Detection of ostium secundum atrial septal defects by transoesophageal cross-sectional echocardiography

PETER HANRATH, MICHAEL SCHLÜTER, BURKHART A LANGENSTEIN, JULIA POLSTER, STEFAN ENGEL, PETER KREMER, HANS-JOACHIM KREBBER

From the Departments of Cardiology and Cardiac Surgery, University Hospital, Hamburg – Eppendorf, Federal Republic of Germany

SUMMARY Transoesophageal cross-sectional echocardiography has special advantages when investigating the interatrial septum which is imaged perpendicularly without echo dropouts from an oesophageal transducer position. The technique was successfully used in 19 out of 20 patients (95%) with an ostium secundum atrial septal defect and in 30 control subjects. In all of the latter the interatrial septum was visualised as a continuous echo structure separating the atria, whereas a distinct discontinuity representing the septal defect was apparent in all patients with atrial septal defect. Echocardiographic measurement of the defect size correlated well with surgical findings in 11 patients who underwent open heart surgery in the course of this study. In a comparative transthoracic examination, adequate recordings were obtained in 18 of the 20 patients and in 26 of the 30 control subjects. Direct subcostal visualisation of the defect was reliable in 10 of 18 patients.

Peripheral venous contrast studies were also performed with the transoesophageal as well as the transthoracic technique. Echo contrast remained confined to the right heart in the control subjects. Left sided contrast appearance diagnostic of an interatrial communication was shown in the patients using the transoesophageal technique (100% sensitivity), with an additional right atrial negative contrast apparent in seven patients. The transthoracic approach, on the other hand, showed left sided echo contrast in 14 of 18 patients and an additional negative contrast effect in two of the 14. It is concluded that transoesophageal is superior to transthoracic cross-sectional echocardiography as a highly sensitive method for the detection and evaluation of ostium secundum atrial septal defects.

Imaging of the interatrial septum by two dimensional echocardiography in normal and pathophysiological states is possible from various thoracic transducer positions.1–6 Because, however, the ultrasonic beams generally do not hit the interatrial septum perpendicularly, echo dropouts quite frequently give false positive appearances of septal defects.7,8 Even though the subcostal transducer position does put the interatrial septum perpendicular to the sound energy, reliable detection of an atrial septal defect remains difficult in adults and is less successful than in children.

Contrast echocardiography9–12 with its ability to detect shunts using the recording of peripherally injected echo contrast appearing on the left side of the heart has therefore gained in importance, but ultrasonic contrast in the left atrium may be caused by a patent foramen ovale, and it is not, therefore, an indication of a pathological state of the interatrial septum.13

In order to avoid these ambiguities we used transoesophageal cross-sectional echocardiography14 to assess its sensitivity in the direct visualisation of atrial septal defects. In addition, peripheral venous contrast studies were performed. The results were compared with those obtained from analogous transthoracic investigations.

Patients and methods

Between April and December 1981, 20 patients (eight men; 12 women), age range 18 to 65 years (mean 41 years), were studied. One of these had to be excluded from the transoesophageal study because of adverse reactions to the gastroscopic procedure, and two others had non-diagnostic transthoracic recordings. All patients had a dominant left to right shunt deter-
Transoesophageal two dimensional echo in secundum atrial septal defects

Table  Haemodynamic and echocardiographic findings in 20 patients with ostium secundum septal defect

<table>
<thead>
<tr>
<th>No.</th>
<th>Age/Sex</th>
<th>Pulmonary artery pressures (mmHg)</th>
<th>Shunt size by oximetry (%)</th>
<th>Direct visualisation of ASD</th>
<th>Contrast echo studies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Syst./Dia. Mean</td>
<td>L→R</td>
<td>R→L</td>
<td>Transoesophageal LAEC</td>
</tr>
<tr>
<td>1</td>
<td>20 F</td>
<td>32/12</td>
<td>19</td>
<td>60</td>
<td>Φ</td>
</tr>
<tr>
<td>2</td>
<td>35 F</td>
<td>20/5</td>
<td>11</td>
<td>65</td>
<td>Φ</td>
</tr>
<tr>
<td>3</td>
<td>65 M</td>
<td>29/6</td>
<td>16</td>
<td>57</td>
<td>Φ</td>
</tr>
<tr>
<td>4</td>
<td>18 F</td>
<td>16/8</td>
<td>13</td>
<td>54</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>41 M</td>
<td>29/9</td>
<td>15</td>
<td>64</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>60 F</td>
<td>20/8</td>
<td>14</td>
<td>43</td>
<td>Φ</td>
</tr>
<tr>
<td>7</td>
<td>61 F</td>
<td>20/8</td>
<td>14</td>
<td>45</td>
<td>Φ</td>
</tr>
<tr>
<td>8</td>
<td>20 M</td>
<td>22/8</td>
<td>12</td>
<td>79</td>
<td>Φ</td>
</tr>
<tr>
<td>9</td>
<td>36 F</td>
<td>20/6</td>
<td>11</td>
<td>33</td>
<td>Φ</td>
</tr>
<tr>
<td>10</td>
<td>43 M</td>
<td>30/10</td>
<td>14</td>
<td>56</td>
<td>Φ</td>
</tr>
<tr>
<td>11</td>
<td>32 M</td>
<td>30/12</td>
<td>15</td>
<td>64</td>
<td>Φ</td>
</tr>
<tr>
<td>12</td>
<td>21 F</td>
<td>20/6</td>
<td>10</td>
<td>41</td>
<td>Φ</td>
</tr>
<tr>
<td>13</td>
<td>25 M</td>
<td>17/5</td>
<td>10</td>
<td>42</td>
<td>Φ</td>
</tr>
<tr>
<td>14</td>
<td>43 F</td>
<td>50/10</td>
<td>18</td>
<td>92</td>
<td>Φ</td>
</tr>
<tr>
<td>15</td>
<td>52 F</td>
<td>42/20</td>
<td>26</td>
<td>36</td>
<td>Φ</td>
</tr>
<tr>
<td>16</td>
<td>59 F</td>
<td>32/13</td>
<td>20</td>
<td>30</td>
<td>Φ</td>
</tr>
<tr>
<td>17</td>
<td>30 F</td>
<td>16/5</td>
<td>10</td>
<td>50</td>
<td>Φ</td>
</tr>
<tr>
<td>18</td>
<td>59 M</td>
<td>90/30</td>
<td>50</td>
<td>75</td>
<td>67</td>
</tr>
<tr>
<td>19</td>
<td>60 F</td>
<td>22/6</td>
<td>10</td>
<td>77</td>
<td>22</td>
</tr>
<tr>
<td>20</td>
<td>37 M</td>
<td>21/6</td>
<td>10</td>
<td>71</td>
<td>Φ</td>
</tr>
</tbody>
</table>

LAEC, left atrial echo contrast; RANC, right atrial negative contrast. * 2D images not suitable. □ Transoesophageal 2D images not obtainable.

mined by oximetry at cardiac catheterisation. An additional right to left shunt was present in two patients (Table). The measured magnitudes of shunts were:

L → R: 30 to 92% (mean 57%)
R → L: 22 and 67%

The diagnosis of an ostium secundum atrial septal defect was confirmed in each patient by cardiac catheterisation and cineangiography.

The control group consisted of 11 women and 19 men. The mean age of this group was 45 years (range: 17 to 81 years). These subjects were patients with various forms of heart disease (coronary artery disease, mitral and aortic valve diseases) who were shown at cardiac catheterisation to have an intact interatrial septum.

All echocardiographic examinations were performed on a Varian 3400 or 3400 R phased array sector scanner within 48 hours of cardiac catheterisation. A 2-2.5 MHz transducer was used for the transthoracic examinations, while the transoesophageal studies were done with a miniature 3-5 MHz transducer array of 32 elements, fitted to the distal end of a conventional 9 mm endoscope. All two dimensional echocardiographic recordings were stored for subsequent analysis on a one inch video tape recorder.

Before the ultrasound investigation, the patients had to undergo a barium x-ray examination in order to exclude a diverticulum of the oesophagus. They were fasted for about eight hours. The premedication consisted of 0.5 mg atropine sulphate subcutaneously (to avoid hypersalivation and reflex bradycardia) and 5 to 10 mg diazepam intravenously. The gastroscope was introduced in a blind manner, with the patient in a supine position. Informed written consent was obtained from all patients.

After insertion of the gastroscope to about 40 cm from the patient's teeth, the aortic root with the cusps of the aortic leaflets was seen (Fig. 1). Further advancement of about 1 cm and a slight clockwise rotation of the gastroscope imaged both atria and the interatrial septum. By up and down shifts of the gastroscope within the oesophagus the total length of the septum could be scanned in a cranio-caudal direction in order to detect the maximal size of the atrial septal defect. Estimation of the size was obtained by measuring the distance between the two margins of the interatrial septum at end-systole directly from a video monitor stop frame of the calibrated cross-sectional echocardiogram. Whenever possible, both axes of the generally oval shaped defects were also measured at operation.

When an optimal transducer position for the visualisation of the defect was found, 10 ml of cold 0-9% saline were rapidly injected into an upper extremity vein through a 17-gauge plastic cannula to produce positive echo contrast in the left atrium or negative echo contrast in the right atrium. For the transoesophageal examination technique an average of three peripheral saline injections was sufficient to confirm shunting of blood at atrial level. All contrast...
Fig. 1 Video stop-frame image of transoesophageal cross-sectional echocardiogram at the level of the aortic root in diastole. All three cusps are visible, as well as the anterior mitral leaflet, the right ventricular outflow tract (RVOT), and parts of the left atrium (LA) and the left ventricular outflow tract (LVOT).

Fig. 2 Video stop-frame of transoesophageal cross-sectional echocardiogram in a patient with an intact interatrial septum. Note the proximity of the left atrium to the ultrasonic transducer at the sector apex and the horizontal echo image of the interatrial septum with a thinning at the level of the foramen ovale. LA; left atrium, RA; right atrium, RV; right ventricle.
Transoesophageal two dimensional echo in secundum atrial septal defects

Fig. 3 Transoesophageal cross-sectional image of an ostium secundum atrial septal defect. The large echo-free space between the two margins of the interatrial septum is clearly visible. (Abbreviations see Fig. 2.)

studies during transoesophageal imaging were performed under normal respiration.

After the transoesophageal investigation, patients were studied in a supine or a 30° left lateral position from three standard thoracic transducer locations (apical four chamber, subcostal four chamber, and parasternal short axis view), of which the subcostal location proved to be the most satisfactory for studies of the interatrial septum. Two elderly emphysematous patients were excluded from the transthoracic study because of insufficient two dimensional imaging; thus recordings of acceptable quality were obtained in 18 of the 20 patients. In the control group of patients, 26 of 30 showed good quality echocardiograms from external transducer positions.

In all cases of adequate transthoracic imaging of the interatrial septum, echo contrast studies with an average of three peripheral venous injections of saline were subsequently performed.

The diagnosis of atrial level shunting was based on the presence of one or more microbubbles in the left atrium and/or the left ventricle, agreed upon by at least two independent observers who were unaware of the diagnosis.

Results

The transoesophageal and the transthoracic ultrasonic

findings as well as the haemodynamic data are listed in the Table for all 20 patients.

Using the transoesophageal technique, the interatrial septum could be imaged in total in all control
Fig. 5  Peripheral venous contrast study in a patient with an intact interatrial septum. Transoesophageal cross-sectional image shows echo contrast entering the right atrium, while the left atrium remains echo-free. (Abbreviations, see Fig. 2, except for Ao: aorta.)

Fig. 6  Passage of echo contrast from the right into the left atrium across an ostium secundum atrial septal defect. Transoesophageal cross-sectional images from the same patient show both atria and a large septal defect before (upper panel) and after peripheral venous injection of saline (lower panel). (Abbreviations see Fig. 2.)
Transoesophageal two dimensional echo in secundum atrial septal defects

Fig. 7  Transoesophageal cross-sectional view of a negative contrast effect in the right atrium. Echo-free blood streaming from the left atrium across the atrial septal defect “washes out” echo contrast in the right atrium. (Abbreviations see Fig. 2.)

subjects as well as in all 19 patients who underwent the examination. In all subjects with no evidence of an atrial septal defect the interatrial septum was seen to rise from the atrioventricular junction to the roof of both atra. Fig. 2 is a representative recording of an intact interatrial septum showing the relation with adjacent anatomical structures and a characteristic thinning of the wall within the foramen ovale.

In each of the 19 patients with a secundum atrial septal defect a discontinuity in the echoes from the interatrial septum was noted. The defects differed in end-systolic size between 13 and 41 mm. Fig. 3 is a characteristic transoesophageal cross-sectional echocardiogram of a patient with such a defect, where the echoes of the central part of the interatrial septum are missing and those of the cranial as well as the caudal margin of the septum can be seen.

Eleven patients underwent open heart surgery for closure of the septal defect, thus enabling transoesophageal echocardiographic measurements of the defect size to be compared with surgical findings. Data were analysed by linear regression and Student’s t test (Fig. 4) and disclosed a correlation coefficient of r=0.85 (p<0.001), a regression line (y=1·1x − 2·5 mm) very close to the line of identity, and a standard error of the estimate (SEE) of 4·5 mm, corresponding to a mean echocardiographic error of about 17%.

The transoesophageal echo contrast study showed that in the control group of patients with no atrial shunting intracavitary echo appearance remained confined to the right atrium and to the right ventricular inflow tract (Fig. 5). This right sided contrast effect cleared rapidly, usually after three to six cardiac cycles.

In all 19 patients, despite dominant left to right shunting, a small right to left passage of echo contrast across the atrial septal defect could be seen (Fig. 6). This passage was largest in the two cases where a right to left shunt (apart from the predominant left to right shunt) was determined by oximetry. An additional negative contrast effect was observed in seven patients (37%), as blood without microcavitations streamed from the left into the right atrium (Fig. 7).

Standard transthoracic echocardiography, on the other hand, was successful only in a certain proportion of patients. An atrial septal defect could be reliably visualised from the subcostal transducer position in 10 of the 18 patients (56%) who had good quality cross-sectional echocardiograms. Echo contrast on the left side of the heart was seen in 14 patients (78%). In two of these an additional negative contrast effect in the right atrium was detected (11%). The remaining four patients showed neither left sided echo appearance nor a negative right atrial contrast effect on transthoracic echocardiography.

Discussion

The purpose of this paper was to investigate a new echocardiographic technique for the detection of
ostium secundum atrial septal defects. The major advantages of the oesophageal phased array system are the small dimensions of the transducer head (15 mm wide, 16 mm thick, and 35 mm long), which represents the only rigid part of our ultrasonic endoscope, the absence of mechanically moving parts that might cause patient irritation, and the absence of a sound coupling oil bag, since close contact between the transducer surface and oesophageal wall is established by transducer angulation. Furthermore, the line density within the sector image is higher than in rotating scanner systems,\textsuperscript{16} thus giving rise to a clearer definition of structural borders.

The transoesophageal cross-sectional imaging technique offers a view of the heart unrestricted by lung tissue, or anatomical malformations of the thorax. It is particularly advantageous in imaging the interatrial septum, since an oesophageal transducer faces this cardiac structure nearly perpendicularly at a relatively short distance. As a consequence, the image quality is superior to transthoracic recordings and echo drop-outs are virtually non-existent. By advancement, withdrawal, and slight rotation of the transducer gastroscope system the total length of the interatrial septum can be imaged and scanned for septal defects. In all 19 patients included in the transoesophageal study we were able to visualise the defect directly as a discontinuity in the two dimensional image of the interatrial septum.

End-systolic diameters of defects could be determined and were compared with surgical findings in 11 patients. The regression analysis showed that, on an average, there was little difference between echocardiographic and surgical measurement of atrial septal defect size, confirming the higher spatial resolution of the system.

Several echocardiographic contrast studies\textsuperscript{17-19} have shown that even with a predominant left to right shunt a small amount of contrast passes from the right into the left atrium in the majority of patients with atrial septal defects. This finding was confirmed in our study with a sensitivity of 100% for the transoesophageal examination.

Using transthoracic echocardiography, we were able to visualise reliably the atrial septal defect from the subcostal transducer position in 10 of 18 patients (56%). Appearance of echo contrast on the left side of the heart, after peripheral venous injection of saline, was observed in 14 of 18 patients, that is with a sensitivity (78%) which is considerably lower than for the transoesophageal approach.

When the Valsalva manoeuvre is carried out transthoracic sensitivity can be increased, yet this may well be the result of false positive diagnoses, since a patent foramen ovale is present in about 25% of normal subjects.

Recent studies have shown\textsuperscript{20} that even without Val-
salva provocation left sided echo contrast can be seen in healthy subjects with a patent foramen ovale. Thus, only in combination with a direct visualisation of the atrial septal defect through which echo contrast is seen to pass can left sided echo appearance be regarded as a diagnostic sign of a pathological interatrial communication. This feature was always seen in patients with secundum atrial septal defect who underwent transoesophageal echocardiographic examination.

The standard method of verifying clinical suspicion of an ostium secundum atrial septal defect is right heart catheterisation and angiography, a technique that, in general, has a very low risk of major complications.\textsuperscript{21} The rate of complications occurring in oesophagoscopies was reported to be of the same order of magnitude.\textsuperscript{22} The information given by transoesophageal echocardiography is both different and complementary to that obtained at catheterisation. It is the shunt size and not the physical size of the defect which is the important measure in the haemodynamic evaluation of an atrial septal defect. With the rapid development of echocardiographic equipment combining two dimensional cardiac imaging and multigated Doppler flowmetry, quantitative determination of atrial septal shunt volume using the transoesophageal approach appears promising, particularly with rotatable transducer arrays for biplane imaging of the defect and biplane flow measurements.

Important differential diagnoses of a secundum atrial septal defect are anomalous pulmonary veins and a sinus venosus defect. The former cannot be detected with transoesophageal echocardiography. Should they occur, however, in conjunction with an atrial septal defect, they are usually found and corrected at operation, since surgical access to an atrial septal defect is generally made from the right atrium under cardiopulmonary bypass. Based on our preliminary results with sinus venosus and ostium primum defects (see addendum), we believe that there is no difficulty in differentiating the three types of atrial septal defect with the transoesophageal technique.

Transoesophageal echocardiographic examination is, of course, less pleasant than transthoracic echocardiography, and we do not suggest that the technique should become routine in the assessment of atrial septal defects, but we feel that it is indicated in patients with inadequate or non-diagnostic transthoracic recordings.

In summary, transoesophageal cross-sectional echocardiography permits the complete and highly sensitive evaluation of the interatrial septum, in a direct way as well as in a peripheral venous contrast study. Even though, at present, a determination of
Transoesophageal two dimensional echo in secundum atrial septum defects

Fig. 8 Transoesophageal cross-sectional images of a sinus venous defect (top panel) and an ostium primum defect (bottom panel).

shunt size is not possible, the method compares favourably with right heart catheterisation, particularly prospectively, when future technological improvements such as reduction of transducer and gastroscope size, use of rotatable transducer arrays, and incorporation of multigated Doppler systems are considered.

Addendum

While this study was being undertaken, we were able to study one patient with an ostium primum defect and one with a sinus venous defect. Both cases were correctly identified (Fig. 8).

References

19 Serruys PW, van den Brand M, Hugenholtz PG,


Requests for reprints to Professor P Hanrath, Department of Cardiology, University Hospital Eppendorf, Martinistrasse 52, D-2000 Hamburg 20, Federal Republic of Germany.
Detection of ostium secundum atrial septal defects by transoesophageal cross-sectional echocardiography.
P Hanrath, M Schlüter, B A Langenstein, J Polster, S Engel, P Kremer and H J Krebber

Br Heart J 1983 49: 350-358
doi: 10.1136/hrt.49.4.350

Updated information and services can be found at:
http://heart.bmj.com/content/49/4/350

These include:

Email alerting service
Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/