Extent and severity of test positivity during dobutamine stress echocardiography

Influence on the predictive value for coronary artery disease

R. Hoffmann, H. Lethen, A. Franke, H. Kühl, W. Lepper and P. Hanrath

Medical Clinic I, University Clinic RWTH Aachen, Aachen, Germany

Aims Recent studies have evaluated the diagnostic accuracy and predictive value of dobutamine echocardiography without considering the additional information implied by the magnitude of induced wall motion abnormalities. We sought to evaluate the positive predictive value of dobutamine echocardiography for coronary artery disease from the extent and severity of the induced wall motion abnormality. In addition, we intended to determine factors associated with false-negative dobutamine echocardiography.

Methods and Results Two hundred and eighty-three consecutive patients with suspected coronary artery disease underwent dobutamine echocardiography (up to 40 μg kg⁻¹ min⁻¹ + atropine up to 1 mg) and coronary angiography. The number of segments and the degree of deterioration were used to describe the extent and severity of induced wall motion abnormality. Analysis of clinical, procedural and echocardiographic variables was performed to determine factors associated with false-negative results. The positive predictive value of dobutamine echocardiography increased from 85% to 90%, 94% and 94% with deterioration of wall motion by one grade in §1, §2, §3 and §4 segments, respectively (P<0·05). Deterioration of wall motion by two grades in one segment had a positive predictive value of 96% as compared to 85% for deterioration by only one grade in one segment (P<0·05). Patients with false-negative test results received atropine more frequently (28% vs 13%, odds ration [OR]=3·87, 95% confidence interval [CI]=1·54–9·75, P=0·028) than patients with a correct positive result. However, angina (15 vs 37%, OR=0·26, 95% CI=0·09–0·71, P=0·010), ECG changes during dobutamine stress (15% vs 35%, OR=0·49, 95% CI 0·19–1·25, P=0·014) and high image quality (OR 1·59, 95% CI 1·07–2·37, P=0·015) were less frequent. The sensitivity of dobutamine echocardiography increased from 67% to 71% and 86% (P<0·05) with increasing achieved maximal heart rate (<75%, 75–85% and >85% of maximal heart rate).

Conclusion The positive predictive value of dobutamine echocardiography increases significantly as the extent and severity of induced wall motion abnormality increases. Thus, the degree of test positivity should be reported in clinical practice. Despite high pharmacological drug doses, the haemodynamic response may still be insufficient in some patients to induce myocardial ischaemia, resulting in false-negative dobutamine echo tests. To maximize the sensitivity of dobutamine echocardiography, the highest haemodynamic stress level, with a heart rate above 85% of the predicted heart rate, should be reached.

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Key Words: Coronary artery disease, dobutamine echocardiography, positive predictive value.

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Introduction

Dobutamine echocardiography has become an established method for the non-invasive diagnosis of coronary artery disease[1–4]. Most dobutamine echocardiography protocols have considered a deterioration of wall motion by at least one grade in at least one segment as a pathological stress echo result[1–6]. It is known from other non-invasive stress tests that the positive predictive value for coronary artery disease increases with the degree of test abnormality[7,8]. No analysis has been conducted on dobutamine echocardiography to find out whether the magnitude of test positivity has an impact on the positive predictive value for coronary artery disease. Similarly, specificity may
increase with more rigid reading criteria requiring more severe wall motion abnormalities. While a high positive predictive value or high specificity may be of importance in some cases, high sensitivity, necessitating a low frequency of false-negative dobutamine echocardiography, is requested under other clinical settings. Clinical, echocardiographic and angiographic parameters associated with false-positive dobutamine echocardiography have been defined\(^9\). Angiographic analysis demonstrated that borderline lesions may result in false-negative dobutamine echocardiography results\(^10\). However, clinical, echocardiographic and procedural parameters associated with false-negative dobutamine echocardiography have not yet been analysed.

Thus, in an attempt to improve the positive predictive value of dobutamine echocardiography, the present study evaluated the influence of the extent and severity of the induced wall motion abnormality on the predictive value. In addition, to improve the understanding for factors associated with low sensitivity, clinical, echocardiographic and procedural parameters associated with a false-negative dobutamine echocardiography result were analysed.

**Methods**

**Study patients**

Two hundred and eighty-three consecutive patients (222 men) with a mean (± SD) age of 56 ± 11 years (range 31 to 79) with suspected or known coronary artery disease, who were referred for coronary angiography for the evaluation of chest pain, were enrolled in the study. The study excluded patients with unstable angina, congestive heart failure, Q wave myocardial infarction, cardiomyopathy, uncontrolled hypertension, congenital or acquired valvular heart disease or documented serious ventricular arrhythmia.

Antianginal therapy before the examination included nitrates in 175 patients, calcium channel antagonists in 103 and beta-blocking agents in 96. Antianginal therapy was withheld only on the day of dobutamine echocardiography. One hundred and ninety-seven patients had angina at the time of examination. Previous myocardial revascularization had been performed in 63 patients (43 with coronary angioplasty, 24 with coronary artery bypass grafting), and 47 patients had a non-Q wave infarction.

**Cardiac catheterization**

Left heart catheterization and coronary angiography was performed in all patients within 30 days of dobutamine echocardiography. Analysis of coronary angiograms was performed with electronic calipers by an independent angiographer. Significant coronary artery disease was defined as ≥50% diameter stenosis of any major branch. Multivessel disease was defined as the presence of significant left main coronary artery or two-or three-vessel disease on the coronary angiogram.

**Dobutamine stress protocol**

Dobutamine was administered with an infusion pump, starting at a rate of 5 μg · kg body weight\(^{-1}\) · min\(^{-1}\), increasing the dosage every 3 min to 10, 20, 30 and 40 μg · kg\(^{-1}\) · min\(^{-1}\). In case 85% of age-predicted maximal heart rate was not reached and the test was negative, 0.25 mg atropine was given every minute up to a maximum of 1.0 mg atropine i.v. Continuous 12-lead ECG monitoring was performed and a 12-lead ECG was recorded at 25 mm · s\(^{-1}\) every 2 min. The presence of horizontal or downsloping ST-segment depression of at least 0.1 mV, 0.08 s after the J point vs baseline recordings was considered diagnostic for ECG evidence of myocardial ischaemia. Blood pressure was measured by the cuff method every 2 min during and up to 15 min after termination of drug administration. The rate–pressure product was calculated by multiplying systolic blood pressure and heart rate. End-points for stopping the infusion were achievement of peak dose, severe symptoms, electrocardiographic changes diagnostic of ischaemia, a systolic blood pressure >240 mmHg or a diastolic blood pressure >120 mmHg, decrease in blood pressure >20 mmHg, serious ventricular arrhythmia, or the development of significant new wall motion abnormalities (affecting more than three segments).

**Image acquisition**

Image acquisition was performed with the patient placed in the left lateral decubitus position. Two-dimensional echocardiography from parasternal long- and short-axis and apical four- and two-chamber views was continuous throughout the study and during recovery until resolution of new wall motion abnormalities that might have occurred during the stress. Images were digitized on-line at baseline, low dose (10 μg · kg\(^{-1}\) · min\(^{-1}\)), peak stress and after recovery, at least 8 min after completion of the stress. A back-up videotape recording was obtained of the complete study.

**Analysis of echocardiograms**

On-line digital images in quad screen format were analysed for the presence, extent, severity and location of segmental wall motion abnormalities. A videotape review was performed in case of uncertainty about the digital image. The left ventricle was divided into 16 segments according to the recommendations of the American Society of Echocardiography\(^11\). Regional myocardial contractile function was graded as normal, hypokinetic, akinetic or dyskinetic, in each myocardial
segment, with reference to systolic wall thickening rather than endocardial motion. An abnormal echocardiographic stress test result was defined as one showing the development of a new or worsening stress-induced regional wall motion abnormality not present at baseline. Test abnormality was further described by (1) the extent and (2) the severity of the induced wall motion abnormality at peak stress. The extent of induced wall motion abnormality was defined by the number of segments with new wall motion abnormalities. Four degrees were defined (a) at least one segment, (b) at least two segments, (c) at least three segments, (d) at least four segments. The severity of the induced wall motion abnormality was described by the degree of deterioration of myocardial contractility (at least one grade vs at least two grades). This allowed the positive predictive value of dobutamine echocardiography for coronary artery disease to be analysed from the extent and severity of the induced wall motion abnormality. In addition, the sensitivity and specificity of dobutamine echocardiography were determined using more rigid criteria for test positivity (new wall motion abnormality in $\geq 2$, $\geq 3$ and $\geq 4$ segments instead of the conventional $\geq 1$ segment criterion). Echo image quality was assessed on a five point scale (5: lowest quality) as described recently.$^{12}$

**Analysis of reasons for false-negative dobutamine stress echocardiograms**

In order to evaluate possible reasons for a false-negative result of dobutamine echocardiography, factors increasing the likelihood of false-negative test results were analysed. These variables included clinical, procedural and echocardiographic variables.

Clinical parameters consisted of the patient’s age and antianginal therapy prior to the dobutamine stress test (nitrates, calcium antagonists, beta-blocking agents). Procedural parameters consisted of maximal dobutamine dosage, additional administration of atropine, premature termination of pharmacological stress, achieved rate–pressure product and achievement of the targeted heart rate. The echocardiographic variables included in the analysis were the image quality of the stress echocardiogram and the presence of resting wall motion abnormalities.

**Statistical analysis**

Statistical analysis was performed using the SAS software package. Continuous variables are expressed as mean value ± SD and categorical data as frequency. Continuous variables were compared using Student’s $t$-test for paired or unpaired data or analysis of variance where adequate and frequency data using the chi-square test. Univariate logistic regression analysis was performed to determine the significant impact on false-negative dobutamine echocardiography test results of clinical, stress procedural and echocardiographic parameters. To demonstrate the association between sensitivity and specificity for different cut-off points on the extent and severity of the induced wall motion, receiver operating characteristics (ROC) curves were calculated. A level of <0.05 was considered significant.

**Results**

**Coronary angiography**

Coronary angiography revealed that 183 of the 283 patients had significant coronary artery disease. One hundred and seven (58%) patients had one-vessel disease, 42 (23%) two-vessel disease and 34 (19%) three-vessel disease.

**Dobutamine stress test**

The average maximal dobutamine dosage was $36 \pm 7 \mu g \cdot kg^{-1} \cdot min^{-1}$ and in 59 patients additional atropine was given. The average dose of atropine was $0.6 \pm 0.3 \text{mg}$. Heart rate increased from $76 \pm 14 \text{min}^{-1}$ to $127 \pm 23 \text{min}^{-1}$ ($P<0.001$), systolic blood pressure from $126 \pm 22 \text{mmHg}$ to $161 \pm 32 \text{mmHg}$ ($P<0.001$) and the rate–pressure product increased from $9581 \pm 2645 \text{mmHg} \cdot \text{min}^{-1}$ at rest to $20278 \pm 5146 \text{mmHg} \cdot \text{min}^{-1}$ ($P<0.001$) with maximal pharmacological stress. Seventy-four patients developed angina during the dobutamine stress test. In 68 patients, the dobutamine ECG was positive and in 52 patients the test was stopped prematurely.

**Diagnostic accuracy of dobutamine echocardiography (Table 1)**

Using the conventional one segment criterion for diagnosis of coronary artery disease, 155 dobutamine echocardiograms were positive and 128 were negative. The calculated sensitivity, specificity and accuracy were 72%, 78% and 74%, respectively. Sensitivity was 69% for one-vessel disease and 78% for multivessel disease. New

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**Table 1** Sensitivity, specificity as well as diagnostic accuracy of dobutamine echocardiography with different extent of induced wall motion abnormality required for test positivity

<table>
<thead>
<tr>
<th>Test positivity</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\geq 1$ segment</td>
<td>72%</td>
<td>78%</td>
<td>74%</td>
</tr>
<tr>
<td>$\geq 2$ segment</td>
<td>65%</td>
<td>90%</td>
<td>73%</td>
</tr>
<tr>
<td>$\geq 3$ segment</td>
<td>47%</td>
<td>94%</td>
<td>64%</td>
</tr>
<tr>
<td>$\geq 4$ segment</td>
<td>27%</td>
<td>97%</td>
<td>51%</td>
</tr>
<tr>
<td>$P$</td>
<td>$&lt;0.001$</td>
<td>$&lt;0.01$</td>
<td>$&lt;0.01$</td>
</tr>
</tbody>
</table>
wall motion abnormalities were induced in an average of 1.8 ± 1.5 segments in patients with one-vessel disease and in 3.0 ± 2.1 segments in patients with multivessel disease (P<0.001).

Extent and severity of induced wall motion abnormality (Tables 1 and 2, Fig. 1)

The positive predictive value of dobutamine echocardiography for coronary artery disease was found to increase with larger and more severe wall motion abnormalities. Deterioration of wall motion by one grade in one segment had a positive predictive value of 85%. The positive predictive value increased to 94% (P<0.05) where the induced wall motion abnormality affected at least four segments. Similarly, it increased to 96% if the wall motion deteriorated in one segment by two grades instead of one grade (P<0.05). The positive predictive value was 100% if the induced wall motion abnormality affected at least four segments, with at least one of them demonstrating deterioration by two grades. The use of more rigid criteria for test positivity resulted in a significant increase of specificity and a significant decrease of sensitivity. Using these more rigid criteria, sensitivity for detection of coronary artery disease was affected more in patients with one-vessel disease than in patients with multivessel disease. Sensitivity decreased from 69% with ≥1 segment criterion to 61% with ≥2 segments criterion (P=0.038) for patients with one-vessel disease. For patients with multivessel disease, sensitivity decreased from 78% with ≥1 segment criterion to 73% with ≥2 segment criterion (ns). Figure 2 demonstrates the receiver operator characteristics curves for different cut-off points in the induced extent of wall motion abnormality, with the severity of wall motion deterioration being either one grade or two grades. It becomes obvious that the criterion of a two-grade deterioration in wall motion is associated with a very high specificity but a low sensitivity.

Parameter associated with false-negative dobutamine echo result (Table 3)

Of the 183 patients with coronary artery disease, 132 had a correct-positive and 51 a false-negative dobutamine echocardiogram. Patients with a false-negative dobutamine echocardiogram tended more frequently to be treated with beta-blocking medication, to obtain a higher dobutamine dosage, reach a lower maximal heart rate, have less frequent premature termination of the dobutamine stress and more frequent

Table 2 Positive predictive value of dobutamine echocardiography with different extent and severity of induced wall motion abnormality

<table>
<thead>
<tr>
<th>Extent</th>
<th>Severity</th>
<th>Deterioration by 1 grade</th>
<th>Deterioration by 2 grades</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥1 segment</td>
<td>85%</td>
<td>96%</td>
<td>&lt;0.05</td>
<td></td>
</tr>
<tr>
<td>≥2 segment</td>
<td>90%</td>
<td>96%</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>≥3 segment</td>
<td>94%</td>
<td>98%</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>≥4 segment</td>
<td>94%</td>
<td>100%</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

* ns; ** P<0.05.
resting wall motion abnormalities. The additional use of atropine, the absence of angina pectoris and ECG changes during the dobutamine stress test, and low image quality were found to be significantly more frequent in patients with a false-negative dobutamine echocardiography result.

**Role of maximal heart rate during dobutamine stress test** *(Table 4, Fig. 3)*

The number of segments with new, induced wall motion abnormalities in patients reaching <75%, 75–85% and >85% of age-predicted maximal heart rate was 1·8 ± 1·7, 2·4 ± 1·8 and 2·7 ± 1·5 (*P*=0·045), respectively. There was a significant increase in sensitivity with the higher maximal heart rates. Specificity and diagnostic accuracy changed non-significantly.

**Discussion**

Dobutamine echocardiography has emerged as an easy to perform stress alternative in patients unable or unwilling to exercise adequately. The diagnostic accuracy

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**Table 3** Univariate parameters associated with false-negative dobutamine echocardiograms in patients with angiographically proven coronary artery disease

<table>
<thead>
<tr>
<th>Parameter</th>
<th>True positive (n=135)</th>
<th>False negative (n=48)</th>
<th>OR</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta-blocking medication</td>
<td>30%</td>
<td>37%</td>
<td>1·19</td>
<td>0·66–2·14</td>
<td>0·113</td>
</tr>
<tr>
<td>Use of atropine</td>
<td>13%</td>
<td>28%</td>
<td>3·87</td>
<td>1·54–9·75</td>
<td>0·028</td>
</tr>
<tr>
<td>Maximal dobutamine dose (µg·kg⁻¹·min⁻¹)</td>
<td>34·8 ± 8·7</td>
<td>36·7 ± 7·0</td>
<td>1·03</td>
<td>0·97–1·09</td>
<td>0·176</td>
</tr>
<tr>
<td>Maximal heart rate (min⁻¹)</td>
<td>124 ± 24</td>
<td>119 ± 22</td>
<td>0·96</td>
<td>0·94–0·98</td>
<td>0·185</td>
</tr>
<tr>
<td>Angina during dobutamine stress</td>
<td>37%</td>
<td>15%</td>
<td>0·26</td>
<td>0·09–0·71</td>
<td>0·010</td>
</tr>
<tr>
<td>ECG changes during dobutamine stress</td>
<td>35%</td>
<td>15%</td>
<td>0·49</td>
<td>0·19–1·25</td>
<td>0·014</td>
</tr>
<tr>
<td>Premature stop of dobutamine stress</td>
<td>23%</td>
<td>14%</td>
<td>0·43</td>
<td>0·15–1·23</td>
<td>0·131</td>
</tr>
<tr>
<td>Resting wall motion abnormality</td>
<td>10%</td>
<td>14%</td>
<td>1·36</td>
<td>1·02–1·81</td>
<td>0·086</td>
</tr>
<tr>
<td>Image quality of echocardiograms</td>
<td>2·4 ± 0·8</td>
<td>2·8 ± 1·2</td>
<td>1·59</td>
<td>1·07–2·37</td>
<td>0·015</td>
</tr>
</tbody>
</table>

CI=confidence interval; OR=odds ratio
and predictive value of dobutamine echocardiography have been demonstrated in several studies to be significantly higher than for exercise ECG\cite{4,5,13–16}. In this study on 283 patients, dobutamine echocardiography had a sensitivity of 72% and a specificity of 78%. This is in the range of previously reported data\cite{16}. The size of the study cohort allowed several additional observations.

**Increased positive predictive value with severe test abnormality**

The conventional criterion for positivity of dobutamine echocardiography is a deterioration of wall motion by at least one grade in at least one segment\cite{1–3}. This is an arbitrary definition based on only four grades commonly used to describe wall motion. Segmentation of the left ventricle is also arbitrary. While most studies used 16 left ventricular segments\cite{1,3,11}, other reports have used 8, 10, 11 and even 20 left ventricular segments\cite{4,13,14,17}. With the induction of more severe and extensive wall motion abnormalities there was a significant increase in the positive predictive value in this study. Under specific conditions, a high positive predictive value is desired, for example to justify coronary angiography in a patient who had a low likelihood of coronary artery disease before a positive non-invasive stress test. In general, Griner \textit{et al.}\cite{18} have stressed the importance of using a test with a high specificity and positive predictive value if there is a suspicion of disease after a first screening test. Thus, in a time of limited resources, a high positive predictive value is desirable to restrict expensive invasive procedures in patients with a high likelihood of disease which requires further diagnostic as well as therapeutic consequences. Even the combination of different stress tests has been performed to obtain a high positive predictive value\cite{7}. An increased positive predictive value has been demonstrated for other non-invasive tests with more extensive test positivity. The positive predictive value of the exercise ECG for the presence of coronary artery disease increases with more pronounced ST-segment depression\cite{7}. The positive predictive value of thallium perfusion scintigraphy for follow-up events has been demonstrated to depend on the extent of test abnormality\cite{8,19}. Similarly, the results of this study indicate that the degree of dobutamine echocardiography abnormality is a clinically useful parameter which should be reported, in addition to the description of a dobutamine echocardiography result, as positive or negative. However, it should be noted that alteration of traditionally used stress end-points may be necessary.

**Table 4** Sensitivity, specificity and diagnostic accuracy of dobutamine echocardiography depending on the obtained maximal heart rate

<table>
<thead>
<tr>
<th></th>
<th>&lt;75% of max. heart rate (n=96)</th>
<th>75–85% of max heart rate (n=105)</th>
<th>&gt;85% of max heart rate (n=82)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>67%</td>
<td>71%</td>
<td>86%</td>
<td>&lt;0·05</td>
</tr>
<tr>
<td>Specificity</td>
<td>93%</td>
<td>81%</td>
<td>82%</td>
<td>ns</td>
</tr>
<tr>
<td>Accuracy</td>
<td>73%</td>
<td>76%</td>
<td>84%</td>
<td>ns</td>
</tr>
</tbody>
</table>

**Figure 3** Comparison of number of segments with induced wall motion abnormalities depending on the achieved maximal heart rate.

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in case the degree of dobutamine echocardiography abnormality is used as an additional parameter of test positivity. Stress protocols which do not stop with the development of minor wall motion abnormalities should be considered, if the aim is to obtain the highest positive predictive value from dobutamine echocardiography. In this study, the development of wall motion abnormalities in more than three segments was used as a stress end-point.

**Parameters associated with false negative test results**

A negative dobutamine stress test, in spite of significant angiographic stenosis, may be due to (1) an incorrect assessment of the angiographic severity of the lesion, (2) an insufficient stress level to induce myocardial ischaemia or (3) insufficient sensitivity to detect the induced myocardial ischaemia. In this study, patients with a false-negative stress test more frequently received atropine as an additional pharmacological stress and tended to have less frequent premature termination of the dobutamine stress protocol. However, in spite of the higher pharmacological stress level, the haemodynamic stress tended to be lower. The association between atropine administration and a false-negative test may therefore be an indirect result of atropine administration to patients with inadequate reaction to dobutamine than a result of the atropine itself. Furthermore, patients with false-negative dobutamine echocardiography less frequently had angina or ECG changes during dobutamine stress. This may indicate that the coronary stenosis defined as significant by angiography was not a functionally significant stenosis, or that the induced stress level was insufficient to induce ischaemia. Dobutamine stress is known to induce less haemodynamic stress and there are several reports indicating that it has a slightly lower sensitivity than exercise stress echocardiography.[5,20]. Rallidis et al.[20] reported a rate–pressure product at peak stress of 19399 ± 3923 for dobutamine stress and of 24577 ± 5680 mmHg . min⁻¹ for exercise stress. The peak wall motion score index was 1·73 ± 0·45 for exercise echocardiography and 1·57 ± 0·44 for dobutamine echocardiography. In a comparative study on 136 patients, Beleslin et al.[4] reported a sensitivity of 82% for dobutamine echocardiography but 88% for exercise echocardiography. Similarly, Marwick et al.[5] reported a sensitivity of 73% for dobutamine echocardiography, but 77% for exercise echocardiography. The findings of this study support the hypothesis that dobutamine stress is insufficient in some patients to induce the necessary stress level for a positive test result. A further parameter in favour of false-negative test results was found to be low image quality, indicating that induced ischaemia might not have been detected. Thus, high image quality is required to obtain the highest possible sensitivity in the detection of induced ischaemia.

**Haemodynamic stress level and test sensitivity**

Dobutamine has a strong positive inotropic effect, in addition to its positive chronotropic effect. It has been postulated that the increase in contractility is the most important factor contributing to myocardial oxygen consumption[21]. Pharmacological stress protocols have been altered with the addition of atropine in order to increase pharmacological stress levels[22–24]. However, the sensitivity of dobutamine echocardiography at different levels of maximal heart rate has not been evaluated in detail. The transfer of the obtained maximal heart rate, as a marker of a sufficient stress level may not be adequate for the dobutamine stress test. The findings of this study support the use of high pharmacological stress levels with the aim of increasing the maximal heart rate at peak pharmacological stress above 85% of the age predicted maximal heart rate and thus the haemodynamic stress level to the highest possible degree. This may also imply that the stress protocol should not be stopped at the conventional end-point of 85% of the age-predicted maximal heart rate, and that a higher heart rate end-point might be advantageous. It also indicates that the obtained maximal heart rate is a good marker of an adequate high stress level even in dobutamine stress testing.

**Limitations**

The use of the extent and severity of an abnormal test result to increase the positive predictive value of dobutamine echocardiography is dependent on the pharmacological stress level induced in the patient and the end-points used. The percentage of patients with additional administration of atropine to increase the maximal pharmacological stress was low in this study. However, Lieng et al.[24] reported, in a study on dobutamine echocardiography in 1171 patients, the use of atropine as an additional agent in 26%, thus a similar ratio as in this study.

Angiographic analysis of coronary lesion severity as parameter for false-negative stress tests was not included in this analysis. However, less severe stenosis has already been defined as a possible reason for negative dobutamine echocardiography results[10,25].

**Clinical implications and conclusions**

The positive predictive value of dobutamine echocardiography increases with the extent and severity of the induced wall motion abnormality. Thus, the degree of positivity offers useful additional information which should be reported in clinical practice in addition to the classification of a test as positive or negative. The specificity of dobutamine echocardiography can intentionally be increased using more rigid criteria for...
test positivity. To minimize the number of false-negative dobutamine echocardiography tests and maximize the sensitivity of dobutamine echocardiography the highest haemodynamic stress level, as assessed by the maximal heart rate, needs to be obtained. However, in spite of a high pharmacological stress level, the obtained haemodynamic response may still not be sufficient to induce myocardial ischaemia, as evident by a lack of new wall motion abnormalities, ECG changes or angina.

We acknowledge the expert statistical analysis of Thorsten Reinecke.

References


