Transeosophageal echocardiography in neonates, infants and children: applicability and diagnostic value in everyday practice of a cardiothoracic unit

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Abstract

Objective—To determine the applicability of and information obtained by transeosophageal echocardiography in neonates, infants, and children in every day practice of a cardiothoracic unit.

Design—Four month prospective study.

Setting—Supraregional centre for paediatric cardiothoracic services.

Patients and methods—58 patients aged between four days and 16 years with a wide range of cardiovascular disease underwent transeosophageal echocardiography under sedation or general anaesthetic. One of two paediatric probes (6 or 7 mm diameter), or an adult probe (13 mm in diameter) was used. Whenever possible the investigation was immediately preceded by precordial echocardiography.

Main outcome measures—Success, failure, technical difficulties, and complications of probe introduction and, when possible, comparison of the information obtained with that obtained from precordial echocardiography.

Results—Introduction of the probe was successful in 57 of the 58 patients. The only complication encountered was transient bradycardia during manipulation of the probe in a 2·2 kg baby. The adult (13 mm) probe was successfully used in children as small as 7·0 kg. Below this weight a smaller paediatric probe was required. In 56% of cases transeosophageal ultrasound provided information not obtained from the precordial approach. The technique was of particular value perioperatively and in the immediate postoperative period in neonates and infants and in the presence of valve prostheses and the investigation of mediastinal tumours in older children.

Conclusions—Transeosophageal echocardiography is a valuable additional investigative tool for children of all ages. It is of particular value when aquisition of precordial image is impaired around the time of and after operation and in children with prosthetic valves or mediastinal tumour. Image quality was superior with the adult probe and we recommend the use of this probe unless the patient's weight is below 7 kg, when a paediatric probe allows this technique to be used usefully and safely in babies as small as 2·2 kg.

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Transoeosophageal echocardiography is a well established technique in adults. Studies in children have been limited in the main to older subjects undergoing surgical repair of congenital cardiac defects and in the assessment of a variety of specific cardiac defects, usually in the cardiac catheterisation laboratory. The role of the transoeosophageal approach remains uncertain outside the operating theatre, especially in children under 20 kg.

Study of small children has become possible with the development of smaller transducers and we report our initial experience with the use and application of newly available paediatric transducers as well as adult transducers in a population of children with a wide range of age and pathology.

Patients and methods

Fifty eight children aged between 4 days and 16 years whose weights ranged from 2 to 63 kg were studied. Thirty one of the children were under 5 years of age. Table 1 summarises the clinical settings of each investigation. Thirty nine children had congenital heart disease of whom 28 had undergone surgical treatment including one who was studied shortly after cardiac transplantation. Seven of the children had prosthetic heart valves (five mitral, two aortic), of whom four were studied in the immediate postoperative period, two because of late development of prosthetic valve regurgitation and one because of suspected endocarditis. Intraoperative assessment was made in one child during surgery for obstructive hypertrophic cardiomyopathy. Echocardiographic study in the cases of suspected endocarditis was made before the availability of results of blood culture.

Twenty eight of the children were investigated under sedation and were ventilated on the intensive care unit, 25 of these were in the early postoperative period. Twenty seven children were under general anaesthesia either in the catheter laboratory or the operating theatre and the remaining three studies were performed under intravenous sedation alone with midazolam. Paediatric transducers (Hewlett
Packard or Aloka with respective diameters of 6 mm and 7 mm) were used in 21 of the examinations and a standard adult transducer of diameter 13 mm (Hewlett Packard) was used in 37.

Introduction of the probe in very young children was often facilitated by guiding the transducer tip into the upper oesophagus with a finger placed on the epiglottis. Preoperative echocardiograms were performed in 52 cases immediately before the transoesophageal study, and the results of the two investigations were compared. Six children did not have preoperative studies performed immediately before transoesophageal study because of restricted access to the chest wall in the theatre or catheter laboratory.

Results
Transoesophageal echocardiography was successfully performed in 57 of the 58 children; the one failure was due to inability to pass the probe into the oesophagus of a 2 kg baby with an endotracheal tube in place. The paediatric probes were used in children ranging from 2.2 to 13.5 kg and the adult probe in others ranging from 7.0 to 63 kg. The only adverse effect of probe introduction was transient bradycardia during manipulation of the probe in a 2.2 kg baby. The investigation was none the less completed by reducing movement of the probe to a minimum. Transoesophageal images that added diagnostic information to images obtained from the precordium were obtained in 29 (56%) of the 52 cases who had the two studies performed nearly simultaneously (table 2).

Early postoperative studies
Six patients were studied to assess ventricular function because of poor clinical progress associated with low cardiac output. In five of these, including one cardiac transplant recipient, precordial images were inadequate due to mediastinal air and the position of drains. In all six cases clear images were obtained with the transoesophageal approach, even when the sternum had been left open. In one child extremely poor left ventricular function was found along with a mobile blood clot in the left ventricle that was invisible on precordial study. Four patients were investigated to assess prosthetic valve function; one had undergone emergency valve replacement for endocarditis. In all four cases there were regurgitant jets that had not been seen in the precordial study. Four children were investigated to assess repair of ventricular or atrioventricular septal defect, and although transoesophageal image quality was high, it did not provide any useful additional information when compared with the precordial study. Three patients were studied to assess venous return after Senning operation (2) or repair of total anomalous pulmonary venous drainage (1). Precordial echo image quality in these was poor, but the transoesophageal approach showed clear pulmonary and systemic venous channels and flow patterns (fig 1) in the children with transposition, and detection of pulmonary venous obstruction (leading to reoperation) in the child with anomalous pulmonary venous drainage. Assessment after Fontan operation in one child gave detailed images of the atrio pulmonary anastomosis which was not possible precordially due to mediastinal air. This was also the case in a patient after correction of double outlet right ventricle with pulmonary stenosis, where transoesophageal study showed a good surgical result but also a small shunt from the coronary sinus to the left atrium that had not been appreciated at cardiac catheterisation and angiography.

Three children were studied to assess patency of aortopulmonary shunts but this was only possible in one case by transoesophageal echocardiography, where a central shunt had been used. Similarly after repair of coarctation of the aorta, the transoesophageal approach failed to add any additional information.

Suspected bacterial endocarditis
Of the seven patients with suspected endocarditis, three subsequently had positive blood cultures (one with ventricular septal defect, one with aortic valve replacement and one with a right Blalock-Taussig shunt). No vegetations were seen at precordial echocardiography in these cases, but the transoesophageal approach showed vegetations on the ventricular septum in the first case and on the aortic valve prosthesis in the second. Although shunt flow in the right pulmonary artery was clearly seen with colour flow Doppler in the third case, anatomical detail of the shunt was not visible and no vegetations were seen. In another child with a Blalock-Taussig shunt we were again unable to get an image of the shunt itself, even in its distal part.

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| Table 2 | A summary of the 29 cases in which transoesophageal imaging provided information unavailable from precordial echocardiography. Results from both imaging approaches were compared in the 52 children who underwent near simultaneous precordial and transoesophageal study |
|---------|-----------------|--------------------------------------------------|
| Clinical setting | No of cases | Additional information from transoesophageal study |
| Early postoperative period | 12 | Imaging of intracardiac venous pathways, evaluation of ventricular function, detection of intracardiac thrombus, detection of paraprosthetic mitral regurgitation. |
| Diagnostic catheterisation | 9 | Imaging of intracardiac venous pathways, assessment of atrial shunts, assessment of subaortic stenosis. |
| Mediastinal mass or trauma | 3 | Extensive cardiac infiltration detected, extent of right atrial tumour clearly seen, useful in guiding transvenous biopsy of right atrial mass, diagnosis of aortic rupture and mediastinal haematomata. |
| Suspected endocarditis | 2 | Vegetations seen in both cases. |
| Late prosthetic valve malfunction | 2 | Detection of aortic prosthesis dehiscence, valve regurgitation. |
| Suspected tricuspid valve abnormality | 1 | Tricuspid chordal attachments clearly traced. |
patient with a Mustard operation was, however, facilitated by transoesophageal imaging and widening of the venous channel (seen particularly well with colour flow imaging) was clearly recognisable immediately after balloon deflation. Before pericardial drainage transoesophageal imaging allowed the posterior pericardium to be clearly seen in a search for a tumour, and needle tip position was fairly easily monitored, although this probably contributed little to the safety of the procedure.

Diagnostic catheter procedures
In six patients precordial imaging showed dilatation of the right heart chambers but no apparent cause. Three had clinical signs suggesting atrial septal defect. In two cases transoesophageal echocardiography showed sinus venosus atrial septal defects with associated anomalous pulmonary venous drainage in one. In the other four, the only abnormality at transoesophageal study was a patient oval fossa with very small left to right shunts in each case. This negated the need to proceed to a catheter study.

Two patients had suspected obstruction of the pulmonary venous channel after Senning operations and in each case transoesophageal echocardiography provided more detailed images of the pulmonary venous channels than did the precordial approach. In one instance transoesophageal Doppler echocardiography enabled detailed anatomical assessment of the obstruction where precordial Doppler had failed and in the other it showed a small baffle leak not found precordially.

In two children with complex cardiac defects transoesophageal study gave anatomical information about the atrioventricular valves not apparent from the precordium. This led to diagnosis of a straddling AV valve in one case and a double orifice mitral valve in the other.

Improved morphological assessment of subaortic stenosis was documented in one child.

MEDIASTINAL PATHOLOGY AND TUMOURS
In a child with extensive trauma of the head and neck precordial echocardiography was normal but the transoesophageal study showed an intimal flap in the descending thoracic aorta and posterior mediastinal haematoma due to dissection and rupture of the aorta, prompting urgent surgical treatment. In a child with precordial echocardiographic findings of an intra-atrial mass, transoesophageal study showed better the extent of the tumour in the right atrium and allowed guided biopsy of the tumour. In a child presenting with acute breathlessness and clinical signs of pulmonary hypertension the transoesophageal study showed extensive mediastinal tumour surrounding the branch pulmonary arteries and extensive invasion of the atrial walls and atrial septum; the only abnormality visible on the precordial study was right ventricular hypertrophy and dilatation (fig 2).

LATE PROSTHETIC VALVE MALFUNCTION
Partial dehiscence of an aortic valve after an
mediastinal regurgitation,1 in the detection of vegetations and other consequences of bacterial endocarditis,2 in the evaluation of thoracic aortic pathology,3 in intraoperative monitoring of left ventricular function,4 and in valve repair.5

In children studies have concentrated mainly on intraoperative assessment of surgical correction of congenital heart disease6 and most studies have been limited to older children due to the size of the widely available adult transoesophageal probes.6 More recently transoesophageal imaging has been found of benefit in the assessment of fixed subaortic obstruction,7 after Fontan operations,8 and in the assessment of anomalous systemic and pulmonary venous connections.9 The advent of smaller probes has extended the potential use of the technique to younger age groups but the indications for study in children less than 20 kg remains to be defined.10

We were able to examine a child of 2.2 kg with the 7 mm diameter probe although we were unsuccessful in a 2 kg baby, largely due to the presence of an endotracheal tube. The smallest child studied with the 13 mm adult probe was 7.0 kg showing that adult equipment may be used safely in comparatively small children. The procedure was well tolerated and clear images of the heart and great vessels were obtained in all cases, often providing information that was unobtainable from a standard precordial echocardiogram. This was particularly the case in the immediate postoperative period when precordial imaging was hampered by the presence of mediastinal air; transoesophageal study allowed rapid assessment of ventricular function and the results of surgical repair. Notable examples were the assessment of systemic or pulmonary venous flow after surgical redirection, early detection of infective vegetations, and the detection of prosthetic valve regurgitation. The technique also enables echocardiographic monitoring during surgery or interventional catheterisation, providing rapid functional assessment of the procedure and complementing radiographic screening and angiography in balloon positioning, possibly making a contribution to the reduction of x-ray exposure to both patient and operator. We found this particularly useful in intra-atrial stenosis after the Mustard operation because of the high quality images obtained of the atrial anatomy. In the child with mediastinal lymphoma full sight of the extent and invasion of the tumour was possible only by the transoesophageal approach. Disappointingly peripheral systemic to pulmonary shunts were usually beyond the reach of the transoesophageal approach.

Tranoesophageal echocardiography is feasible and well tolerated even in the neonate and it frequently provides information which is unobtainable by precordial study. The 13 mm

Discussion
Tranoesophageal echocardiography is well established in the investigation of adult native and prosthetic valve regurgitation,1 in the detection of vegetations and other consequences of bacterial endocarditis,2 in the evaluation of thoracic aortic pathology,3 in intraoperative monitoring of left ventricular function,4 and in valve repair.5

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episode of endocarditis and a mitral paraprosthetic leak in a child with a murmur of uncertain aetiology were both detected by transoesophageal study but not by precordial study.

STUDIES BEFORE AND DURING OPERATION
In a case of transposition of the great arteries and ventricular septal defect precordial echocardiography of suboptimal image quality had suggested the possibility of straddling of the tricuspid valve. Tranoesophageal study allowed detailed inspection of the chordal anatomy that was normal. Perioperative transoesophageal study of a three year old undergoing left ventricular outflow resection for hypertrophic cardiomyopathy and mitral regurgitation allowed monitoring of the effect of muscle resection, which was accompanied by dramatic improvement in severity of mitral regurgitation detected by colour flow imaging. An elective decision to replace the mitral valve was abandoned and the mitral valve was conserved with an excellent postoperative result.
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A probe can be safely passed in children as small as 7 kg but for those under this weight, a paediatric probe should be used and this will allow investigation of babies as small as 2.2 kg.

It is therefore of value in children under certain circumstances—namely, in the immediate postoperative period, in the presence of prosthetic valves and atrial or mediastinal pathology, or suspected endocarditis, where the benefits are the same as for adult patients.

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