

European Accreditation in Pediatric and Congenital Echocardiography

European Association of Echocardiography (EAE), Association for European Pediatric Cardiology (AEP), WG on Grown-up Congenital Heart Disease of ESC (WG 22)

Syllabus Pediatric and Congenital examination

Part I. General Concepts

The place of echocardiography in pediatric and congenital heart disease

The clinical role of echocardiography and Doppler in paediatric and congenital heart disease:

- Information that echocardiography can, and cannot provide
- 'Ruling out' pathology (sensitivity, specificity & Baye's theorem)
- Likelihood of findings influencing patient management
- Indications for echocardiography
- Competing and complementary technology
 - Cardiac catheterisation
 - Multislice CT scan
 - Magnetic resonance imaging
 - Nuclear Cardiology

Service Provision

- Advantages/disadvantages of technician-led versus physician-led service
- Specific requirements for pediatric and congenital echocardiography laboratory
- Provision and indication for specialised techniques, e.g. TOE. Availability and access
- Controlling workload: time required studies
- Training & motivation of staff
- Audit, Quality Control, Clinical Governance

Relationship with patients

- Explaining the procedure in terms relevant to the particular patient and parents
- Respect for patients' dignity and cultural backgrounds
- Relationships with patient, parents and colleagues.
- Handling requests for information about the study findings

Conscious sedation in children

- Explaining the procedure in terms relevant to the particular patient and parents
- Specific environment for performing studies in children/adults with CHD
- Indications for conscious sedation
- Precautions, dosage, follow-up

Reporting and Documentation of pediatric and congenital studies

- Standard methods & terminology used for describing congenital heart disease
- Distinction between Technical and Clinical reports
- Responsibility for reporting
- Medico-legal considerations (Data Protection Act)

Safety of ultrasound

- Potential hazardous biological effects: heating, resonance and cavitations 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

Part II. Imaging Physics & Instrumentation in pediatric and congenital echocardiography

Concepts and terminology of cardiac ultrasound

- 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 in children and adults with CHD
- 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

Part III. Doppler physics & fluid dynamics in pediatric and congenital echocardiography

Basic Fluid Dynamics

- Fluid flow: significance of peak and 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
- 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

Part IV. Cardiac anatomy and physiology for pediatric and congenital echocardiography

Anatomy of the thorax

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

General concepts of cardiac morphology and echo identification

- Atrial situs: definition, abdominal aorta and great vein relationship
- Systemic venous return: morphology
- Pulmonary venous return: morphology
- Atrial anatomy: difference between right and left atrium, atrial appendages
- Ventricular anatomy: morphology of right and left ventricle, A-V valve arrangement, trabecular pattern, ventricular shape, right-handed vs left handed ventricular configuration, inlet and outlet valve relationships, chordal attachments
- Atrioventricular valves: anatomy of mitral and tricuspid valve
- Semilunar valves: anatomy of pulmonary and aortic valve
- The intra-atrial septum: morphology, primum and secundum septum, foramen ovale, sinus venosus
- The interventricular septum: morphology, inlet septum, outlet septum, membranous septum, trabecular
- Pulmonary artery anatomy
- Aortic anatomy
- Coronary artery anatomy: normal anatomy and variants
- The arterial duct: normal anatomy and normal variants
- The pericardium: anatomy
- Visualisation of normal cardiac anatomy and normal variants in standard echocardiography planes
- Normal valve function, normal Doppler parameters and normal variants

Terminology of congenital heart disease

- Atrial situs and situs abnormalities: situs inversus, right and left isomerism
- Atrioventricular connections concordant, discordant, double inlet, absent connection, straddling valves, criss-cross connections
- Ventriculo-arterial connections: concordant, discordant, single outlet, double outlet
- 'Univentricular' heart: description of different variants
- Great artery relationships

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

Fetal and neonatal physiology

- The fetal circulation: how it differs from the postnatal circulation
- Circulatory changes at birth: the neonatal circulation
- Adaptations in circulatory physiology during the first weeks of life

The physiology of congenital heart disease

- Causes of chamber dilation and hypertrophy
- Ventricular pressure and volume overload

- Physiological effect of shunts at atrial, ventricular and great artery level
- Physiological effect of regurgitation through all 4 valves
- Physiological effect of stenosis on all 4 valves

Part V. The different congenital heart defects and treatment for the pediatric and congenital echocardiographer

A. Septation defects

Ventricular septal defect

- Anatomical variations
- M-mode and 2D echo features: location and size of defects
- Assessment of shunt size and pulmonary pressure
- Aortic valve prolapse
- Discrete subvalvular aortic stenosis
- Double chambered right ventricle
- Malalignment VSD: anterior and posterior malignment
- Surgical treatment for ventricular septal defects: echocardiographic aspects
- Percutaneous treatment for different types of VSD: echocardiographic aspects

Atrial septal defect

- Anatomical variations: secundum, primum and sinus venosus defects and common associated lesions
- M-mode and 2D echo features
- Assessment of shunt size
- Other causes of right ventricular volume overload
- Surgical treatment of different types of ASD: echocardiographic aspects
- Percutaneous treatment of ASD: echocardiographic aspects

Atrioventricular septal defect

- Anatomical variations
- Atrioventricular valve function in atrioventricular septal defects
- Echocardiographic features of different defects
- Evaluation of pulmonary hypertension in patients with atrioventricular septal defects
- Surgical requirements for corrective surgery
- Echocardiographic evaluation of postoperative patient

B. Shunt lesions not caused by septation defects

Arterial duct

- Anatomical variations with different cardiac defects
- Imaging planes for isolated duct
- Assessment of shunt size
- Ductal flow patterns and pulmonary artery pressure
- Other defects causing shunt at great artery level
- Surgical treatment for patent arterial duct: echocardiographic aspects
- Percutaneous treatment: echocardiographic aspects

Partial anomalous pulmonary venous drainage

- Anatomy
- Echocardiographic diagnosis
- Surgical treatment: echocardiographic aspects

Basic anatomy and echo features of other acyanotic shunts

- Aorto-pulmonary window
- Origin of one pulmonary artery from aorta
- Unroofed coronary sinus
- Sinus of Valsalva fistula

C. Cyanotic congenital heart defects

Transposition of the great arteries

- Anatomy and variants
- Echocardiographic diagnosis of transposition of the great arteries
- Associated lesions: VSD, pulmonary stenosis
- Coronary anatomy in transposition of the great arteries
- Echocardiographic aspects of surgical treatments
- Echocardiographic evaluation of postoperative patient after atrial switch (Mustard, Senning)
- Echocardiographic evaluation of postoperative patient after arterial switch procedure
- Echocardiographic evaluation of postoperative Rastelli patient

Tetralogy of Fallot / pulmonary atresia with VSD

- Anatomy and variants
- Pulmonary perfusion in different variants
- Echocardiographic evaluation of uncorrected patient with tetralogy of Fallot
- Coronary anatomy in tetralogy of Fallot patients
- Aortic arch laterality: evaluation
- Surgical treatments: echocardiographic aspects
- Evaluation of the postoperative tetralogy patient

Pulmonary atresia with intact septum (PA-IVS)

- Anatomy and variants
- Echocardiographic evaluation of patients with PA-IVS
- Coronary perfusion in PA-IVS
- Percutaneous and surgical treatments: echocardiographic aspects
- Echocardiographic evaluation of the post intervention/post surgical patient

Double outlet right ventricle (DORV)

- Anatomy and variants
- Echocardiographic evaluation of uncorrected patient with DORV
- Surgical treatments: echocardiographic aspects
- Evaluation of the postoperative DORV patient

Total anomalous pulmonary venous drainage of different types

- Anatomy and variants
- Echocardiographic aspects
- Surgical treatment and postoperative evaluation

Truncus arteriosus

- Anatomy and different variants
- Echocardiographic aspects
- Surgical treatment and postoperative evaluation

Univentricular heart including double inlet and absent connection

- Anatomy and different variants
- Echocardiographic evaluation
- Surgical and interventional treatments: echocardiographic aspects
- Echocardiographic evaluation after different stages: banding, different types of shunts, bidirectional Glenn shunt, total cavopulmonary connection
- Evaluation of different types of 'Fontan' connections by echocardiography

Double discordance (atrioventricular and ventriculoarterial discordance)

- Anatomy and different variants
- Echocardiographic evaluation
- Surgical and interventional treatments: echocardiographic aspects
- Aspects of long-term follow up of unoperated patients
- The double switch procedure: pre-operative and post-operative echocardiographic considerations

Ebstein Malformation of the tricuspid valve (see valvular disease)

D. Congenital valvular disease

Congenital mitral valve disease

- Anatomy and different variants of mitral valve anomalies
- Mitral valve prolapse: definition and echocardiographic aspects
- Echocardiographic evaluation of mitral valve disease
- Qualitative description of valve and sub-valvular apparatus
- Measurement of orifice area by planimetry
- Doppler assessment of mean and end-diastolic gradient
- Doppler assessment of area by 'pressure half-time': technique and limitations
- Echocardiographic aspects of surgical mitral valve repair
- Echocardiographic evaluation of prosthetic mitral valves

Congenital aortic valve disease

- Anatomy of aortic valve abnormalities
- Assessment of severity of aortic valve disease
 - Peak and Mean gradients
 - Apical, right parasternal and suprasternal positions
 - Continuity equation

- Assessment of left ventricular hypertrophy and function
- Percutaneous and surgical techniques for aortic valve repair and replacement: echocardiographic aspects
- Echocardiographic evaluation of prosthetic aortic valves
- Echocardiographic evaluation of the postoperative Ross patient
- Effect of aortic valve disease on the aortic root
- Associated left ventricular outflow tract problems

Congenital pulmonary valve disease

- Anatomy of pulmonary valve disease
- Echocardiographic assessment of severity
- Percutaneous and surgical techniques
- Echocardiographic evaluation of treatment

Congenital tricuspid valvular disease (especially Ebstein malformation)

- Anatomy of Ebstein malformation and different variants
- Echocardiographic evaluation of Ebstein malformation
- Surgical/other treatment options for Ebstein malformation
- Other congenital tricuspid valve lesions

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

E. Left ventricular outflow tract obstruction

Aortic valve disease (see supra)

Subvalvular aortic stenosis

- Anatomy and variants
- Associated lesions
- Echocardiographic assessment of severity
- Evaluation of surgical treatment

Supravalvular aortic stenosis

- Anatomy and variants
- Associated lesions
- Echocardiographic assessment of severity
- Evaluation of surgical treatment

Coarctatio of the aorta

- Different morphological types and sites
- Echocardiographic imaging planes
- Different echocardiographic appearances
- Spectral Doppler appearances
- Peak velocity and diastolic pattern
- Relationship to measured gradient
- Relationship to severity of obstruction
- Effect of arterial duct on imaging and Doppler appearances
- Percutaneous and surgical treatment: echocardiographic aspects
- Evaluation of the patient treated for coarctation of the aorta

Interrupted aortic arch

- Different morphological types and sites
- Echocardiographic diagnosis
- Associated lesions
- Surgical treatment: echocardiographic aspects and imaging the postoperative patient

F. Right ventricular outflow tract obstruction

Pulmonary valve stenosis (see supra)

Subvalvular stenosis (infundibular stenosis, double chambered right ventricle)

- Anatomy and variants
- Associated lesions: tetralogy of Fallot, double outlet RV, VSD
- Echocardiographic evaluation of severity
- Post operative evaluation

Supravalvular stenosis and peripheral branch stenosis

- Anatomy and variants
- Associated lesions: tetralogy of Fallot, double outlet RV, supra-valvular AS
- Echocardiographic evaluation of severity

G. Congenital coronary anomalies

- Anatomy and variants
- Echocardiographic evaluation
- Echocardiographic aspects of surgical and interventional treatments

H. 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

I. Miscellaneous congenital lesions: anatomy, variants echocardiographic aspects of diagnosis and treatment

Cor-triatritum dexter and sinister

- Anatomy and echocardiographic appearance

Intracardiac Masses

- Typical locations for intracardiac tumours
- Echocardiographic features intracardiac tumours
- Differentiation of 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

Pulmonary Hypertension not related to congenital heart disease

- 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

Part VI. Acquired heart disease in paediatrics and congenital heart disease

Kawasaki disease

- Diagnostic echocardiographic criteria
- Echocardiographic follow-up

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
- Diagnostic echocardiographic criteria
- Echocardiographic follow-up

Rheumatic fever

- Diagnostic criteria
- Typical echocardiographic appearance
- Evaluation of severity
- Echocardiographic follow-up

Intravascular thrombosis

- Diagnostic echocardiographic criteria
- Echocardiographic follow-up

Part VII. Cardiac functional evaluation in paediatric and congenital heart disease

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 measurements and/or calculations

Doppler determination of cardiac output, diastolic function, pulmonary hypertension

- Echocardiographic calculation of cardiac output
- 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