Original Research

Transesophageal Atrial Pacing Stress Echocardiography: Difficulties in the Performance and the Interpretation of the Test

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Introduction: Transesophageal atrial pacing stress echocardiography (TEAPSE) has been proposed as an alternative stress echo test in selected patients with known or suspected coronary artery disease. The purpose of this study was to determine: (1) whether TEAPSE could serve as a suitable provocative stress test in patients with stroke and (2) to investigate whether the pseudohypertrophy during TEAPSE that has been observed in experimental studies is also seen in the clinical setting.

Methods: TEAPSE at increasing heart rates was performed in 29 patients with stroke. The end-diastolic and end-systolic left ventricular (LV) wall/cavity circumferential area was traced and the ratio was calculated at each pacing stage, as well as the percent systolic thickening.

Results: A progressive increase in LV wall thickness was noted at high TEAPSE rates (from 1.31 ± 0.21 mm at baseline to 1.47 ± 0.27 mm at +50 beats/min of TEAPSE, $p<0.05$). The ratio wall/cavity area increased significantly at end diastole (from 1.65 ± 0.36 at baseline to 2.12 ± 0.49 at +50 beats/min, $p<0.05$). Percent systolic thickening was inversely correlated with the increase in wall thickness ($r=-0.30$, $p<0.004$) and the ratio wall/cavity area in diastole ($r=-0.41$, $p<0.001$). Feasibility of TEAPSE was 52% (15 of the 29 patients).

Conclusions: The occurrence of pseudohypertrophy during TEAPSE in conjunction with the low feasibility rate makes the performance and the interpretation of the test problematic. Therefore, other modalities of stress echocardiography should be considered for routine clinical use and TEAPSE could be applied in specific circumstances when other modalities are either contraindicated or unavailable.

Transesophageal atrial pacing echocardiography (TEAPSE) is a combination technique that allows high resolution visualization of the heart, for detecting potential intracardiac sources of cerebral emboli, and is an alternative stress test for the assessment of coronary artery disease.[1-3] Experimental studies have reported a transient increase in left ventricular (LV) diastolic thickness (pseudohypertrophy) and a decrease in percent systolic thickening in non-ischemic myocardium during rapid atrial pacing.[4-6] Since the above variables are used in the interpretation of stress echocardiograms they could be a source of potential error. These phenomena constitute a normal response and do not indicate stress-induced LV dysfunction. However, the direct application of these experimental findings in humans is questionable. The purpose of this study was to determine: (1) whether TEAPSE combined with simultaneous two-dimensional echocardiography could serve as a suitable provocative stress test in patients with stroke; and (2) to investigate whether the pseudohypertrophy during rapid atrial pacing that has been observed in experimental studies is also seen in the clinical setting.

Methods

Patient selection

Twenty-nine consecutive patients with a recent transient ischemic attack (focal ischemic cerebral dysfunction lasting less than 24 hours from onset)[7] or stroke (deficit persisting for more than 24 hours) were investigated. Patients with a history or presence of angina or myocardial infarction, or ECG changes indicating a prior myocardial infarction or ischemia, were excluded from the study. None of these patients had any of the following: rhythm other than sinus, severe valvular disease, cardiac failure, complex ventricular arrhythmias, uncontrolled systemic hypertension, or complete atrioventricular block. Informed consent was obtained for participation in this study. The investigation was in accordance with the Helsinki Declaration of 1975, as revised in 2000 and was approved by the Institution's Scientific Committee governing research in human subjects.

Echocardiography

Transthoracic two-dimensional echocardiography was performed using a Hewlett-Packard ultrasound system (Sonos 2500, Andover, MA, USA). A commercially available 5.0 MHz phased-array, multi-plane, transesophageal transducer mounted on the tip of a gastroscope was connected. The esophageal echoscope with the attached pacing catheter was introduced into the esophagus and advanced a distance of 35 to 45 cm from the patient's incisors. At this level the optimal transgastric short-axis view of the left ventricle is achieved. The complete studies were recorded on VHS videotape for later replay and analysis.

Transesophageal atrial pacing

Specially designed flexible silicone rubber-coated, octapolar catheters, in conjunction with a transesophageal cardiac stimulator (model 7A, Arzco Medical Electronics, Inc.), were used to induce pacing tachycardia. The pacing catheter was attached to the anterior aspect of the esophageal echoscope using transpore tape. The distance between the most proximal electrode and the transducer was 75 mm. The optimal bipolar combination was defined as the pair of electrodes from which the largest amplitude of the esophageal P wave on the ECG was recorded. A stimulus artifact suppressor (Arzco Medical Electronics, Inc.) was used to eliminate the pacing atrial spike from the ECG recording.

After satisfactory echocardiographic imaging and atrial electrogram recording were achieved at rest, pacing was started at 10 beats/min above the patient's baseline heart rate and at 5 mA above the threshold for stable atrial capture. A pulse width of 10 ms was used. The pacing protocol consisted of 2 min stages with the paced heart rate increasing by 10 beats/min at every stage, until one of the following endpoints occurred: (1) achievement of >85% of the patient's maximal age-predicted heart rate; (2) development of new or worsening wall motion abnormalities of at least moderate severity; (3) occurrence of horizontal or downsloping >2 mm ST-segment depression or elevation; (4) ventricular or supraventricular tachycardia. The test was also stopped in the case of severe angina, hypotension, hypertension or intolerable discomfort from pacing.

Imaging analysis

Real-time images were analyzed off-line for each patient by two independent, experienced echocardiographers who were unaware of the ECG response to pacing.

Cross-sectional LV epicardial and endocardial borders were traced in end-diastolic and end-systolic frames from images obtained in the short-axis view at the mid-papillary muscle level. The area was measured by planimetry using software incorporated in the ultrasound system. End-diastolic and end-systolic frames were selected for analysis using the onset of the Q waves in lead II to define end-diastole and the smallest ventricular cavity to define end-systole. All measurements were averaged over three consecutive beats. Mean wall thickness was calculated as the radius of epicardial area minus the radius of endocardial area at both end-diastole and end-systole. Percent systolic thickening was calculated as mean systolic wall thickness minus mean diastolic wall thickness divided by mean diastolic wall thickness and multiplied by 100. The end-diastolic and end-systolic LV wall/cavity circumferential area ratio was calculated at each pacing stage. Fractional area change ([end-diastolic area - end-systolic area]/end-diastolic area) was calculated.

M-mode echocardiographic tracings, obtained under 2-dimensional control, were measured according to the recommendations of the American Society of Echocardiography.[8] LV mass was calculated according to the Penn Convention.[9] LV hypertrophy was prospectively defined as a value of LV mass ≥177 g for men and ≥118 g for women.[10]

Statistical analysis

The data are presented as mean value ± SD. Intergroup comparisons of variables during different stages of transesophageal atrial pacing were performed with the General Linear Model for repeated measurements using Hotelling's trace multivariate test. Correlations were investigated using linear regression analysis. The criterion of significance was a p-value <0.05.

Results

Patient characteristics and baseline transthoracic and transesophageal findings are presented in Tables 1 and 2.

Resting ECG abnormalities (incomplete bundle branch block, LV hypertrophy, left atrial enlargement, non specific ST-T abnormalities) were found in 13 of the 29 patients (45%).

None of the patients experienced angina, presented significant ST deviation, or developed wall motion abnormality at maximum pacing rates. One patient developed transient hypokinesia of the inferior wall at maximum pacing rate. A dipyridamole-thallium scan was performed and showed reversible ischemia in the inferior wall, while coronary angiography revealed a 50% stenosis in the right coronary artery. This patient was excluded from the study.

Feasibility of transesophageal atrial pacing stress echocardiography

The feasibility of TEAPSE was 52% (15 of the 29 patients). The reasons for TEAPSE failure are presented in Table 3. Patients with unsuccessful TEAPSE were more likely to have an abnormal cardiothoracic ratio (93% versus successful 60%, p<0.03), resting ECG abnormalities (64% versus successful 27%, p<0.04) and an increased LV end-diastolic wall thickness (1.00 ± 0.15 cm versus 0.86 ± 0.18 cm, p<0.03).

Table 1. Demographic and clinical data.

Age (years)	69 ± 9
Sex (male/female, %)	13/16 (45/55%)
History of hypertension (no. of pts, %)	28 (97%)
Family history of CAD (no. of pts, %)	8 (28%)
Hyperlipidemia (no. of pts, %)	8 (28%)
Obesity (no. of pts, %)	2 (7%)
Smoking (no. of pts, %)	8 (28%)
Diabetes mellitus (no. of pts, %)	16 (56%)
TIA (no. of pts, %)	7 (24%)
CT-brain positive findings (no. of pts, %)	23 (79%)
Rest ECG abnormalities (no. of pts, %)	13 (45%)
Cardiac enlargement (no. of pts, %) (cardiothoracic ratio >50%)	18 (62%)

CAD – coronary artery disease; CT – computed tomography; ECG – electrocardiogram; TIA – transient ischemic attack.

Table 2. Baseline transthoracic and transesophageal echocardiographic-Doppler findings.

LV end-diastolic dimension (cm)	5.01 ± 0.84
LV end-systolic dimension (cm)	2.8 ± 0.57
Fractional shortening (%)	43 ± 6
Ejection fraction (%)	74 ± 6
Left atrium (cm)	3.60 ± 0.54
IVS end-diastolic thickness (cm)	1.01 ± 0.17
LV posterior wall end-diastolic thickness (cm)	0.93 ± 0.18
LV mass (g)	203.95 ± 60.67
LV hypertrophy (no. of pts, %)	20 (74%)
Transmitral E/A wave ratio >1 (no. of pts, %)	23 (82%)
Mitral and/or aortic valve calcification (no. of pts, %)	11 (38%)
MVR (absence/trivial/mild) (no. of pts, %)	11/10/8 (38/34/28%)
AVR (absence/trivial/mild) (no. of pts, %)	19/5/5 (66/17/17%)
Left atrium/appendage smoke/thrombus (no. of pts, %)	1/0 (3/0%)

AVR – aortic valve regurgitation; IVS – interventricular septum; LV – left ventricular; MVR – mitral valve regurgitation.

LV cavity area and wall thickness

A progressive increase in LV wall thickness was noted at high atrial pacing rates. Mean end-diastolic wall thickness was 1.31 ± 0.21 cm at baseline, 1.24 ± 0.18 cm at +10 beats/min of atrial pacing, 1.26 ± 0.13 cm at +20 beats/min, 1.32 ± 0.14 cm at +30 beats/min, 1.37 ± 0.19 cm at +40 beats/min and 1.47 ± 0.27 cm at +50 beats/min of atrial pacing (p<0.05, Table 4). In addition, mean end-systolic wall thickness increased, though not significantly, at high pacing rates (from 1.45 ± 0.25 cm at baseline to 1.55 ± 0.27 cm at +50 beats/min of atrial pacing, p=0.35, Table 4). The circumferential area of the LV wall increased, though not significantly, whereas the cavity area decreased significantly during atrial pacing at both end-diastole and end-systole (p<0.02 and p<0.04, respectively, Table 5). The ratio wall/cavity area did not increase significantly at end-systole (p=0.47), whereas it did at end-diastole (p<0.05, Table 5). Percent systolic thickening did not decrease significantly during atrial pacing, but was inversely correlated with the increase in wall thickness (r=-0.30, p<0.004) and the ratio wall/

Table 3. Transesophageal atrial pacing stress echocardiography.

Rest heart rate (beats/min)	88 ± 13
Peak heart rate (beats/min)	128 ± 17
Successful TEAPSE (no. of pts, %)	15 (52%)
Total failures (no. of pts, %):	14 (48%)
Unsuccessful atrial capture	3 (10%)
Discomfort	2 (7%)
Wenckebach	2 (7%)
Atrial fibrillation	2 (7%)
Inadequate image quality	4 (14%)
≤85% age-predicted peak heart rate	1 (3%)

cavity area in diastole (r=-0.41, p<0.001, Figures 1, 2). The increase in mean wall thickness in diastole was correlated with the increase of the LV wall area (r=0.87, p<0.001) and the increase of the LV wall/cavity area ratio (r=0.71, p<001).

Discussion

Previous studies have shown that an increase in heart rate without a simultaneous increase in venous return during atrial pacing results in reduced cardiac volumes.[11-13] In experimental studies, the reduction of LV volume may cause a transient increase in LV wall thickness (pseudohypertrophy).[4,5] Since the evaluation of LV wall thickening constitutes a significant factor in the assessment of myocardial ischemia, it is important to determine the response of the myocardium during atrial pacing echocardiography in the clinical setting. The present study verifies that pseudohypertrophy, as expressed by mean LV wall thickening in diastole, is the result of decreased LV cavity dimensions and a significant increase in the LV wall/cavity area ratio in diastole during atrial pacing. An experimental study showed that pseudohypertrophy did not correlate with coronary stenosis severity.[5] The mean LV wall thickening in systole increased to a lesser extent, resulting in a non-significant decrease as far as the percent systolic thickening was concerned. However, the decrease in percent systolic thickening was significantly correlated with the increase in LV wall thickness and the LV wall/cavity area ratio during

Table 4. Wall thickness and fractional area changes (FAC) during transesophageal atrial pacing stress echocardiography.

Pacing rate	Diastolic wall thickness (cm)	Systolic wall thickness (cm)	Systolic wall thickness (%)	FAC (%)
Baseline	1.31 ± 0.21	1.45 ± 0.25	11.38 ± 10.20	46.58 ± 7.70
+10	1.24 ± 0.18	1.36 ± 0.19	10.76 ± 12.07	46.50 ± 6.14
+20	1.26 ± 0.13	1.40 ± 0.16	11.87 ± 10.63	46.18 ± 7.80
+30	1.32 ± 0.14	1.47 ± 0.19	10.98 ± 8.35	46.79 ± 5.75
+40	1.37 ± 0.19	1.50 ± 0.20	9.84 ± 10.07	46.62 ± 5.87
+50	1.47 ± 0.27	1.55 ± 0.27	5.62 ± 9.26	41.60 ± 5.66
F	2.27	1.13	0.58	0.94
p	<0.05	0.35	0.72	0.45

Table 5. Two-dimensional echocardiographic measurements of left ventricular wall and cavity during transesophageal atrial pacing stress echocardiography.

Pacing rate	LVWAd (cm^2)	LVWAs (cm^2)	LVCAd (cm^2)	LVCAs (cm^2)	LVW/CAd ratio	LVW/CAs ratio
Baseline	23.10 ± 5.71	21.03 ± 5.20	14.50 ± 4.03	7.76 ± 2.54	1.65 ± 0.36	2.88 ± 0.81
+10	20.71 ± 2.94	18.70 ± 3.39	13.44 ± 3.92	7.15 ± 2.14	1.66 ± 0.55	2.79 ± 0.88
+20	20.36 ± 3.07	18.84 ± 3.61	12.23 ± 3.92	6.67 ± 2.64	1.77 ± 0.45	3.11 ± 0.94
+30	22.34 ± 4.16	20.46 ± 4.45	13.01 ± 4.03	6.93 ± 2.38	1.81 ± 0.42	3.13 ± 0.79
+40	22.58 ± 4.23	20.42 ± 4.18	11.82 ± 2.50	6.35 ± 1.73	1.95 ± 0.42	3.35 ± 0.84
+50	25.03 ± 7.03	22.17 ± 6.05	11.97 ± 2.64	7.01 ± 1.78	2.12 ± 0.49	3.26 ± 0.83
F	1.65	1.11	4.30	3.69	2.27	0.92
p	0.16	0.36	<0.02	<0.04	<0.05	0.47

LVCAd – left ventricular cavity area in diastole; LVCAs – left ventricular cavity area in systole; LVWAd – left ventricular wall area in diastole; LVWAs – left ventricular wall area in systole; LVW/CAd – left ventricular wall/cavity area ratio in diastole; LVW/CAs – left ventricular wall/cavity area ratio in systole.

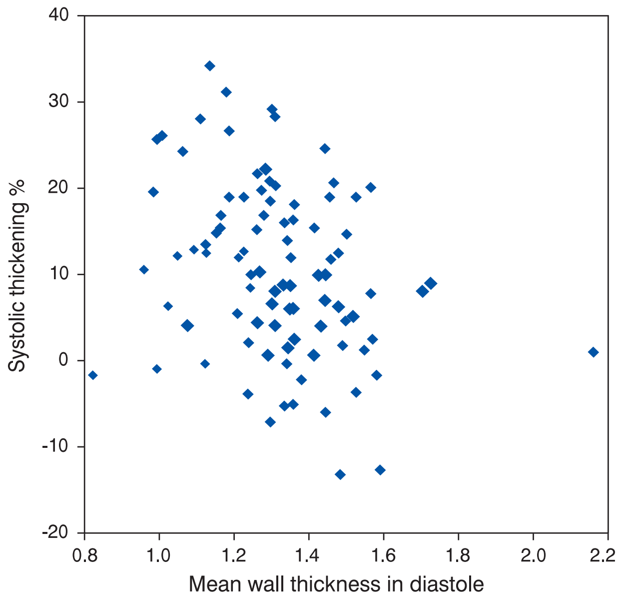

Figure 1. Percent systolic thickening correlates inversely with the mean wall thickness in diastole (r=-0.30, p<0.004).

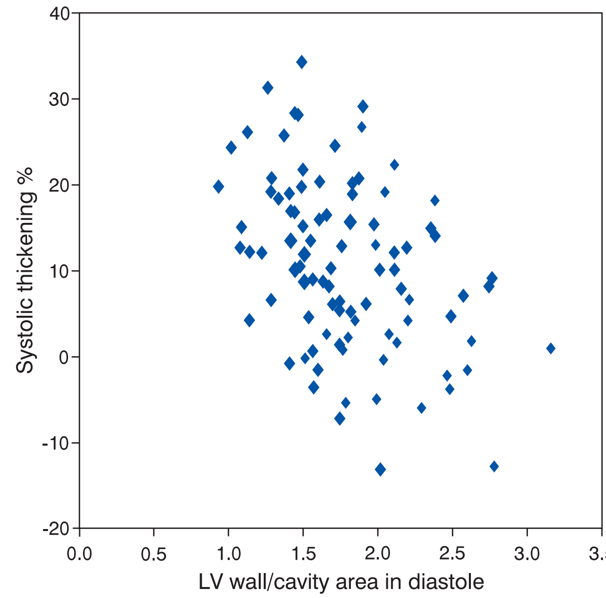

Figure 2. Percent systolic thickening correlates inversely with the increase of left ventricular wall/cavity area ratio in diastole (r=-0.41, p<0.001).

pacing. Given that percent systolic thickening is considered as an important criterion for stress-induced ischemia, the present study reveals a major source of potential error during the interpretation of stress echocardiograms. In TEAPSE, the decrease of percent systolic thickening associated with an increased LV wall thickness is a normal response and does not indicate stress-induced ischemia.

Previous studies have shown that cross-sectional and M-mode measurements of LV internal dimensions, septal and posterior wall thickness as derived by transesophageal echocardiography are valid and comparable to transthoracic echocardiography.[14,15] TEAPSE has some advantages over exercise-stress echocardiography.[16] The high expectations associated with the introduction of the former technique[17-19] for wider use have been diminished by severe disadvantages: 1) compared with other stress test methods this technique is partially invasive; 2) the nature of the stress is artificial; 3) the possible inefficiency of the transesophageal approach (unsuccessful atrial capture); 4) intolerable chest discomfort; 5) the development of second degree Wenckebach-type atrioventricular block at submaximal heart rates; and finally, 6) the higher cost of this method in comparison with other stress modalities such as exercise or pharmacological stress test. One previous study reports a 27% failure of TEAPSE in patients with suspected coronary artery disease.[20] According to our population study (elderly patients with stroke) this stress modality showed a higher percentage of failure (48%). That fact could explain why TEAPSE is very seldom used today.

A limitation of the study needs to be addressed. Coronary angiography was not performed in our study population as none of our patients had a history or presence of angina or myocardial infarction, or ECG changes indicating a prior myocardial infarction or ischemia. Patients with wall motion abnormalities at rest or during TEAPSE were excluded from the study.

Conclusions

The occurrence of pseudohypertrophy during TEAPSE, in conjunction with its low feasibility rate, makes the interpretation and the performance of the test problematic. Therefore, other modalities of stress echocardiography should be considered for routine clinical use, while TEAPSE could be applied in specific circumstances when other modalities are either contraindicated or unavailable.

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