Transoesophageal stress echocardiography

F. A. Flachskampf, H. Lethen, R. Hoffmann and P. Hanrath

Med.Klinik I, RWTH Aachen, Aachen, Germany

Transoesophageal echocardiography has been performed in conjunction with pacing, dobutamine, or dipyridamole stress to detect stress-inducible ischaemia, and has proved to be a highly accurate diagnostic tool. Its advantages of improved image quality and high diagnostic accuracy have to be weighed against the disadvantages of semi-invasiveness and patient discomfort. The existing data on this stress echo modality and on special applications (diastolic dysfunction, ischaemic mitral regurgitation, hibernating myocardium, peri-operative risk assessment) are reviewed.

Key Words: Pacing stress, stress echocardiography, transoesophageal echocardiography.

Introduction and physiological background

Stress echocardiography by transoesophageal imaging offers the advantage of improved image quality and is independent of the ability of the patient to exercise. Transoesophageal echocardiography for the detection of inducible wall motion abnormalities has been used in conjunction with (a) atrial pacing via the transoesophageal echoscope or (b) pharmacological agents, mainly dobutamine, as stress modalities. Both have cardiovascular effects which markedly differ from exercise stress. Atrial pacing increases myocardial oxygen demand almost exclusively by augmenting the heart rate. Since blood pressure does not change appreciably, the increase in the rate pressure product, and thus, myocardial oxygen demand, is lower than in physical exercise. Pacing can be terminated at once. The original heart rate is immediately reestablished, while the induced wall motion abnormalities persist and can be recorded for a time interval that depends on the severity of the disease. Dobutamine stress increases both myocardial contractility and heart rate; blood pressure is little affected at low doses and augmented at high doses. With both atrial pacing and dobutamine, there is a marked reduction of left ventricular end-diastolic volume, contrasting with the effect of exercise. Fractional shortening by M-mode does not increase with atrial pacing, sharply in contrast to exercise. Fractional shortening by M-mode does not increase with atrial pacing, sharply in contrast to exercise.

Methods

Pacing for stress echocardiography was first used together with transthoracic echocardiography. Pacing was effected by a pill electrode swallowed by the patient, and remarkably high diagnostic accuracy was reported. The combination of atrial pacing stress with transoesophageal imaging of the detection of coronary artery disease was first introduced in 1990. A customized echoscope was used, which had three ring electrodes mounted on the shaft. Later, a disposable one-way plastic foil with eight embedded electrodes and adhesive backing became commercially available, which was attached to the echoscope and removed after use. The pacing echoscope or the foil were connected to an external cardiac stimulator (Arzco Inc., Chicago IL, U.S.A.). This device allowed selection of the best pair of electrodes for bipolar pacing (depending on the actual position of the echoscope in the esophagus) and delivered square wave direct current pulses of 10 ms duration and 10–20 mA at an adjustable rate. In our protocol, we increased the heart rate in 20 beats min⁻¹ intervals every 2 min from baseline to the age-adjusted submaximal heart rate (85₀% x (220 - age)). Atropine 0.5–1.0 mg was added if second-degree atrioventricular block occurred. With a monoplane transducer, systolic wall motion and wall thickening were monitored in a transgastric short axis view at the mid-papillary muscle level. This cross-section contains perfusion territories of all
Figure 1 Disposable plastic sheath with eight embedded electrodes wrapped around the echoscope shaft for transoesophageal pacing.

Figure 2 Transgastric short axis view of the left ventricle. Example of a lateral wall motion abnormality (arrow) induced by transoesophageal atrial pacing at 120 min.

Figure 3 14-segment scheme of the left ventricle for analysis of transgastric short axis and transoesophageal four-chamber and two-chamber views. The left anterior descending territory is in yellow, and the combined right and circumflex territory is in green. See text.
Table 1  Published results of transoesophageal pacing stress echocardiography

<table>
<thead>
<tr>
<th>Detection of</th>
<th>Modality</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>n</th>
<th>Feasibility (%)</th>
<th>Reference</th>
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<tr>
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<td>100</td>
<td>50</td>
<td>100</td>
<td>[6]</td>
</tr>
<tr>
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<td>mono TEE pacing</td>
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<td>93</td>
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<td>85</td>
<td>60</td>
<td>97</td>
<td>[13]</td>
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<tr>
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<td>83</td>
<td>94</td>
<td>83</td>
<td>92</td>
<td>[7]</td>
</tr>
</tbody>
</table>

CAD = coronary artery disease; PTCA = percutaneous transluminal coronary angioplasty; mono = monoplane; bi = biplane; multi = multiplane; TEE = transoesophageal echocardiography; Feasibility = percentage of original study group in whom both imaging and stress were successful and tolerated; n = number of patients with successful stress examinations to whom sensitivity and specificity refer.

Three major coronary arteries (Fig. 2). Later, investigators used biplane transducers and both transgastric and transoesophageal views (Fig. 3). The transgastric short axis and the transoesophageal four-chamber view and two-chamber view are the preferred cross-sections with a biplane transducer. Note that these views do not contain the basal anteroseptal and the basal inferior segment of the usual transthoracic segment scheme since a long axis view is lacking. In contrast, stable imaging in the transgastric long axis view is often difficult and the apex of the left ventricle may not be visualized in this view. The transoesophageal window also allows pulsed Doppler sampling of transmitral and pulmonary venous flow velocities. During pacing, imaging has to be performed in an echoscope position that allows stable atrial capture. Hence, the true difficulty of this test is to find and maintain an echoscope position which at the same time allows good imaging and stable pacing, and which is well tolerated by the patients. If satisfactory imaging cannot be achieved during pacing, wall motion abnormalities can still be detected satisfactorily 1–2 min immediately after termination of pacing. Persistence of wall motion abnormalities depends on the severity of underlying disease, but even in patients with one vessel disease, wall motion abnormalities were still present 2 min after cessation of pacing in half of the patients[6].

For pharmacological stress, the usual protocols have been used: dobutamine 5–40 μg kg⁻¹ min⁻¹ plus atropine, if needed, in 2–3 min steps up to a heart rate of 85% (220 – age); dipyridamole 0.56 mg kg⁻¹ over 4 min, if necessary followed by 0.28 mg kg⁻¹ over 2 min.

The usual precautions and termination criteria for stress tests and transoesophageal echocardiography have to be observed. ECG monitoring is mandatory, and preferably a six-channel ECG should be recorded and observed during the test. In our practice we used topical pharyngeal anaesthesia and, if necessary, mild sedation with midazolam. Apart from the transoesophageal examination and the induction of angina, pacing itself can cause discomfort and may necessitate premature termination of the test.

Results

(a) Detection of coronary artery disease

High diagnostic accuracy for the detection of coronary artery disease has been reported in all series (Tables 1 and 2). Analysis of patients with previous myocardial infarction has revealed slightly reduced sensitivity, but high specificity (77% and 100%, respectively) for the detection of remote wall motion abnormalities in the presence of significant multivessel disease[7]. In a study comparing transoesophageal pacing echo to dipyridamole thallium single-photon emission computed tomography (SPECT), the indices of diagnostic accuracy were not significantly different (sensitivity, 86% vs 95%; specificity, 89% vs 56%, respectively)[8].

For transoesophageal pharmacological stress echo with dobutamine or dipyridamole, a similar high diagnostic accuracy, notably a very high specificity has been documented[9–13].

(b) Detection of restenosis after PTCA and bypass surgery

In a group of 60 patients 5.4 ± 3.7 months after PTCA, diagnostic accuracy was almost identical to MIBI-SPECT performed in the same patients (sensitivity 84% vs 86%, specificity 85% vs 84%), and far superior to exercise ECG, compared to quantitatively evaluated coronary angiography (Fig. 4)[13].

Patients after bypass surgery (mean, 6.2 years) were evaluated comparing transthoracic and transoesophageal dobutamine stress echo. This showed the
Table 2  Published results of transoesophageal echocardiography with pharmaco-
ological stress agents

<table>
<thead>
<tr>
<th>Detection of</th>
<th>Modality</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>n</th>
<th>Feasibility (%)</th>
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<td>92</td>
<td>100</td>
<td>32</td>
<td>100</td>
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</tr>
<tr>
<td>or bypass</td>
<td>mono TEE</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>stenosis</td>
<td>dobu mono/bi/multi TEE</td>
<td>90</td>
<td>94</td>
<td>81</td>
<td>100</td>
<td>[10]</td>
</tr>
<tr>
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<td>100</td>
<td>76</td>
<td>100</td>
<td>[11]</td>
</tr>
<tr>
<td>Bypass</td>
<td>dobu bi TEE</td>
<td>82</td>
<td>93</td>
<td>45</td>
<td>88</td>
<td>[12]</td>
</tr>
<tr>
<td>stenosis</td>
<td>dobu bi TEE</td>
<td>93</td>
<td>93</td>
<td>60</td>
<td>100</td>
<td>[14]</td>
</tr>
</tbody>
</table>

(Abbreviations see Table 1.)

Figure 4  Schematic drawing of differential effects of exercise, pacing, and dobutamine stress on the normal left ventricle viewed in a short axis. Top, baseline; left, effects of exercise stress; right, effects of high rate pacing or high-dose dobutamine stress. In exercise, end-diastolic wall thickness (ED-TH) is unchanged, wall thickening (ΔTH) increases, left ventricular end-diastolic cavity dimension is moderately increased and end-systolic cavity dimension is moderately decreased. In contrast, in pacing and high-dose dobutamine stress, end-diastolic cavity dimension decreases, end-diastolic wall thickness increases, and wall thickening is diminished.

Figure 5  Ability of transoesophageal pacing echocardiography to distinguish high and low degrees of coronary (re-)stenosis after PTCA. Mean and standard deviation of percent area stenosis at follow-up examination in the group with inducible wall motion abnormalities (WMA; left) and without inducible wall motion abnormalities (right)\(^{13}\).

higher diagnostic accuracy of transoesophageal echo (sensitivity, 93% vs 78%, respectively; specificity, 93% vs 86%, respectively\(^{14}\)). However, the difference in sensitivity was statistically significant only in patients with impaired external image quality, who comprised 38% of the total group.

(c) Ischaemic mitral regurgitation

In patients with pacing-induced ischaemic wall motion abnormalities and mitral regurgitation, mitral regurgitant colour Doppler jet area increases after pacing\(^{12}\). In this small group of 15 patients increase in size was associated more with posterior than with anterior wall motion abnormalities.

(d) Diastolic left ventricular function

The transoesophageal window allows high quality recordings to be made of pulmonary venous inflows. A transoesophageal pacing study analysed the effects of transoesophageal pacing on diastolic left ventricular function by acquiring pulsed Doppler transmitral and pulmonary venous inflow profiles before and after pacing. Patients with coronary artery disease and with hypertrophic non-obstructive cardiomyopathy were compared to normals. While normals showed no significant change in either pulmonary venous or mitral flow profiles after pacing, there was a clear transmitral flow...
pattern of ‘impaired relaxation’ with a decrease in the E wave after pacing in patients with coronary artery disease or cardiomyopathy. Also the size of the retrograde A wave in the pulmonary venous flow recording more than doubled in these patients, indicating increased atrial pressure rather than decreased preload, which could have mimicked the impaired relaxation pattern. Thus, combined analysis of pulmonary venous flow and transmitral inflow confirmed that impaired diastolic left ventricular function was present after pacing[16].

(e) Pre-operative risk stratification

In a small group of 20 patients with clinically suspected coronary artery disease undergoing hip replacement, pre-operative transoesophageal pacing echocardiography was performed and the patients were monitored intra-operatively for new wall motion abnormalities. Eight out of 20 patients had pacing-inducible wall motion abnormalities pre-operatively, and 6/8 developed wall motion abnormalities in the same segments during surgery, mostly during induction of anaesthesia or periods of hypotension or hypertension[17]. However, no cardiovascular events occurred peri-operatively in this small group.

Problems and outlook

A small risk is entailed by all stress tests and by transoesophageal echocardiography per se. Pacing apparently is a very safe stress modality, and no serious adverse events have been reported. For pharmacological stress, however, a small risk is well documented in the literature.

The main disadvantage of transoesophageal stress is patient discomfort resulting from both oesophageal intubation and from the stress modality, particularly atrial pacing. Furthermore, a stable pacing position sometimes cannot be achieved. On the other hand, pacing is particularly rapid and safe. Importantly, at present, no pacing equipment attachable to the transoesophageal echoscope is commercially available.

An emerging application of transoesophageal echocardiography is the detection of viable myocardium which is akinetic at rest by eliciting a contractile response in response to low dose dobutamine (5–20 μg·kg⁻¹·min⁻¹). Such contractile improvement is often subtle and difficult to detect by transthoracic echo. A good agreement of this method has been reported with positron emission tomography as reference standard (agreement, 89% by segments)[18].

In summary, transoesophageal echo with pacing or pharmacological stress yields diagnostic accuracies comparable with or superior to transthoracic stress echo and nuclear perfusion imaging. Furthermore, it provides access to Doppler sampling from the pulmonary veins. It constitutes a feasible, safe, and effective diagnostic option in patients who are difficult to image.

References

