Usefulness of real-time three-dimensional transoesophageal echocardiography in the assessment of chronic aortic dissection

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Aims
To assess the usefulness of three-dimensional transoesophageal echocardiography (3D-TOE) vs. two-dimensional (2D)-TOE in the evaluation of morphological and dynamic findings of aortic dissection, and compare the results with those obtained by multi-slice computed tomography (CT).

Methods and results
Twenty-six patients (21 men and 5 women, median age: 67 years, range: 28–74 years) diagnosed of chronic aortic dissection with patent false lumen were studied. A comprehensive 2D-TOE and a real-time 3D-TOE study targeted at assessing dissection variables were performed and compared with CT within 3 months. Both 3D-TOE and 2D-TOE visualized the intimal flap extension and presence of flow in aortic dissection lumina in the same aortic segments. Three-dimensional TOE correctly identified true lumen in all cases, being superior to 2D-TOE in three cases with a spiroidal course of the dissection in descending aorta. Maximum entry tear diameter measured by 3D-TOE showed a better correlation with CT than 2D-TOE (0.96 and 0.87, P < 0.001, respectively). Compared with CT, 2D-TOE underestimated maximum entry tear diameter (−1.75 ± 3.28 mm, P < 0.01) but 3D-TOE did not (−0.20 ± 1.92 mm, P: n.s.). However, entry tear area measured by 3D-TOE and CT showed the best correlation (r: 0.97) and agreement (0.05 ± 0.20 cm², P: n.s.).

Conclusion
Three-dimensional TOE provides additional information to 2D-TOE in aortic dissection assessment, particularly in entry tear size quantification. Agreement between entry tear area defined by 3D-TOE and CT was excellent. Three-dimensional TOE permits better morphological and dynamic understanding of aortic dissection when the flap is spiroidal.

Keywords
Three-dimensional transoesophageal echocardiography • Aortic dissection

Introduction
Since the multicentre European study was published by Erbel et al.¹ in 1990, several studies have shown the usefulness of transoesophageal echocardiography (TOE) in the diagnosis of aortic dissection. TOE is currently one of the reference techniques for aortic dissection assessment, with similar sensitivity and specificity to computed tomography (CT) and magnetic resonance imaging (MRI).²–⁴ However, information on some variables may be relevant to determine prognosis and indicate appropriate treatment.⁵–¹⁰ In this respect, extension of the dissection,⁶ maximum aortic diameter,⁶,⁷ entry tear location and size,⁶,⁷ true lumen identification,⁹,¹⁰ flow dynamics in both lumina,¹¹–¹³ and partial false lumen thrombosis are variables to be considered in aortic dissection assessment.¹³,¹⁴ Although three-dimensional (3D)-TOE has potential advantages over two-dimensional (2D)-TOE in several clinical applications,¹⁵–²¹ the usefulness of this new technology in aortic dissection assessment has been
only reported in some case reports, and remains to be determined.

The aim of the present study was to assess the usefulness of 3D-TOE vs. 2D-TOE in the evaluation of morphological and dynamic findings of aortic dissection, and compare the results with those obtained by multi-slice CT.

Methods

Twenty-six patients (21 men and 5 women, median age: 67 years; range: 28–74 years) diagnosed of chronic aortic dissection with patent false lumen were studied. Fourteen patients had undergone surgery for type A dissection and were discharged with patent false lumen dissection in descending aorta; 12 patients presented type B dissection and were treated medically. All patients were followed up at our centre every 6 months and were asymptomatic, showing adequate blood pressure control and stable findings on imaging techniques. The interval between 3D-TOE and acute phase was 9–38 months (median: 28 months). The Ethics Committee of our institution approved the protocol, and all patients gave their written consent to participate in the study.

Transoesophageal echocardiography

All echocardiographic studies were performed using the iE33 ultrasound system (Philips Medical System, Andover, MA, USA) equipped with a matrix-array X7–2t transducer (Philips Medical Systems). After a comprehensive 2D-TOE, a real-time 3D-TOE study targeted at assessing dissection variables was performed. Settings were optimized using the narrow acquisition mode and real 3D imaging of a pyramidal volume (around 30 × 60 × 80 mm3) of the aorta at the level of the structure to be analysed. When necessary, live 3D zoom was used with the volume adapted to the visualized structure up to 104. Frame rates were kept between 23 and 28 Hz and depth ~8–10 cm. Image processing was performed off-line at the workstation using the QLAB/3DQ module software (Philips Medical Systems). This workstation software allows any-plane reconstruction from the original pyramidal data set and was used to determine entry tear size.

Computed tomography

Multi-detector CT angiography was performed with a 16 detector Siemens Sensation, which produced 1 mm slices at 0.5 mm intervals (50% overlap), iodinated contrast material (100–120 mL) was injected at a 4–5 mL/s flow rate through a vein in the right arm to obtain a high-quality CT aortogram with no venous contrast artefacts from the innominate trunk obscuring the supra-aortic arteries. A bolus tracking method was used to trigger the CT scan when high aortic enhancement was reached. The aortography started at the ascending aorta and ended at the femoral arteries. The true lumen aortogram permitted the detection of intimal tears in the descending aorta, frequently associated with a jet of enhanced blood from the true to the false lumen (from high to low pressure). An additional second scan was performed discretionally to assess slow flow in the false lumen and the presence or evolution of false lumen thrombosis. The almost isometric resolution (0.4, 0.4, and 0.75 mm) of multi-detector CT permits reconstruction of the scanned volume along arbitrary planes. The image plane can be aligned with the intimal tear plane, so that its area can be measured with a polygon.

Imaging variables

The following variables were analysed: (i) extension of dissection throughout the aorta, (ii) true lumen identification, (iii) false lumen thrombosis, and (iv) location and size of the entry tear or the main residual communication between true and false lumina. To measure entry tear or the main communication size between lumina, two orthogonal planes were set through the entry tear. A third plane (perpendicular to the previous two planes) was set through the entry tear, and re-oriented as needed to ensure that the minimal orifice area was identified. Finally, entry tear area was planimetred. TOE results, both 2D and 3D, were compared with a multi-detector CT study performed at an interval <3 months, median 34 days.

Statistical analysis

Variables are expressed as proportions, mean and standard deviation, or median, and inter-quartile range as appropriate. Correlation between measurements obtained by different techniques was analysed and inter-modality agreement was evaluated by Bland–Altman plots. Differences were considered statistically significant at the two-sided P < 0.05 level. All computations were carried out with the SPSS 15.0 software.

Results

Both 3D-TOE and 2D-TOE visualized the intimal flap extension and presence of flow in aortic dissection lumina in the same aortic segments: 8 involved distal ascending aorta, 16 aortic arch, and 26 descending thoracic aorta (Figure 1). Three-dimensional TOE correctly identified the true lumen in all cases, being superior to 2D-TOE in three cases with a spiroidal course of the dissection in descending aorta (Figure 2). Three-dimensional and 2D-TOE correctly located the entry tear in all cases: distal ascending aorta in 6 cases, arch in 4, proximal descending aorta in 10, and medial descending aorta in 6 (Figure 3). Maximum entry tear diameter measured by 3D-TOE showed a better correlation with CT than 2D-TOE (0.96 and 0.87, P < 0.001, respectively). Two-dimensional TOE underestimated maximum entry tear diameter compared with CT (–1.75 ± 3.28 mm, P < 0.01) but 3D-TOE did not (–0.20 ± 1.92 mm, P: n.s.; Table 1; Figure 4A and B). The greatest discrepancies of 2D-TOE occurred in 6 of the 11 cases with non-circular entry tear (Figure 5). However, entry tear area measured by 3D-TOE and CT showed the best correlation (r:...
0.97) and agreement (0.05 ± 0.20 cm², P: n.s.; Figure 4C). One or more secondary tears were seen in 22 cases by both 2D and 3D-TOE but in only 14 cases by CT. Partial false lumen thrombosis was visualized in 15 cases by both 2D and 3D-TOE techniques and CT.

**Discussion**

The results of the present study show that 3D-TOE improves the information obtained by 2D-TOE in aortic dissection assessment, particularly in quantifying entry tear size and facilitating more adequate understanding of dissection morphology when the dissection course is spiroidal. Although TOE, CT, and MRI have similar accuracy in the diagnosis of aortic dissection, TOE provides better dynamic information than CT and better morphological information than MRI. In acute phase, CT is the most used imaging technique owing to its wider availability. However, TOE is better than CT in haemokinetic assessment of false lumen flow and communication flow between lumina. Similarly, TOE is better than MRI at defining certain morphological variables such as entry tear size and facilitating more adequate understanding of dissection morphology when the dissection course is spiroidal.
On the other hand, TOE is the technique of choice for perioperative assessment of aortic dissection both in open surgery and endovascular treatment. Some studies have shown 2D-TOE usefulness in guiding intra-operative stent-graft implantation and 3D-TOE may provide additional important information. The present study analyses for the first time the additional value of 3D-TOE vs. 2D-TOE in a chronic aortic dissection series. Although 2D-TOE provides similar information to 3D in the diagnosis and extension of the dissection and partial false lumen thrombosis, 3D-TOE is clearly better than 2D-TOE in entry tear size quantification, permitting excellent agreement with the entry tear area determined by multi-slice CT. Entry tear size is of major prognostic significance since it causes greater inflow volume into the false lumen which may increase its diastolic pressure and lead to an increase in wall stress and, consequently, a greater risk of aortic dilatation or rupture. Adequate measurement of entry tear size may be useful to consider more aggressive management of aortic dissection in the subacute phase. An interesting finding of the present study was that although 3D-TOE improves agreement with CT in maximum entry tear diameter measurement, entry tear area shows the best agreement between both methods, which could warrant this variable being standardized as the reference parameter. Although both TOE techniques play a similar role in the assessment of dissection extension, partial false lumen thrombosis, and visualization of

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<thead>
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<th>Entry tear</th>
<th>2D-TOE</th>
<th>3D-TOE</th>
<th>CT</th>
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<tr>
<td>Maximum diameter (mm)</td>
<td>10.69 ± 6.31 (2–25)</td>
<td>12.23 ± 6.36 (2–24)</td>
<td>12.44 ± 6.65 (2–27)</td>
</tr>
<tr>
<td>Maximum area (cm²)</td>
<td>1.01 ± 0.76 (0.11–5.20)</td>
<td>1.06 ± 0.84 (0.15–4.80)</td>
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Table 1  Entry tear size measured by two-dimensional/three-dimensional transthoracic echocardiography and computed tomography

![Figure 4 Bland–Altman plots of maximum entry tear quantified by two-dimensional transthoracic echocardiography, three-dimensional transthoracic echocardiography, and computed tomography. (A) Maximum diameter determined by two-dimensional transthoracic echocardiography and computed tomography; (B) maximum diameter determined by three-dimensional transthoracic echocardiography and computed tomography and, (C) maximum area determined by full-volume three-dimensional and computed tomography.](image-url)
secondary tears, a further advantage of 3D-TOE is that it improves understanding of aortic dissection features when the intimal flap is spiroidal.

Limitations
The present study has a small number of cases and should be validated by larger series. Patients in acute phase were not included although similar results of the technique regarding the variables analysed are foreseeable. However, 3D-TOE may be useful in the diagnosis of aortic regurgitation mechanisms before surgical treatment is planned. Ascending aorta dissection involvement is correctly diagnosed by 2D-TOE and the treatment of choice is surgery. Nevertheless, knowing the real size of residual or distal communications in the arch or descending aorta in type A dissections or the entry tear in type B dissections may be crucial for deciding on the most adequate surgical management. Although the maximum interval between TOE and CT was 3 months, it was <1 month in >50% of cases, and all cases included were stable both clinically and on imaging techniques.

Conclusion
Three-dimensional TOE provides additional information to 2D-TOE in aortic dissection assessment, particularly in entry tear size quantification. Agreement between entry tear area defined by 3D-TOE and CT is excellent. Three-dimensional TOE permits better morphological and dynamic understanding of aortic dissection when the flap is spiroidal. This technique may be particularly useful in the indication and monitoring of surgical or endovascular treatment of aortic dissection.

Figure 5 Measurement of entry tear size of type B dissection. (A) Maximum entry tear diameter by two-dimensional transoesophageal echocardiography (arrow) was 10 mm; (B) by three-dimensional TOE maximum orthogonal diameters were 17 mm × 11 mm. Area measured by full-volume was 1.54 cm²; (C) computed tomography showed similar elliptical shape and size.

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References


