Use of non-standard views
- Adapting for subjects with difficult windows, ventilated patients, ward-based echos

Storage and Display of Images

- Basic concept of digital systems.
- Scan converters and digital memories.
- Display devices and controls, recording techniques

Doppler physics & fluid dynamics

Basic Fluid Dynamics

- Fluid flow: significance of peak & mean velocities
- Determination of volumetric flow
- Continuity equation
- Laminar & turbulent flow: Reynolds' equation (qualitative)
- Transition from Laminar to turbulent flow: inlet jet
- Bernoulli equation

Basic Principles of Doppler

Interaction of ultrasound waves with moving blood: the Doppler effect
The Doppler equation: factors influencing magnitude of Doppler shift
Spectral analysis: fast Fourier transform (qualitative)
The spectral Doppler display: determination of mean, modal and peak velocities
Limitation of CW Doppler caused by lack of depth discrimination
Audible range of Doppler shift frequencies
The effect of beam angle errors on Doppler velocities
Aliasing: how it is caused and how it manifests in practice: the Nyquist limit
Influence on aliasing of: transducer frequency; sample depth (range x velocity product); and beam angle
High pulse repetition frequency (extended range) PW Doppler
Relative advantages and disadvantages of CW, PW and HPRF modes
Concept of colour flow imaging as multi-sampled PW
Velocity estimation, by moving target indication and autocorrelation (qualitative)
Limitations of mean velocity: use of velocity variance to show high velocities/turbulence
Aliasing in colour Doppler
Packet size, colour mode and sector size and their effect on frame rate and aliasing

Doppler instrumentation

Spectral Doppler Instrumentation

Duplex Doppler using imaging transducers
The 'Stand-alone' Doppler probe
Features of the spectral display: positive & negative velocities; scale & baseline controls.
Effect of high- and low-pass filter and intensity threshold ('reject') settings
Pulsed Doppler sample volume: influence of gate length and distance (beam width)
Representation of signal strength by image intensity
How aliasing manifests on the spectral display

Colour Flow Instrumentation

The colour display: BART convention
Colour maps to show velocity scales
Image domination and additive colour modes
Basic principles of Tissue Doppler Imaging, including optimisation of filters for detecting tissue versus blood velocities
Difference between velocity and power (signal amplitude) displays

TOE Instrumentation

Transducer types: single plane, biplane, multiplane
Optimising machine settings for TOE
Patient monitoring for TOE and general safety considerations
Control of infection

Safety of ultrasound

Potential hazardous biological effects: heating, resonance and cavitation effects
Measurement of beam intensity (SPTA)
Practical precautions: power levels, use of colour and CW Doppler

Recording methods

Advantages/disadvantages of recording on: videotape, photographic or dye-transfer prints, thermal strip chart
Basic understanding of digital image processing and recording methods: pixel density, volume of data, concept of data compression, storage in RAM or magneto-optical disc format

Cardiac Anatomy and Physiology

Anatomy of the thorax

Thorax contained by rib cage & diaphragm
Lungs & pleura; heart & pericardium; mediastinum
Blood vessels within the thorax

Gross anatomy of the heart

Basic cardiac embryology
Nomenclature of chambers and valves
Major relationships of chambers, valves and blood vessels
Distinguishing features of valves and chambers as related to echocardiography
The pericardial sac

Cardiac anatomy and physiology as demonstrated by echocardiography

Detailed structural anatomy of the heart, great vessels and pericardium
Visualisation of normal cardiac anatomy and normal variants in standard echocardiographic planes
Normal valve function, normal Doppler parameters and normal variants

The Cardiac Cycle

Temporal relationships of the ECG, chamber pressures and valve movements
Typical values for intracardiac pressures
Relationship of valve movements to heart sounds

Cardiac functional parameters

Measurements and calculations

On-screen measurement of length, slope, area, volume and time interval, and their significance for 2-D images, M-mode and spectral Doppler displays
Standard M-mode measurements and calculations, both using machine software and manual methods
Derivation of Stroke Volume, Ejection Fraction and LV Mass
Methods of measuring LV volume, including biplane area, area-length and Simpson's rule methods
Limitations of measurement and/or calculation validity in presence of poor quality and/or off-axis images

Doppler determination of cardiac output, ejection time and velocity acceleration

Methods of measuring diastolic dysfunction: E/A ratio, deceleration time, pulmonary venous flow patterns
Peak and Mean pressure gradient measurements by Doppler and their relationship to catheterisation data
Measurement of pulmonary pressures from tricuspid and pulmonary regurgitant flow velocities and assessment of inferior vena cava contraction

Contrast Studies

Significance of spontaneous echo contrast
Optimisation of machine control settings for detecting contrast
Indications for a bubble contrast study
Technique for performing a hand-agitated contrast study
Clinical precautions

Awareness of encapsulated contrast agents and techniques

Interaction of ultrasound with encapsulated agents
Generation of harmonic energy by bubble distortion and fracture
Doppler signals generated by bubbles (Power Mode)
Clinical application for LV opacification and Doppler enhancement

PATHOLOGY

Mitral Valve Disease

2D, M-mode and Doppler features of the normal mitral valve

Mitral Stenosis

Qualitative description of valve and sub-valve calcification and fibrosis
Measurement of orifice area by planimetry
Factors favouring successful balloon valvuloplasty
Doppler assessment of mean and end-diastolic gradient
Doppler assessment of area by 'pressure half-time': technique and limitations

Rheumatic mitral stenosis

Assessment of severity (see 2.1.2)

Mitral regurgitation

Assessment of severity by:

- Chamber sizes and volume overload
- CW Doppler
- PISA
- Pulmonary vein flow patterns
- Indirect effects

Aetiologies and typical echocardiographic features of:

- rheumatic
- mitral annular calcification
- 'Floppy MV'
- ischaemic
- functional
- infective endocarditis

Aortic Valve Disease

2D, M-mode and Doppler features of the normal aortic valve

Aortic Stenosis

Assessment by CW Doppler

- Peak and Mean gradients
- Apical, right parasternal and suprasternal positions
- Continuity equation
- Assessment of left ventricular hypertrophy and function

Aetiologies and echocardiographic features:

- Rheumatic

- Bicuspid
- Senile degenerative
- Sub- and supra-valve obstruction

Aortic regurgitation

Aetiologies and typical echocardiographic features of:

- rheumatic
- bicuspid valve
- aortic root disease
- infective endocarditis (including root abscesses)

Assessment of severity by:

- Chamber sizes/volume overload
- CW Doppler
- Colour Doppler
- Indirect effects

Role of TOE in assessing aetiology and severity

Tricuspid Valve Disease

2D, M-mode and Doppler features of the normal tricuspid valve

Rheumatic tricuspid valve stenosis

Echocardiographic features

Assessment of severity by imaging and Doppler

Tricuspid Regurgitation

Assessment of severity by:

- 2D imaging and M-mode
- CW Doppler
- Colour Doppler
- Indirect effects

Aetiologies and echocardiographic features of:

- rheumatic
- prolapse
- congenital
- endocarditis
- carcinoid
- functional

Pulmonary Valve Disease

2D, M-mode and Doppler features of the normal pulmonary valve

Pulmonary Valve Stenosis

Echocardiographic features

Assessment of severity by spectral Doppler

Detection of infundibular obstruction by spectral Doppler

Pulmonary Regurgitation

Aetiologies and echocardiographic features

Assessment of severity by

- CW Doppler
- Colour Doppler
- Indirect effects

Infective Endocarditis

Typical echocardiographic appearance of vegetations in bacterial and fungal endocarditis
Preferred locations for vegetations
'Jet' lesions
Endocarditis associated with congenital disease and HCM
Complications: abscess, fistula, perforation
Role of TOE in suspected endocarditis

Prosthetic Valves

2D, M-Mode and Doppler features of the main types of replacement valves

- Ball & cage
- Tilting Disc
- Bi-leaflet
- Stented Bioprostheses

Age-related deterioration of bioprostheses
Role of TOE in examining normal and malfunctioning prosthetic valves

Prosthetic valve stenosis

Assessment by 2D, M-mode and Doppler
Normal ranges
Use of Continuity Equation for aortic prostheses

Prosthetic valve regurgitation

Trans- versus para-valvar regurgitation
Normal versus abnormal regurgitation
Assessment by CW, PW and Colour Doppler
Colour artefacts from mechanical prostheses

Cardiomyopathies

Dilated Cardiomyopathy

2D, M-mode and Doppler features of dilated cardiomyopathy
Detection and assessment of associated lesions: Functional valve regurgitation
Thrombus in cardiac chambers
Pericardial effusions
Role of echocardiography in assessment and follow-up

Hypertrophic Cardiomyopathy

2D, M-mode and Doppler features of Hypertrophic Cardiomyopathy
Differentiation from other causes of hypertrophy, e.g. 'athletic heart'
Techniques for measurement of left ventricular wall thickness, detection of intracavity flow acceleration
Assessment of right ventricular involvement
Associated abnormalities, e.g. mitral regurgitation

Intracardiac Masses

Typical locations for formation of intracardiac thrombus
Echocardiographic features of typical LA Myxoma
Differentiation of myxoma from other cardiac tumours
Features suggestive of malignancy
Role of TOE in assessment of intracardiac masses

Pericardial Disease

Anatomy of the normal pericardium

Relationships of serous pericardium to heart and great vessels
Transverse and oblique sinuses of the pericardium

Echocardiographic features of pericardial fluid

Location of fluid in relation to patient position and fluid volume
Differentiation from pleural effusion
Assessment of volume of pericardial fluid
Role of echocardiography in pericardiocentesis

Features of tamponade

Collapse of RA and/or RV walls
Effect on IVC
Effect on A-V valve flow velocities

Features of pericardial constriction

Effect on A-V valve flow velocities
Effect of respiration
SVC/hepatic vein flow
Differentiation from restrictive cardiomyopathy

Coronary Artery Disease and Systolic LV function

Anatomy & nomenclature of the major branches of the coronary arteries
Relationship of coronary anatomy to standard echocardiographic imaging planes
Nomenclature for describing myocardial segments (ASE convention)
Analysis of segmental systolic myocardial function
Diastolic dysfunction in coronary artery disease
Global measures of LV function:

- Ejection Fraction
- Stroke Distance
- Stroke Volume

Myocardial Infarction and its sequelae

2D, M-mode and Doppler features of:

- post-infarction VSD
- mitral papillary muscle rupture
- tamponade
- mural thrombus
- myocardial scarring
- Dressler's syndrome
- left ventricular aneurysm – true aneurysm vs pseudoaneurysm

Pulmonary Hypertension

2-D, M-mode and Doppler features of pulmonary hypertension
Aetiologies: primary; post pulmonary embolism; secondary to left-sided lesions; lung disease

Diseases of the Aorta

Technique for examining the ascending and descending thoracic aorta
Echocardiographic features of the normal aortic root, sinuses of Valsalva, ascending aorta and aortic arch
2-D, M-mode and Doppler features of:

- Marfan's syndrome
- sinus of Valsalva aneurysm
- thoracic aortic aneurysm
- aortic dissection
- Additional features related to aortic dissection:

- aortic cusp prolapse
- aortic regurgitation
- fluid in pericardium

Role of transoesophageal echocardiography in the diagnosis of aortic dissection

Adult Congenital Heart Disease

Anatomy, pathophysiology and natural history of common congenital lesions present in adults:

2-D, M-mode and Doppler features of the following, pre-operatively and post-operatively, as seen in the older child or adult

- Ostium Secundum Atrial septal defects
- Perimembranous and muscular ventricular septal defects
- Partial and complete atrio-ventricular septal defects
- Persistent ductus arteriosus
- Bicuspid aortic valve
- Sub- and supra-valve aortic stenosis
- Aortic coarctation
- Pulmonary stenosis
- Ebstein's anomaly
- Fallot's tetralogy

Role of contrast echocardiography in evaluating shunts in adults

Calculation of shunts

Role of TOE in adult congenital disease

Likely echocardiographic findings for common clinical presentations:

Heart failure or breathlessness
 Arrhythmia
 Ejection systolic murmur
 Hypertension
 Collagen abnormalities
 Renal failure
 Stroke