PRINCIPLES OF STRESS ECHO

Even a relatively severe stenosis in one of the major epicardial coronary arteries does not cause myocardial ischaemia at rest, as the myocardial vasculature compensates to maintain resting blood flow by dilating the arterioles downstream of the stenosis. However, this is inadequate to prevent ischaemia with stress, as the increase in myocardial oxygen demand exceeds the ability of the arterioles to dilate further. Thus a patient with a significant coronary stenosis will usually have normal myocardial perfusion (and therefore contractility) at rest, but will develop myocardial ischaemia (and abnormal wall motion) with stress.

The myocardium can be 'stressed' by increasing myocardial oxygen demand, either with physical exercise or pharmacologically using an intravenous (IV) infusion of Dobutamine. Alternatively, an IV infusion of a vasodilator (e.g. dipyridamole, adenosine) can be used as the stressor. Vasodilators work by redistributing coronary blood flow, causing dilatation of normal coronary arteries but not of abnormal ones. This increases blood flow down the normal arteries but leads to a reduction in blood flow to areas supplied by stenosed coronaries, via a 'steal' mechanism, leading to ischaemia.

All stress studies (exercise, Dobutamine, dipyridamole and adenosine) permit the identification of normal, ischaemic and necrotic myocardium. To assess viability, a Dobutamine stress study (using low-dose as well as higher doses of Dobutamine) is necessary, in order to assess wall motion at different levels of stress.

INDICATIONS FOR STRESS ECHO

- Diagnosis of suspected coronary artery disease
- Risk assessment of patients with known coronary artery disease (e.g. to predict anaesthetic risk for major surgery.
- Identification of viable myocardium prior to revascularization
- Localization of myocardial ischaemia ('culprit coronary lesion' identification prior to revascularization)
- Assessment of myocardial perfusion following revascularization.
- Low-gradient aortic stenosis with LV dysfunction
- Mitral stenosis where there is disparity between severity and symptoms.

Sensitivity and Specificity- Stress echo is reported as having a sensitivity of 88% and a specificity of 83% in the detection of coronary artery disease (coronary stenosis >50%). This is similarly sensitive to, but more specific than, nuclear myocardial perfusion imaging. Stress echo does not, however, involve exposure to ionizing radiation.

Response to Stress Echocardiography

Condition	Resting	Low-dose (5-10)	Peak & post-stress
1. Normal	**Normal**	Normal	**Hyperdynamic**
2. Mild/moderate ischemia	**Normal**	Normal	**New WMA**
3. Severe ischemia	**Normal**	**New WMA**	**LV dilatation**
4. Scar (non-viable)	**Resting WMA**	No change	No change
5. Stunning (viable & not ischemic)	**Resting WMA**	**improved**	**improved**
6. Hibernating (viable & ischemic)	**Resting WMA**	**Improved**	**Decreased (biphasic response)**
7. Non-specific	**Resting WMA**	**No change**	**Improved**

Worsening MR during stress echo: the progressive increase of MR can be linked to myocardial ischaemia, though sometimes is also related to haemodynamic conditions (preload, afterload and LV inotropic state) during the test. A 15% of patients with mitral valve prolapse can worsen the MR severity solely due to haemodynamic conditions and not because of inducible myocardial ischaemia.

STRESS TESTING IN AORTIC STENOSIS

1. **Stress testing for asymptomatic severe AS**- In patients with aortic stenosis (AS), the onset of symptoms and/or LV systolic dysfunction represents a clear indication for AVR. Exercise testing is contraindicated in patients with severe AS with definite or probable cardiac symptoms. However, exercise testing is recommended to unmask symptoms or abnormal blood pressure responses in AS patients without apparent symptoms. Exercise testing, with appropriate physician supervision and close monitoring of the ECG and blood pressure, is safe in AS patients without apparent symptoms. Approximately one-third of patients exhibit exercise-limiting symptoms; these patients have worse outcomes. In patients with asymptomatic severe AS exercise stress echo has been shown to provide incremental prognostic value beyond exercise testing alone. (1) An increase in mean aortic pressure gradient by ≥18–20 mmHg, (2) the absence or limitation of LV contractile reserve (decrease or no change in LVEF suggesting subclinical LV dysfunction) and (3) induced PH (SPAP . 60 mmHg) during exercise are markers of poor prognosis.
2. **Stress testing for low gradient AS**
   - **Mean gradient is flow-dependent** (a squared function of flow) such that low flow rate may underestimate the MG → underestimate severity of AS. In LV dysfunction, there is a low-flow rate, resulting in a lower gradient and underestimation of severity of AS. Infusion of dobutamine augments cardiac output and if the valve is truly severely stenosed, the MG will increase due to increased flow rate.
   - **Valve opening is also flow dependent** such that low flow rate may inhibit the valve opening, leading to a lower AVA → overestimation of severity of AS (pseudo severe AS).
   - **Low gradient AS** is defined as MG <40 mmHg & AVA ≤1 cm^2
   - **Low flow** is defined as a **SVi** <35 mL/m^2 and is present in up to 35% of patients with AS *(SVi represents the flow)*
   - **LF-LG** is devided into (1) classical LF-LG (EF<50%) and (2) paradoxical LF-LG (EF≥50, but SVi <35).
   - If SVi >35 → normal flow, low gradient AS.
   - **Classical LF-LG** is divided into (1) true severe AS (MG↑ in response to low dose DSE) and (2) pseudo severe AS (AVA↑ in response to low dose DSE)

Stepwise management of low gradient AS (MG <40 mmHg & AVA ≤1 cm^2):

Step 1: Echo derived LVEF
A. EF < 50% → Classical LF-LG → low dose DSE (**step 3**)
B. EF ≥ 50% → Calculate SVi (**step 2**)

Step 2: Echo derived SVi (CSA_{LVOT} x VTI_{LVOT}) /BSA
A. SVi ≤ 35 ml/m^2 *(low SV paradoxical to normal EF)* → Paradoxical LF-LG
B. SVi > 35 ml/m^2 *(normal SVi = normal flow)* → Normal flow-LG → (1) rule-out measurement errors, (2) assess symptomatic status, (3) check for presence of hypertenison (may lead to a substantial decrease in gradient) and then (4) confirm stenosis severity by MDCT AV calcium scoring and/or DSE (step 3)

Step 3: low dose DSE (5-20 mcg/kg/min)
A. MG↑ ≥ 40 mmHg → True severe AS
B. AVA↑ > 1 cm^2→ Pseudo severe AS
C. No change → Check projected AVA & AV Ca score → If AVA_P < 1 cm^2 and/or AV_{Ca} > 2000 in men/1200 in women → True severe AS. If doubt remains about the diagnosis a TOE could be considered

CONTRAINDICATIONS TO A STRESS ECHO STUDY

For all forms of stress:

- acute coronary syndrome in first 24–72 h (high-dose Dobutamine should not be used for 7 days after myocardial infarction)
- known left main stem coronary artery stenosis
- LV failure with symptoms at rest
- recent life-threatening arrhythmias
- severe dynamic or fixed left ventricular outflow tract obstruction
- severe systemic hypertension (systolic blood pressure >220 mmHg and/or diastolic blood pressure >120 mmHg)
- recent pulmonary embolism or infarction
- thrombophlebitis or active deep vein thrombosis
- hypokalaemia
- active endocarditis, myocarditis, or pericarditis.

For atropine:

- closed-angle glaucoma
- severe prostatic disease.

For vasodilator (dipyridamole, adenosine) stress:

- suspected or known severe bronchospasm
- sick sinus syndrome, second or third degree atrioventricular block (unless a functioning pacemaker is present)
- hypotension (systolic blood pressure <90 mmHg)
- xanthine (e.g. caffeine, aminophylline) use in the last 12 h or dipyridamole use in the last 24 h.

Vasodilator stress is relatively contraindicated by

- bradycardia of <40 beats/min
- equivocal left main stem coronary artery stenosis
- recent cerebral ischaemia or infarction.

Reasons for test termination

1. Submaximal non-diagnostic end points

- Non-tolerable symptoms (severe chest pain)
- Hypertension, with systolic blood pressure > 220 mmHg or diastolic blood pressure > 120 mmHg
- Symptomatic hypotension, with > 40 mmHg drop in blood pressure
- Supraventricular arrhythmias, such as supraventricular tachycardia or atrial fibrillations
- Complex ventricular arrhythmias, such as ventricular tachycardia or frequent, polymorphic premature ventricular beats
- Electrocardiographic positivity (> 2 mV ST-segment shift) not associated with wall motion abnormalities

2. Diagnostic end points

- Maximum workload (for exercise testing)
- Maximum dose (for pharmacological)
- Achievement of target heart rate for dobutamine and exercise
- Echocardiographic positivity (dyssynergy ≥ 2 LV segments)