Tilt table exercise echocardiography assessment in the diagnosis of coronary artery disease

Évaluation de l’échocardiographie d’effort sur table basculante pour le dépistage de la maladie coronarienne

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Summary
Objectives. — To assess the diagnostic performance of per-exercise echocardiography using a recent tilt table to investigate for coronary artery disease with a significance threshold for stenosis ≥70%.

Methods. — 104 consecutive patients (93 men) referred for elective coronary angiography underwent tilt table exercise echocardiography in which second harmonic imaging was used systematically. Images were recorded and interpreted by the same operator.

Results. — The investigation was contributory in 81 patients (target HR at least 85% of the age-predicted maximal HR or criterion for discontinuation). The most common reason for a non-contributory investigation (negative investigation but submaximal or uninterpretable investigation) was submaximal exercise (91%). The prevalence of significant coronary artery disease in the cohort of 81 contributory investigations was 38%. Sensitivity and specificity to detect significant lesions was 90% and 94% respectively. The positive and negative predictive values were 90% and 94% respectively. The three false negatives involved distal lesions. The three false positives occurred in patients with regional wall motion abnormalities in the context of various heart diseases (severe mitral incompetence, diabetic and hypertensive cardiomyopathy, left bundle branch block).

Conclusion. — Using a high performance echocardiography machine with second harmonic imaging per-exercise tilt table echocardiography offers excellent diagnostic performance to detect significant coronary artery disease under everyday clinical practice conditions.

Résumé
Objectifs. — Nous avons évalué les performances diagnostiques de l’échocardiographie per-effort en utilisant une table basculante récente pour dépister une maladie coronarienne avec un seuil de significativité des sténoses ≥ 70 %.

Méthodes. — 104 patients consécutifs (93 hommes) adressés pour coronarographie élecrite ont subi une échographie d’effort sur table basculante avec utilisation systématique de l’imagerie de seconde harmonique. La prise des images et l’interprétation ont été effectuées par le même opérateur.

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Introduction

Most of the diagnostic performance validation studies on exercise echocardiography were performed between 1987 and 1996, before the introduction of second harmonic imaging. Post-treadmill exercise echocardiography is the longest standing and most widely used exercise technique particularly in Anglo-Saxon countries. The diagnostic performance and prognostic value of this technique have been well validated [1-5]. Its main disadvantages are the “acrobatic” nature of the technique, the time taken moving quickly from the treadmill to the examination couch and the inability to record images has led to more widespread use of the per-exercise echocardiography using recent tilt tables (little-used, images difficult to take) or on an ergometric table [7, 9, 11-13]. The emergence of tilt tables allowing semi-seated investigation with the option of a lateral tilt to optimise images has led to more widespread use of the per-exercise technique in Europe. Nevertheless, relatively limited data have been published on the diagnostic performance of per-exercise echocardiography using recent tilt tables although the experience of centres which use it suggest good feasibility [6].

In most of the exercise echocardiography validation studies the level of significance for stenosis was ≥50% [1] although many centres only consider stenoses ≥70% to be significant in clinical practice (excluding the left main stem). Furthermore, in these validation series image interpretation was generally blinded to the clinical and electrocardiographic findings of the test, although, in everyday practice, an exercise echocardiogram is usually interpreted by the cardiologist performing the echocardiogram with the knowledge of these data.

Methods

Patients

These were consecutive patients referred for elective coronary angiography. The patients were included over a period of 18 months. Patients unable to undertake sufficient physical exercise were excluded as were all patients with contraindications to conventional exercise stress. Current beta-blocker treatment was not an exclusion criterion.

Exercise echocardiography

The patients were assessed by a semi-seated echocardiogram (back rest tilted to 45°) with slight left lateral inclination on a tilt table (er900L, Ergoline) if necessary to optimise images the day before the coronary angiography. The ergometric protocol used varied from 20 to 40Watt increments per 2-minute step according to the estimated functional capacity of the patient with regular monitoring of blood pressure and the electrocardiogram. The test was continued up to at least 85% of the age-predicted maximal HR. The criteria for stopping the test were the same as those for a conventional exercise stress test, or the development of a contractile abnormality involving several territories. Images were recorded continuously on a SONOS 5500 equipped with an S3 probe (Philips Medical Systems) using second harmonic imaging and digital image storage at different stages (resting, start of exercise, peak exercise, immediate recovery and late recovery). Five views (parasternal long and short axes, apical 4-, 2- and 3-cavity views) were recorded. Imaging and interpretation were done by the same operator (HM). An investigation was considered to be positive for myocardial ischaemia if the regional kinetics in at least one normal or hypokinetic segment at rest deteriorated by at least one grade (using the ASE 16 segment model [14]). The interpretation was performed immediately after the end of the investigation after rereading the images on-line on the
echocardiography machine. The interpretation was blinded to the results of the coronary angiography.

**Coronary angiography**

The severity of stenoses was estimated visually in the catheterisation laboratory by the interventional cardiologist on duty the day of the investigation, with no knowledge of the results of the exercise echocardiogram. A stenosis of ≥70% was considered to be significant. One of ≥50% in the left main stem was considered to be significant. Multi-vessel disease was defined by the presence of a significant stenosis in at least two major vessels (or bypasses) or in the left main stem.

**Statistics**

Sensitivity, specificity, positive and negative predictive values of the test were defined by comparing the interpretation of the exercise echocardiogram with the coronary angiography. Data are shown as mean value ± one standard deviation.

**Results**

104 consecutive patients (93 men, 61±11 years old) referred for elective coronary angiography, were assessed by tilt table exercise echocardiography. Most of the patients were referred to confirm or exclude significant coronary artery disease (n=88), and the others for assessment of valvular heart disease (n=16). The examination was contributory (target HR at least 85% of the age-predicted maximal HR or criterion for stopping the test and interpretable imaging) in 81 patients (78%) which constituted the cohort analysed (tables 1 and 2). The most common reason for a non-contributory investigation was submaximal exercise (91% of non-contributory investigations). Some of the patients were on beta-blocker therapy (8 investigations). Imaging quality compromised interpretation of the investigation in two patients. The prevalence of significant coronary artery disease in the cohort of 81 contributory investigations was 38%. Sensitivity and specificity to detect lesions of ≥70% or ≥50% in the left main stem were 90% and 94% respectively. The positive and negative predictive values were 90% and 94% respectively. The sensitivity to detect multi-vessel and single vessel lesions was 100% and 82% (figure 1). No major complications occurred. The three false negative results occurred in distal lesions (it should be noted that these patients were not on beta-blocker therapy). The three false positive results occurred in patients with wall motion abnormalities in the context of different heart diseases (severe mitral incompetence, diabetic and hypertensive cardiomyopathy with marked hypertensive response at peak exercise, left bundle branch block) (table 3).

By analysing the contributory results using a significance threshold for stenosis of >50%, three additional investigations were classified as false negatives (two 50-60% lesions in marginal branches and one 50-70% lesion in the vertical segment of the circumflex artery). Sensitivity and specificity in this situation were 82% and 94% respectively and the positive and negative predictive values were 90% and 88% respectively. Diagnostic performance was therefore slightly reduced, with a loss of sensitivity (82% vs. 90%) and negative predictive value (88% vs. 94%) compared to a threshold of 70%.
Nevertheless, the visual
Diagnostic performance of 81 contributing investigations.

<table>
<thead>
<tr>
<th>Patients with significant lesions *: n=31</th>
<th>Patients with non significant lesions: n=50</th>
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</thead>
<tbody>
<tr>
<td>True Positives n=28</td>
<td>True Negatives n=47</td>
</tr>
<tr>
<td>False Negatives n=3</td>
<td>False Positives n= 3</td>
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*stenosis ≥70% / LMS ≥50%

Discussion

Our study highlights that per-exercise echocardiography on a recently introduced tilt table in the era of second harmonic imaging is a high performance tool to detect significant coronary artery disease in everyday practice. Comparisons with other series, however, must be made with caution because of the different features of the patients included. Nevertheless our results are similar or even better than the published diagnostic performance in the literature for the per-exercise technique (sensitivities and specificities varying depending on the publications from 76% to 93% and 76% to 95% respectively) [2, 7-9, 11-13]. The systematic use of second harmonic imaging and of a multi-adjustable ergometric table facilitating image acquisition during exercise undoubtedly contributed to this good result. On the other hand it must be noted that the level of significance for stenosis used in our series is higher than for other per-exercise echocardiography validation studies (70% vs. 50% [7, 8, 11, 13]). Nevertheless, using a threshold of >50%, the diagnostic performance of our series remains good and similar to the performance reported in the literature.

The causes of false positive and negative diagnoses in our series are the reasons commonly mentioned for exercise echocardiography in the literature [4, 6, 15].

Our work also shows the technique to offer good feasibility, with a contributory investigation rate of 78%, consistent with the experience of centres using this instrumentation [6], despite ongoing beta blocker treatment in approximately a quarter of the patients at the time of the test. However, it is generally preferable to reduce and stop this treatment before the test for diagnostic investigations [6]. A third of the investigations on beta blocker treatment (8/24) in our series were non-contributory because of sub-maximal exercise which was undoubtedly related to this treatment.

The results were obtained using an interpretation method which is widely used in clinical practice at least in Europe in which the echocardiographer acquires the images and interprets the investigation, incorporating the clinical and electrocardiographic findings of the test.

Limitations

- In most diagnostic validation series for exercise echocardiography (per and post-exercise), image interpretation was blinded against the other test data. Our work however shows that the overall interpretation method appears to be valid in view of the good diagnostic performance obtained.
- The method for estimating severity of stenoses in our series is different from most other per exercise technique validation series (visual estimation versus quantitative angiography [7, 9, 11, 13]). Nevertheless, the visual estimation method is a widely used daily practice in many coronary angiography laboratories.
- Ongoing beta-blocker treatment was not an exclusion criterion. However, it must be noted that the diagnostic performance does not appear to have been particularly adversely affected in this series, as none of the false negative investigations were in patients on beta-blocker treatment.
- Our patient series consisted of persons referred for elective coronary angiography, unlike a consecutive series of patients referred for exercise echocardiography. The diagnostic performance therefore relates to this population and not to another, such as a population with a lower prevalence of coronary artery disease. However, this limitation is minor, as the prevalence of significant lesions is relatively low (38%).

Conclusion

Using a high performance echocardiography machine with second harmonic imaging, exercise echocardiography on a tilt table provides excellent diagnostic performance under common clinical practice conditions to detect significant coronary artery disease. Diagnostic performance remains good if a significant threshold for stenosis of >50% is used.

References


[14] Lang RM, Bierig M, Devereux RB, et al. Recommendations for chamber quantification: a report from the American Society of Echocardiography’s Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr 2005;18:1440-63.