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Stress echocardiography

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Noninvasive tests play a pivotal role in everyday cardiology practice in risk-stratifying patients for adverse cardiac events. They are particularly useful for the 10-80% of patients at intermediate risk after initial clinical assessment. If noninvasive tests are indicative of lower risk, invasive investigations could then be avoided in such patients, saving them from the inherent risks of invasive procedures. This approach may also translate into significant cost reduction to our health care system. Exercise electrocardiography (EX-ECG) has been widely used, but its modest sensitivity (68%) and specificity (77%) limit its popularity.[1] Radionuclide myocardial perfusion imaging (MPI) provides superior accuracy, but it is more time-consuming, labour-intensive, and relatively costly. Stress echocardiography (SE) has gained tremendous acceptance in the last 5 years as an alternative to MPI. Its advantages over MPI are multi-fold:

- Additional information such as valvular anatomy, intra-cardiac thrombus and pericardial effusion, and other aspects of left ventricular anatomy and function are available
- the test and reporting can be completed within one hour
- there is no radiation hazard
- the cost is significantly less.[2]

Stressors

Both exercise or pharmacological stressors are used in SE. Exercise treadmill test (ETT), using the Bruce protocol, is more popular in North America. Echocardiographic image acquisition has to be completed within 90 seconds after peak exercise to preserve test sensitivity.[3] In Europe, where cycling is more prevalent, supine or upright bicycle stress is more widely used. Its added advantage is that it allows image acquisition at rest, low stress, peak stress, and in recovery. Exercise testing provides additional information on a patient's exercise capacity, symptoms, hemodynamic response, and ECG changes during exercise. It is technically more challenging because of the limited time window for image acquisition after peak stress, and post-exercise hyperventilation often obscures the images.

During image acquisition, patients lie left laterally after ETT or remain supine or upright on the bicycle. Four views (parasternal long axis, short axis, apical 4, and 2 chambers) are recorded. The 16-segment model recommended by the American Society of Echocardiography is adopted for wall motion analysis. Stress and rest images are digitally displayed side-by-side in a quad-screen format to enhance accurate interpretation. Good image quality is paramount and tissue harmonic imaging as well as contrast echocardiography has enhanced SE accuracy. Nevertheless, 5% of studies remain non-diagnostic.[4]

For patients who cannot exercise for various reasons, pharmacological stress with either dobutamine, arbutamine, dipyridamole, or adenosine is used. Dobutamine has predominant ß2 and some ß1 and α1 agonistic properties.[5] It mimics the hemodynamic responses seen during exercise. Myocardial contractility, heart rate, and cardiac output are augmented and systemic vascular resistance is lowered. Blood pressure usually improves or remains unchanged due to a higher cardiac output. The increased myocardial oxygen demand is met by augmented coronary blood flow. Dobutamine has a half-life of 2 minutes and lasts only 10-15 minutes after the cessation of infusion. Arbutamine is a synthetic catecholamine that mimics the effects of dobutamine. It is administered by a closed-loop delivery system that allows continuous hemodynamic feed-

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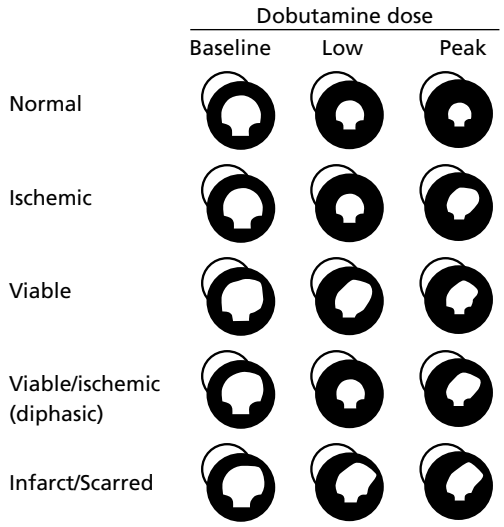
Figure 1: Short axis view of left ventricle at end systole demonstrating various responses of the anterolateral wall to low and high doses of dobutamine infusion.[10]



back from the patient for dose adjustment to reach target heart rate.[6] Its efficacy and side effects are similar to dobutamine,[7-9] but it is more expensive.

The normal myocardium responds to dobutamine by increasing wall thickening, endocardial excursion, and ejection fraction (EF) (Figure 1).[10] Segments that show normal response at low doses, but become dyssynergic at higher doses, represent regional ischemia. Dyssynergic segments at rest that show increased wall thickening and contractility at low and high doses of dobutamine indicate stunning. Dyssynergic segments at rest that show increased wall thickening and endocardial excursion only at low dose (5-15 µg/kg/min), but become dyssynergic again at higher doses (biphasic response), represent viable myocardium supplied by a critically stenosed artery. Dyssynergic segments that do not improve at low and high dose of dobutamine represent scar tissue.

Dobutamine stress echocardiography (DSE) protocols vary between laboratories. Usual dose ranges are 5-40 µg/kg/min in 10 µg/kg/min increments every 3-5 minutes until target heart rate of 85% maximum predicted heart rate is reached. Atropine (0.5-2.0 mg) in small boluses is given if target heart rate is not reached at peak dobutamine infusion. Echocardiographic images are recorded before each dose increase and in recovery. Intravenous esmolol can be given to reverse any untoward effects of dobutamine at the end of study. When DSE is performed for diagnostic indications, oral beta-blockers are held 2 days prior to the test. Endpoints to terminate dobutamine infusion include:

- achievement of target heart rate
- significant new or worsening regional wall motion abnormality
- severe cardiopulmonary symptoms
- severe side effects
- significant ST changes or arrhythmias
- drop in SBP > 20 mm Hg;
- significant hypertension [SBP >240 mm Hg or DBP >120 mm Hg
- maximum dose of dobutamine is reached.

The safety profile of DSE has been established in 7,000 patients.[11-14] Serious complications including ventricular tachycardia (VT), ventricular fibrillation, myocardial infarction (MI), sustained supraventricular arrhythmias, and significant hypotension requiring hospitalization occurred in about 0.5% of patients. There were no deaths. Fifteen per cent of patients had minor complications such as premature atrial or ventricular beats, atrial fibrillation or flutter, non-sustained VT, hypertension, and hypotension. Non-cardiac side effects such as nausea, vomiting, headache, tremor and anxiety occurred in about 10% of patients. Contraindications to DSE include contraindications to exercise testing; acute phase of unstable angina or MI; uncontrolled tachyarrhythmia or hypertension; severe aortic stenosis or obstructive hypertrophic cardiomyopathy. Contraindications to atropine are glaucoma and prosthetic obstruction.

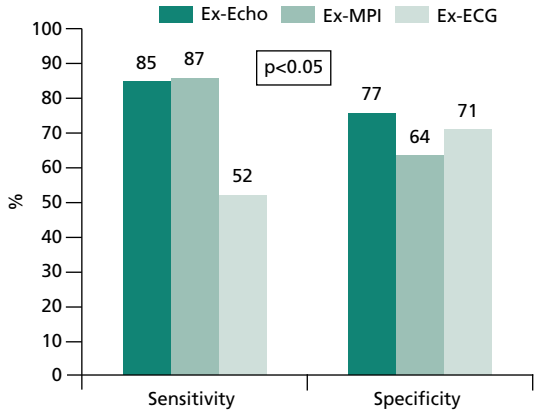
Dipyridamole stress echocardiography (DPE) is more popular in Europe.[15] Dipyridamole, often given as 0.56-0.84 mg/kg, augments adenosine receptor stimulation leading to vasodilatation of coronary resistance vessels. Flow maldistribution or true ischemia results by either "horizontal or vertical coronary steal." If target heart rate is not reached, atropine is given to enhance test sensitivity. In an overview of 24 DPE reports in 2,038 patients,[16] serious complications (MI, 3rd degree heart block, VT) occurred in 1/1500 patients. Mortality rate was 1/9000. 5% of patients reported mild adverse effects such as hypotension, bradycardia, headache, dizziness, nausea and flushing. Contraindications to DPE include sick sinus syndrome, 2nd or 3rd degree heart block and active bronchospastic disease.

Detection of coronary artery disease (CAD)

SE has been reported to have similar accuracy as radionuclide MPI for detecting CAD. Fleischmann et al performed a meta-analysis on 44 articles published between 1990-1997 examining the diagnostic accuracy of exercise echocardiography (EXE) and exercise thallium or sestamibi SPECT MPI.[17] The overall sensitivity and specificity (unadjusted for referral bias) were 85 % and 77%, respectively, for EXE, compared to 87% and 64 % for exercise MPI, and 52% and 71% for exercise ECG (Figure 2). The receiver operating curves showed that EXE had better discriminating power then exercise SPECT MPI.

Numerous reports on DSE in detecting CAD have been published recently. In an overview of 28 DSE reports involving 2,246 patients using angiography as the reference standard,[18] the weighted mean sensitivity,

Figure 2: Sensitivity and specificity of EXE, EX-MPI and Ex-ECG for detection of CAD.[17]



specificity and accuracy of DSE was 80%, 84% and 81%, respectively. As expected, the sensitivity improved with the number of coronary arteries involved. Mean sensitivity increased from 74% for 1-vessel disease to 86% for 2-vessel disease and to 92% for 3-vessel disease. DSE is also useful in revealing the stenosed artery. The mean sensitivity and specificity were 72% and 88%, for left the anterior descending artery, 55% and 93% for the circumflex artery, and 76% and 89% for the right coronary artery. The lower sensitivity for detecting circumflex disease is often due to suboptimal visualization of the lateral wall endocardium.

In 4 studies comparing DSE with dobutamine sestamibi MPI in 318 patients, sensitivity was 76% vs. 81%, specificity 85% vs. 71% ($p<0.01$), and accuracy 80% vs. 78%. The lower sensitivity of DSE is consistent with the "ischemic cascade" theory[19] that suggests that regional hypoperfusion precedes contractile dysfunction.

When different modes of SE were compared, EXE had better sensitivity (85% vs. 75%, $p<0.01$) than DSE , but similar specificity (88% vs. 87%). DSE was more sensitive than DPE (73% vs. 65%, $p<0.05$), but its specificity was not significantly different (82% vs. 89%).

Factors that increase the sensitivity of SE in detecting CAD include the severity of disease (% stenosis and number of involved arteries), achievement of target heart rate, quality of images, and definition of positivity. The intra-observer and inter-observer agreement ranged from 95% to 98% and from 92% to 96%, respectively. For individual segments, agreement ranged from 84% to 97 %.[20-23] Several factors may affect the specificity of SE: true ischemia may be present without angiographically significant coronary stenosis; and normal variation in the degree of wall thickening in different regions exist. Overinterpretation is common among inexperienced readers, especially in the basal posterior wall.[24]

Risk stratification in patients with CAD

Geleijnse et al reported superior prognostic value of DSE over sestamibi SPECT MPI in their prospective study in 220 patients with chest pain.[25] Half of these patients had previous MI. All patients underwent DSE and simultaneous sestamibi SPECT MPI. DSE was positive for ischemia in 76 and MPI was positive in 91 patients (agreement 77%, $\kappa=0.51$). Within 31±15 months of follow-up, 24 patients (11%) had nonfatal MI (NFMI) or cardiac death. Multivariate analysis showed that ischemia on DSE (odds ratio 4.0) or MPI (O.R. 3.0) had independent predictive values. The addition of MPI to non-diagnostic DSE studies increased the odds ratio to 5.7, whereas the addition of DSE to nondiagnostic MPI studies was not helpful. Marwick et al evaluated the prognostic value of EXE in 463 patients with suspected CAD.[26] After 44±11 months, 33 patients (7%) had spontaneous cardiac death, MI, or unstable angina. Ischemia on EXE was strongly predictive of spontaneous events (RR 8.2, $p<0.001$). The addition of echocardiography to exercise and clinical data offered incremental predictive value.

Risk stratification after MI

In these higher risk patients, SE has also been shown to be useful. Ryan et al performed EXE and Ex-ECG tests in 40 patients 10-21 days post-infraction and followed them for 6-10 months.[27] 20 patients had cardiac events (cardiac death, NFMI, unstable angina or revascularization). The sensitivity and specificity of EXE for cardiac events were 80% and 95%, respectively, as compared to 55% and 65%, respectively, for Ex-ECG. The positive and negative predictive values of EXE were 94% and 83%. Quintana studied 70 patients 7±4 days post-infarction in the thrombolysis era.[28] In 3 years of follow-up, 22 of 27 patients (81%) with positive EXE results had cardiac events (death, NFMI, revascularization), as compared to 12 of 43 patients (28%) with negative EXE results ($p<0.0001$). There was a 43% relative reduction in cumulative event-free survival in those with negative compared to positive EXE results ($p=0.001$). EXE also had superior predicting power than Ex-ECG for cardiac events.

Pharmacological SE has also been studied in this population. 178 post-MI patients underwent predischarge DSE and symptom-limited Ex-ECG and were followed for 17±13 months.[29] There were 5 deaths and 6 NFMI. DSE had similar positive (24% vs. 23%) and negative predictive values (98% vs. 95%) for these events when compared to Ex-ECG. Patients with a positive DSE were 5 times more likely to develop hard cardiac events compared to those with a negative DSE. In another study of 406 patients within 10 days of MI, Bigi et al found that symptom-limited Ex-ECG or DSE had low positive predictive values for predicting spontaneous cardiac death, NFMI or unstable angina.[30] However, their negative predictive values were excellent (91% and 90%, respectively). Multivariate analy-

sis showed that positive low-workload Ex-ECG and positive low-dose DSE were predictive of cumulative cardiac events.

In the Echo Dobutamine International Cooperative (EDIC) Study,[31] 778 patients underwent DSE 12±5 days post-infarction and were followed for 9±7 months. There were only 14 (1.8%) cardiac deaths and 24 (2.9%) NFMI in this cohort. Cardiac mortality (2.2% vs. 1.2%) and NFMI (2.5% vs. 4 %) were not significantly different in those with or without an abnormal DSE. However, the wall motion score index at peak dobutamine dose was the best predictor of cardiac death (hazard ratio 9.2, $p<0.0001$). In the Echo Persantine Italian Cooperative (EPIC) Study,[32] DPE was shown to have discriminatory value in risk stratification. 1080 patients 10±5 days post-infarction underwent DPE and were followed for 14 months. Cardiac death rates were 5.6% in those with a positive DPE and 2.3% in those with a normal DPE ($p<0.02$). NFMI rates were 5% and 3.3% ($p<0.05$), and the 1-year infarct-free survival was 92.2% and 96.6%, respectively ($p<0.005$) for those with a positive vs. negative DPE.

Cardiac assessment before vascular surgery

Numerous reports have been published on DSE as a tool to risk-stratify patients who are at intermediate risks of adverse cardiac events during or after vascular surgery. A meta-analysis of 5 DSE studies (446 patients) and 10 dipyridamole-thallium SPECT MPI studies (1994 patients) published between 1985-1994 was performed by Shaw et al.[33] The odds ratio for death/NFMI was 14-27 for DSE and 4 for thallium MPI. The wide confidence interval for DSE was due to a smaller patient population studied. The positive and negative predictive values for these hard events for DSE were 13% and 99%, respectively. Poldermans et al studied 316 patients with DSE before vascular surgery and followed them for 19±11 months.[34] Patients were risk-stratified into low, intermediate and high risk groups, based on the amount of ischemic myocardial segments on DSE and history of prior MI. There were a total of 32 (10%) deaths, NFMI or revascularization in this cohort. The event rates for these 3 groups were 5%, 20% and 52%, respectively.

Cardiac allograft vasculopathy (CAV)

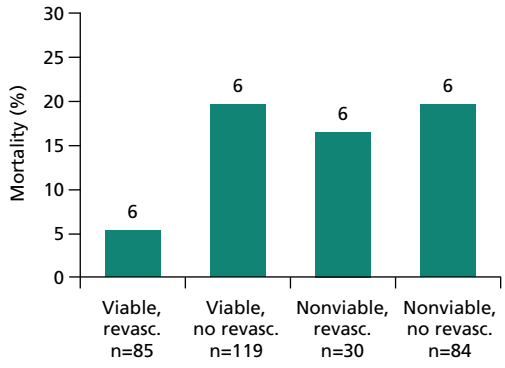
CAV is a major cause for late mortality in cardiac transplant recipients. Noninvasive techniques in detecting hemodynamically significant CAV had been disappointing due to the diffuse, concentric nature and aggressiveness of the disease. Surveillance traditionally relies on routine annual coronary angiography. Data had been gathered recently on the utility of DSE to risk-stratify these patients and to avoid routine angiography. Akosah reported a 2-year follow-up series on 77 cardiac transplant survivors.[35] Fifty-seven patients (74%) had positive DSE; 19 patients (33%) experienced 22 deaths, MI, unstable angina,or heart failure episodes. No events occurred in patients with a normal DSE. The peak wall motion score index also had a predictive value for cardiac events. In another study comparing DSE with coronary angiography and intravascular ultrasound (IVUS) in 109 heart transplant recipients,[36] DSE had a sensitivity of 72% and specificity of 90% in detecting CAV as defined by IVUS and angiography. Over 5 years of follow-up, adverse cardiac events occurred in only 1.9% of patients with normal DSE. Worsening of serial DSE indicated a 7-fold increase in the risk of cardiac events. The authors concluded that the prognostic value of DSE was comparable to angiography and IVUS, and a normal DSE identified low risk patients whose angiography could be postponed.

Assessment of myocardial viability

Definition of myocardial viability within infarcted regions is important in the decision pertaining to revascularization. The presence of viability as determined by positron emission tomography or thallium MPI had been shown to be predictive of improved ventricular function and prognosis after revascularization.[37,38] DSE has also been used to define myocardial viability in patients with CAD and chronic left ventricular dysfunction. The hallmark of viability of a dyssynergic segment is increased wall thickening and endocardial excursion after inotropic stimulation. A "biphasic" response is seen in chronically ischemic but viable myocardium supplied by a critically stenosed artery.

Afridi et al reported outcomes of 318 patients with chronic CAD and LVEF <35% over 18 months.[39] Viability was defined as ≥4 dyssynergic segments demonstrating improvement, worsening or a biphasic response during DSE. Patients were categorized into four groups according to the presence of viability and their revascularization status. There were 51 deaths (16%). The group with viable myocardium who went for revascularization had the lowest mortality (6%) compared to the other groups ($p=0.01$)(Figure 3). Meluzin reported 133 patients with CAD and LVEF <40% who had DSE and underwent revascularization.[40] Patients were divided into Group A (≥6 viable segments), Group B (2-5 viable segments) and Group C (≤1 viable segments). Over 20 months of follow up, the change in EF was +8% (Group A), +6% (Group B) and +1% (Group C), respectively, ($p<0.01$). The rate of death, MI, readmission for angina, and heart failure in each group was 7%, 30% and 39%, respectively ($p<0.01$). Qureshi compared DSE with quantitative rest-redistribution thallium SPECT MPI in predicting functional recovery in 34 patients with CAD

Figure 3: Mortality in patients with CAD and LV dysfunction based on viability and revascularization status.[39]



and mean LVEF of 40%.[41] For predicting segmental contractile recovery 6 weeks after revascularization, the sensitivity, specificity, positive and negative predictive values of DSE were 74%, 89%, 72% and 89%, respectively, as compared to 90%, 56%, 45% and 94%, respectively, for rest-redistribution thallium MPI. The lower sensitivity and higher specificity of DSE have also been reported by other investigators.[42,43] Possible explanations for this discrepancy include tethering of viable segments on thallium MPI to scar tissues which impede contractile recovery; inadequate amount of viable cardiocytes in the scar area to reach the "critical mass" for functional recovery; and incomplete revascularization.

Valvular heart diseases

SE provides important hemodynamic information in patients whose symptoms are incongruent with the severity of their valvular disease.[44] The estimation of mitral inflow gradient, severity of mitral regurgitation, and pulmonary systolic pressure during EXE or DSE enables the clinician to correlate patients' symptoms with their valvular abnormalities. DSE is also useful in patients with 2D-echocardiographic findings of a small aortic valve area (AVA), low aortic gradient (AVG) and low EF.[45] Increases in AVA, AVG and EF with dobutamine infusion suggest systolic dysfunction is the predominant problem. Increases in EF, AVG, but unchanged AVA indicate fixed aortic valve obstruction.

Conclusion

Exercise or pharmacological SE has emerged as a reasonable alternative to radionuclide MPI for detecting CAD and for risk stratification of patients in various clinical settings. It has certain logistic and cost advantages over MPI. However, the reports of accuracy of SE are from dedicated centres with tremendous experience and may not be replicable in centres of lower volumes. A learning curve definitely exists for sonographers and echocardiographers for this new technique. The choice of noninvasive test often is determined by local availability, expertise of the facility, patient characteristics and the quality of echocardiographic images obtained.

References

1. Gianrossi R, Detrano R, Mulvihill D, et al. Exercise-induced ST depression in the diagnosis of coronary artery disease. A meta-analysis. *Circulation* 1989;80(1):87-98.
2. Gibbons RJ, Chatterjee K, Daley J, et al. ACC/AHA/ACP-ASIM guidelines for the management of patients with chronic stable angina: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Management of Patients With Chronic Stable Angina) [published erratum appears in *J Am Coll Cardiol* 1999 Jul;34(1):314]. *J Am Coll Cardiol* 1999;33(7):2092-2197.
3. Bossone E, Armstrong WF. Exercise echocardiography. Principles, methods, and clinical use. *Cardiol Clin* 1999;17(3):447-60, vii.
4. Crawford MH. Choosing the appropriate stress modality. A clinical cardiologist's perspective. *Cardiol Clin* 1999;17(3):597-606.
5. Leier CV, Unverferth DV. Drugs five years later. Dobutamine. *Ann Intern Med* 1983;99(4):490-496.
6. Dennis CA, Pool PE, Perrins EJ, et al. Stress testing with closed-loop arbutamine as an alternative to exercise. The International Arbutamine Study Group. *J Am Coll Cardiol* 1995;26(5):1151-1158.
7. Bach DS, Cohen JL, Fioretti PM, et al. Safety and efficacy of closed-loop arbutamine stress echocardiography for detection of coronary artery disease. International Arbutamine Study Group. *Am J Cardiol* 1998;81(1):32-35.
8. Cohen JL, Chan KL, Jaarsma W, et al. Arbutamine echocardiography: efficacy and safety of a new pharmacologic stress agent to induce myocardial ischemia and detect coronary artery disease. The International Arbutamine Study Group. *J Am Coll Cardiol* 1995;26(5):1168-1175.
9. Shehata AR, Ahlberg AW, Gillam LD, et al. Direct comparison of arbutamine and dobutamine stress testing with myocardial perfusion imaging and echocardiography in patients with coronary artery disease. *Am J Cardiol* 1997;80(6):716-720.
10. Orsinelli DA, Daniels CJ. Pharmacologic stress echocardiography. Dobutamine and arbutamine stress testing. *Cardiol Clin* 1999;17(3):461-79, viii.
11. Mertes H, Sawada SG, Ryan T, et al. Symptoms, adverse effects, and complications associated with dobutamine stress echocardiography. Experience in 1118 patients. *Circulation* 1993;88(1):15-19.
12. Picano E, Mathias W, Jr., Pingitore A, Bigi R, Previtali M. Safety and tolerability of dobutamine-atropine stress echocardiography: a prospective, multicentre study. Echo Dobutamine International Cooperative Study Group [see comments]. *Lancet* 1994;344(8931):1190-1192.
13. Smart SC, Knickelbine T, Stoiber TR, et al. Safety and accuracy of dobutamine-atropine stress echocardiography for the detection of residual stenosis of the infarct-related artery and multivessel disease during the first week after acute myocardial infarction. *Circulation* 1997;95(6):1394-1401.
14. Secknus MA, Marwick TH. Evolution of dobutamine echocardiography protocols and indications: safety and side effects in 3,011 studies over 5 years. *J Am Coll Cardiol* 1997;29(6):1234-1240.
15. Picano E, Sicari R, Varga A. Dipyridamole stress echocardiography. *Cardiol Clin* 1999;17(3):481-99, viii.
16. Picano E, Marini C, Pirelli S, et al. Safety of intravenous high-dose dipyridamole echocardiography. The Echo-Persantine International Cooperative Study Group. *Am J Cardiol* 1992;70(2):252-258.
17. Fleischmann KE, Hunink MG, Kuntz KM, Douglas PS. Exercise echocardiography or exercise SPECT imaging? A meta-analysis of diagnostic test performance [see comments]. *JAMA* 1998;280(10):913-920.
18. Geleijnse ML, Fioretti PM, Roelandt JR. Methodology, feasibility, safety and diagnostic accuracy of dobutamine stress echocardiography. *J Am Coll Cardiol* 1997;30(3):595-606.
19. Nesto RW, Kowalchuk GJ. The ischemic cascade: temporal sequence of hemodynamic, electrocardiographic and symptomatic expressions of ischemia. *Am J Cardiol* 1987;59(7):23C-30C.

20. Cohen JL, Greene TO, Ottenweller J, et al. Dobutamine digital echocardiography for detecting coronary artery disease. *Am J Cardiol* 1991;67(16): 1311-1318.
21. Previtali M, Lanzarini L, Fetiveau R, et al. Comparison of dobutamine stress echocardiography, dipyridamole stress echocardiography and exercise stress testing for diagnosis of coronary artery disease. *Am J Cardiol* 1993;72 (12):865-870.
22. Cohen JL, Ottenweller JE, George AK, Duvvuri S. Comparison of dobutamine and exercise echocardiography for detecting coronary artery disease. *Am J Cardiol* 1993;72(17):1226-1231.
23. Beleslin BD, Ostojic M, Stepanovic J, et al. Stress echocardiography in the detection of myocardial ischemia. Head-to-head comparison of exercise, dobutamine, and dipyridamole tests. *Circulation* 1994;90(3):1168-1176.
24. Bach DS, Muller DW, Gros BJ, Armstrong WF. False positive dobutamine stress echocardiograms: characterization of clinical, echocardiographic and angiographic findings. *J Am Coll Cardiol* 1994;24(4):928-933.
25. Geleijnse ML, Elhendy A, van Domburg RT, et al. Cardiac imaging for risk stratification with dobutamine-atropine stress testing in patients with chest pain. Echocardiography, perfusion scintigraphy, or both? *Circulation* 1997;96(1):137-147.
26. Marwick TH, Mehta R, Arheart K, Lauer MS. Use of exercise echocardiography for prognostic evaluation of patients with known or suspected coronary artery disease. *J Am Coll Cardiol* 1997;30(1):83-90.
27. Ryan T, Armstrong WF, O'Donnell JA, Feigenbaum H. Risk stratification after acute myocardial infarction by means of exercise two-dimensional echocardiography. *Am Heart J* 1987;114(6):1305-1316.
28. Quintana M, Lindvall K, Ryden L, Brolund F. Prognostic value of predischarge exercise stress echocardiography after acute myocardial infarction. *Am J Cardiol* 1995;76(16):1115-1121.
29. Greco CA, Salustri A, Seccareccia F, et al. Prognostic value of dobutamine echocardiography early after uncomplicated acute myocardial infarction: a comparison with exercise electrocardiography. *J Am Coll Cardiol* 1997;29(2): 261-267.
30. Bigi R, Galati A, Curti G, et al. Prognostic value of residual ischaemia assessed by exercise electrocardiography and dobutamine stress echocardiography in low-risk patients following acute myocardial infarction [see comments]. *Eur Heart J* 1997;18(12):1873-1881.
31. Sicari R, Picano E, Landi P, et al. Prognostic value of dobutamine-atropine stress echocardiography early after acute myocardial infarction. Echo Dobutamine International Cooperative (EDIC) Study. *J Am Coll Cardiol* 1997;29(2):254-260.
32. Picano E, Pingitore A, Sicari R, et al. Stress echocardiographic results predict risk of reinfarction early after uncomplicated acute myocardial infarction: large-scale multicenter study. Echo Persantine International Cooperative (EPIC) Study Group. *J Am Coll Cardiol* 1995; 26(4):908-913.
33. Shaw LJ, Eagle KA, Gersh BJ, Miller DD. Meta-analysis of intravenous dipyridamole-thallium-201 imaging (1985 to 1994) and dobutamine echocardiography (1991 to 1994) for risk stratification before vascular surgery [see comments]. *J Am Coll Cardiol* 1996; 27(4):787-798.
34. Poldermans D, Arnese M, Fioretti PM, et al. Sustained prognostic value of dobutamine stress echocardiography for late cardiac events after major noncardiac vascular surgery [see comments]. *Circulation* 1997; 95(1):53-58.
35. Akosah KO, Olsovsky M, Kirchberg D, Salter D, Mohanty PK. Dobutamine stress echocardiography predicts cardiac events in heart transplant patients. *Circulation* 1996; 94(9 Suppl):II283-II288.
36. Spes CH, Klauss V, Mudra H, et al. Diagnostic and prognostic value of serial dobutamine stress echocardiography for noninvasive assessment of cardiac allograft vasculopathy: a comparison with coronary angiography and intravascular ultrasound [see comments]. *Circulation* 1999; 100(5):509-515.
37. Di Carli MF, Asgarzadie F, Schelbert HR, et al. Quantitative relation between myocardial viability and improvement in heart failure symptoms after revascularization in patients with ischemic cardiomyopathy. *Circulation* 1995; 92(12):3436-3444.
38. Gioia G, Powers J, Heo J, Iskandrian AS. Prognostic value of rest-redistribution tomographic thallium-201 imaging in ischemic cardiomyopathy. *Am J Cardiol* 1995; 75(12):759-762.
39. Afridi I, Grayburn PA, Panza JA, et al. Myocardial viability during dobutamine echocardiography predicts survival in patients with coronary artery disease and severe left ventricular systolic dysfunction. *J Am Coll Cardiol* 1998; 32(4):921-926.
40. Meluzin J, Cerny J, Frelich M, et al. Prognostic value of the amount of dysfunctional but viable myocardium in revascularized patients with coronary artery disease and left ventricular dysfunction. Investigators of this Multicenter Study. *J Am Coll Cardiol* 1998; 32(4):912-920.
41. Qureshi U, Nagueh SF, Afridi I, et al. Dobutamine echocardiography and quantitative rest-redistribution 201Tl tomography in myocardial hibernation. Relation of contractile reserve to 201Tl uptake and comparative prediction of recovery of function. *Circulation* 1997; 95(3):626-635.
42. Perrone-Filardi P, Pace L, Prastaro M, et al. Assessment of myocardial viability in patients with chronic coronary artery disease. Rest-4-hour-24-hour 201Tl tomography versus dobutamine echocardiography [see comments]. *Circulation* 1996; 94(11):2712-2719.
43. Arnese M, Cornel JH, Salustri A, et al. Prediction of improvement of regional left ventricular function after surgical revascularization. A comparison of low-dose dobutamine echocardiography with 201Tl single-photon emission computed tomography [see comments]. *Circulation* 1995; 91(11):2748-2752.
44. Decena BF, III, Tischler MD. Stress echocardiography in valvular heart disease. *Cardiol Clin* 1999; 17(3):555-72, ix.
45. deFilippi CR, Willett DL, Brickner ME, et al. Usefulness of dobutamine echocardiography in distinguishing severe from nonsevere valvular aortic stenosis in patients with depressed left ventricular function and low transvalvular gradients. *Am J Cardiol* 1995; 75(2):191-194.

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