



CLINICAL PRACTICE GUIDELINES Exercise Stress Testing

PiCSA would like to acknowledge the work performed by QLD Department of Health in the development of the original Guideline from which this document has been adapted and modified

1. Purpose

This guideline provides recommendations regarding best practice to support high quality exercise stress testing practice throughout Queensland Health facilities.

2. Scope

This guideline provides information for all health practitioners who perform exercise stress testing (EST) as part of their clinical duties. This guideline also relates to the performance of ESTs during pharmacological stress testing.

3. Related documents

This guideline is primarily based on the following documents:

- The Cardiac Society of Australia and New Zealand and Freedman B (2010) *Safety and performance guidelines for Clinical Exercise Stress Testing*.¹

References from alternate sources of information have been identified in this document.

Policy and Standard/s:

- Informed Decision-making in Healthcare (QH-POL-346:2011)²

Procedures, Guidelines, Protocols

- Australian Guidelines for the prevention and control of infection in healthcare (CD33:2010)³
- PiCSA Clinical Practice Guideline: Electrocardiography

Forms and templates

- Queensland Health (2011) Consent form: Exercise Stress Test. Version 5.00⁴



4. Guideline for performing exercise stress test (EST)

4.1. Emergency Protocol

- For arrest situations or other emergency situations follow Hospital and Health Service (HHS) protocols or procedures.
- All staff members are required to be trained in basic life support and cardiopulmonary resuscitation (CPR) in order to perform an EST.
- Staff performing an EST should be able to recognise all major clinical arrhythmias that can be seen on an ECG and recognise any ischaemic and ST changes on an ECG.
- Staff performing an EST should be familiar with *Section 4.4 Identifying Indications and Contraindications* for performing EST's.
- Please see Appendix 1 for a complete list of equipment available in the event of a medical emergency.

4.2. Infection Control Procedures

- Adhere to relevant Hospital and Health Service infection control protocols or procedures at all times and in all facets of EST.
- Australian Guidelines for the prevention and control of infection in healthcare (CD33:2010)³

4.3. Gaining Consent

- Gain consent in accordance recognised Informed Decision-making In Healthcare guidelines².
- Every patient should be given a copy of the local Hospital/Health Service Exercise Stress Test consent form⁴ prior to the commencement of the test.
- This consent form should outline the basics of what will occur during the test, the risks of ESTs and allows patients the opportunity to inquire about alternative tests and treatments.
- Once a patient has agreed to undertake the test and given signed consent a medical officer must also sign the consent form stating that the test and all the risks have been properly explained to the patient.
- The patient has the right to revoke consent at anytime before or during the test.
- Confirm the patient has fasted (avoid heavy meals, caffeinated beverages including tea, coffee or cola) and not smoked cigarettes for at least three hours prior to the EST⁵ (these instructions should be included on the patients appointment letter/advice), also verbally confirm if the patient has ceased beta-blockade and nitrate medication under the advice of a referring medical officer⁵ if necessary.



4.4. Identifying Indications and Contraindications ⁶

4.4.1. Absolute and relative contraindications to exercise testing

Absolute

- acute myocardial infarction (MI) (within 2 days)
- high-risk unstable angina
- uncontrolled cardiac arrhythmias causing symptoms of hemodynamic compromise
- active endocarditis
- symptomatic severe aortic stenosis
- decompensated symptomatic heart failure
- acute pulmonary embolus or pulmonary infarction
- acute noncardiac disorder that may affect exercise performance or be aggravated by exercise (eg, infection, renal failure, thyrotoxicosis)
- acute myocarditis or pericarditis
- physical disability that would preclude safe and adequate test performance
- inability to obtain consent
- acute aortic dissection ⁷.

Relative

- left main coronary stenosis or its equivalent
- moderate stenotic valvular heart disease
- electrolyte abnormalities
- tachyarrhythmias or bradyarrhythmias
- atrial fibrillation with uncontrolled ventricular rate
- hypertrophic cardiomyopathy
- mental impairment leading to inability to cooperate
- high-degree AV block
- severe arterial hypertension ⁷.

Note: Relative contraindications can be superseded if benefits of conducting test outweigh risks of exercise.

4.4.2. Indications for terminating exercise testing ⁶

Absolute Indications

- ST-segment elevation (>1.0 mm) in leads without Q waves (other than V1 or aVR)
- drop in systolic blood pressure >10 mmHg (persistently below baseline), despite an increase in workload, when accompanied by any other evidence of ischemia
- moderate-to-severe angina (grade 3 to 4); Table 5 details descriptions and grades for angina scale
- central nervous system symptoms (eg, ataxia, dizziness, or near syncope)
- signs of poor perfusion (cyanosis or pallor)
- sustained ventricular tachycardia
- technical difficulties in monitoring the ECG or systolic blood pressure
- patient's request to stop.



Relative Indications

- ST or QRS changes such as excessive ST displacement (horizontal or downsloping of >2 mm) or marked axis shift
- drop in systolic blood pressure >10 mm Hg (persistently below baseline), despite an increase in workload, in the absence of other evidence of ischemia
- increasing chest pain
- fatigue, shortness of breath, wheezing, leg cramps, or claudication
- arrhythmias other than sustained ventricular tachycardia, including multifocal ectopic, ventricular triplets, supraventricular tachycardia, heart block, or bradyarrhythmias
- general appearance (see below)
- hypertensive response (systolic blood pressure >250 mmHg and/or diastolic blood pressure >115 mmHg)
- development of bundle-branch block that cannot be distinguished from ventricular tachycardia.

*Exercise Stress Test Limitations*⁸

There are two patient groups who should be excluded from EST due to lower sensitivity and specificity when determining ischaemia from coronary artery disease (CAD). EST is not contraindicated in these groups, however alternatives such as coronary angiography or pharmacological stress testing produce higher sensitivity and specificity when determining ischaemia from CAD.

A: Inappropriate patients

Patients that are unable to exercise sufficiently (ability to reach 85% of age predicted maximal heart rate) due to leg claudication, arthritis, deconditioning or associated pulmonary disease in the absence of angina or abnormal ECG.

B: ECG interpretation issues which lower sensitivity & specificity (in determining ischaemia from CAD)

Those patient's with resting ECG changes that can interfere with interpretation of the EST. These changes include pre-excitation syndrome, paced ventricular rhythm, >1mm ST depression at rest, left bundle branch block (LBBB), those on digoxin therapy and patients with LVH criteria.

While patients in group B should not be stress tested for determination of ischaemia, there is still the ability to utilise EST for the purposes of determining functional capacity, chronotropic competence and arrhythmia induction in a suitable patient and under appropriate medical supervision.



4.5. Facilities and equipment

Required Equipment^{1, 5}

- A suitable electrocardiographic recording system capable of continuous monitoring of the heart rhythm, rate and ischaemic changes.
- Blood pressure monitoring, manual (most accurate) or automatic with a variety of cuff sizes.
- Electronic treadmill that ranges in speed between 1.6km/h and 12.8km/h and gradient range of 0% to 22%. Treadmills should have a front rail and at least one side rail for safety and should be fitted with an emergency stop button.
- Automated external defibrillator (tested daily) and other emergency equipment readily available (see Appendix 1 for further information on emergency equipment requirements).

4.6. Test Procedure

4.6.1. Skin Preparation and ECG Placement

- Refer to *PiCSA Guideline: Adult and Paediatric Electrocardiography (ECG)*; section 4.7.2 regarding skin preparation.
- After a standard resting 12 lead recording, a modified limb lead ECG should be recorded. Compare the modified ECG to the standard ECG prior to exercise to assess for any significant ECG differences.

Modifications should be made to the limb leads by moving them onto the torso. The left and right arm should be placed as close to the shoulder as possible while the leg electrodes should be placed below the umbilicus (see Figure 1 regarding the Mason-Likar lead placement).

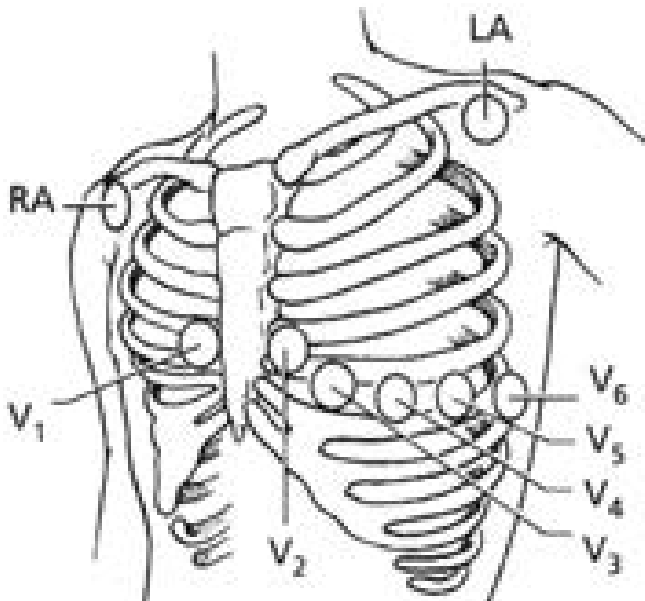


Figure 1 Mason-Likar Lead placement⁹ taken from Welinder (2004).



4.6.2. Performing the EST and Data Collection

- Greet the patient and introduce yourself (name and title).
- Confirm the patient's identity by request the patient's name, date of birth and the procedure they are undergoing.

Note: Asking them if their name is John is not confirming their identity.

- Explain the procedure fully, detailing what is going to happen during the EST.
- Inform the patient that in order to perform the EST, unrestricted access to the chest area will be required.
- Ensure a consent form has been read and signed once the procedure has been explained to the patient.
- The patient should be covered with a gown during the procedure to ensure their modesty.
- Make every effort to respect the patient and minimise embarrassment and allow the patient to dress and undress in private.
- Enter the patient's demographic details into the machine, including name, date of birth and hospital UR number (unit record number).
- Enter any clinically significant information i.e. indication/s for test, medications, staff performing test.
- Select the appropriate protocol for the patient as per doctor's request (see Appendix 2: Exercise Protocols to determine the appropriate protocol).
- Once the patient has been set-up, record a standard resting supine 12 lead ECG.
- Change the limb lead positions and record a modified limb lead resting supine 12 lead ECG.
- Demonstrate the correct use of the exercise equipment to the patient before commencing the test.
- Record the patient's blood pressure:
 - prior to starting exercise as a baseline reference
 - once during every stage of exercise
 - at peak exercise, and
 - at least twice in recovery or until blood pressure has returned to values similar to pre exercise pressure ⁵.
- Continuous ECG monitoring of a minimum of three leads covering anterior (V1,V2), lateral (I, V5) and inferior (II, aVF) myocardial territories should be easily viewed through a digital display for the entire duration of exercise ⁶.
- 12 lead ECGs (stored digitally, hard copy or both) should be taken at the end of each minute of exercise and at peak exercise ⁶.
- Instruct the patient to mention the development of any symptoms during the test and document the symptoms appropriately.
- Termination of an EST is at the discretion of the attending staff should any termination criteria arise (see section 4.4.2. *Indications for terminating exercise testing*).



- Once an EST has been terminated and peak exercise ECG's and blood pressure recorded, the patient should be positioned in a supine position in order to achieve maximum sensitivity⁶. For patient comfort, a sitting position can be used and if indicated a cool down period, however this may delay or eliminate the appearance of ST depression post exercise⁶.
- Monitoring of the patient should continue for 6-8 minutes post exercise or until the heart rate, blood pressure, patient symptoms and ST changes have resolved to near pre-exercise values.
- Once the test has been completed disconnect the patient from the ECG module and remove all electrodes and allow the patient once again to change in private.

4.7. Quality Control Procedures

Please refer to the *PiCSA Guideline: Electrocardiography (ECG); section 4.7 Test Procedure* under sub headings patient preparation, skin preparation, electrode placement and recording for relevant quality control requirements.

High quality EST equipment recommended by Queensland Health should be used in all instances when performing ESTs. This equipment should undergo regular manufacturer recommended calibration and maintenance schedules conducted through local biomedical technology services.

5. Definition of Terms

Definitions of key terms are provided below.

Abbreviation	Term	Definition / Explanation / Details
VC	Vital capacity, litres (L)	The volume change between the position of full inspiration and complete expiration ¹⁰
EST	Exercise stress test	ETT – exercise tolerance test MEST – maximal exercise stress test
MI	Myocardial infarction	
CAD	Coronary artery disease	

6. Consultation

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7. Guideline Revision and Approval History

Version No.	Modified by	Amendments authorised by	Approved by
1.0			

8. Appendices

Appendix 1: Emergency Equipment^{1, 5}

- Oxygen and related masks and tubing.
- Airways: A plastic or rubber airway and self-inflating bag should be available for maintenance of adequate airways and to ventilate the patient in the event of respiratory or cardiorespiratory arrest.
- Suction apparatus and supplies (eg, gloves, tubing).
- Drugs and equipment for placing intravenous cannulae and appropriate giving sets should be available. The intravenous medications that should be readily available include Atropine, Lignocaine, Adrenaline, and Sotalol or Amiodarone. A beta-2 agonist spray such as salbutamol inhaler should be available for bronchoconstriction. Short acting sublingual nitrates such as Glyceryl Trinitrate or Isosorbide Dinitrate or Glyceryl Trinitrate spray should be available.
- Emergency alarms should be available to summon nearby personnel in the event of an emergency situation. At the very minimum a working phone must be available to contact the medical emergency team as per local Hospital and Health Service guidelines.



Appendix B: Exercise Protocols ⁵

FUNCTIONAL CLASS	CLINICAL STATUS	O ₂ REQUIREMENTS ml O ₂ /kg/min	STEP TEST	TREADMILL TESTS				BICYCLE ERGOMETER**			
				BRUCE*	KATTUS*	BALKE**	BALKE**				
NORMAL AND I	PHYSICALLY ACTIVE SUBJECTS	METs	NAGLE, BALKE, NAUGHTON*	BRUCE*	KATTUS*	BALKE**	BALKE**	For 70 kg body weight kgm/min			
			2 min stages 30 steps/min	3-min stages	3-min stages	% grade at 3.4 mph	% grade at 3 mph				
			16 56.0	(Step height increased 4 cm q 2 min)			26				
			15 52.5				24				
			14 49.0	Height (cm)	mph %gr		4 22		22	1500	
			13 45.5		4.2 16				20		
			12 42.0	40			4 18		18 22.5	1350	
			11 38.5	36					16 20.0	1200	
			10 35.0	32			4 14		14 17.5	1050	
			9 31.5	28	3.4 14				12 15.0	900	
			8 28.0	24			4 10		10 12.5	750	
			7 24.5	20	2.5 12				3 10	8 10.0	600
			6 21.0	16					6 7.5	450	
			5 17.5	12	1.7 10				2 10	4 5.0	300
			4 14.0	8					2 2.5	150	
3 10.5	4					0.0					
2 7.0											
1 3.5											
II	SEDENTARY HEALTHY										
III	DISEASED, RECOVERED										
IV	SYMPTOMATIC PATIENTS										

Figure 2 Taken from: The Cardiac Society of Australia and New Zealand and Freedman B (2010) *Safety and performance guidelines for Clinical Exercise Stress Testing*.

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Bruce Protocol

Stage	Time (Minutes)	Km/hour	% Gradient
1	3	2.7	10
2	3	4.0	12
3	3	5.4	14
4	3	6.7	16
5	3	8.0	18
6	3	8.8	20
7	3	9.6	22

Modified Bruce Protocol

Stage	Time (Minutes)	Km/hour	% Gradient
1	3	2.7	0
2	3	2.7	5
3	3	2.7	10
4	3	4.0	12
5	3	5.4	14
6	3	6.7	16
7	3	8.0	18
8	3	8.8	20
9	3	9.6	22

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Naughton Protocol

Stage	Time (Minutes)	Km/hour	% Gradient
1	2	1.6	0
2	2	3.2	0
3	2	3.2	3.5
4	2	3.2	7
5	2	3.2	10.5
6	2	3.2	14
7	2	3.2	17.5
8	2	3.2	21



Appendix C: Paediatric Exercise Testing

For exercise stress testing within the paediatric age group, the required equipment, required staff, consent, performance and data collection of the test is as per the guidelines used in the adult population with age appropriate variances. There should be appropriately sized blood pressure cuffs and a treadmill with appropriate height handrails, with at least one supervising staff member trained in paediatric advanced life support. Standard paediatric cardiopulmonary resuscitative equipment should be immediately available during testing.

Before beginning the test, children who lack experience walking on a treadmill should be offered a chance to practice and gain confidence in walking, running and stepping on and off the treadmill. This should be judged on a case by case basis with consideration of the child's size, ability and coordination.

Unless otherwise indicated on the request or by the attending medical officer the Bruce protocol should be used. This protocol can be used on subjects of all ages and thus it can provide comparative exercise data using the same protocol as a child grows. Normative data on the exercise responses and endurance times in children aged 4 to 14 years using the Bruce protocol exist¹¹.

*Indications and Contraindications for Clinical Stress Testing in the Paediatric Age Group*¹²

Indications for stress testing in the paediatric age group may vary on the basis of the child's clinical issues. Common indications for paediatric stress testing are listed in Figure 3.



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1. Evaluate specific signs or symptoms that are induced or aggravated by exercise
 2. Assess or identify abnormal responses to exercise in children with cardiac, pulmonary, or other organ disorders, including the presence of myocardial ischemia and arrhythmias
 3. Assess efficacy of specific medical or surgical treatments
 4. Assess functional capacity for recreational, athletic, and vocational activities
 5. Evaluate prognosis, including both baseline and serial testing measurements
 6. Establish baseline data for institution of cardiac, pulmonary, or musculoskeletal rehabilitation
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Figure 3 Common Reasons for Paediatric Stress Testing taken from Paridon (2006) ¹²

There are very few absolute or relative contraindications to paediatric exercise testing however it is useful to distinguish between patients at a low risk for adverse events and patients at a higher risk of adverse events. Patients with acute myocardial or pericardial inflammatory disease or patients with severe outflow obstruction in whom surgical intervention is indicated should not be tested. Relative risks for paediatric stress testing are listed in Figure 4.



Lower Risk	Higher Risk
Symptoms during exercise in an otherwise healthy child who has a normal CVS exam and ECG	Patients with pulmonary hypertension
Exercise-induced bronchospasm studies in the absence of severe resting airways obstruction	Patients with documented long-QTc syndrome
Asymptomatic patients undergoing evaluation for possible long-QTc syndrome	Patients with dilated/restrictive cardiomyopathy with CHF
Asymptomatic ventricular ectopy in patients with structurally normal hearts	Patients with a history of a hemodynamically unstable arrhythmia
Patients with unrepaired or residual congenital cardiac lesions who are asymptomatic at rest, including	Patients with hypertrophic cardiomyopathy who have
<ol style="list-style-type: none"> 1. Left to right shunts (ASD, VSD, PDA, PAPVR) 2. Obstructive right heart lesions without severe resting obstruction (TS, PS, ToF) 3. Obstructive left heart lesions without severe resting obstruction (cor triatriatum, MS, AS, CoA) 4. Regurgitant lesions regardless of severity 	<ol style="list-style-type: none"> 1. Symptoms 2. Greater than mild LVOTO 3. Documented arrhythmia
Routine follow-up of asymptomatic patients at risk for myocardial ischemia, including	Patients with greater than moderate airways obstruction (on pulmonary function tests)
<ol style="list-style-type: none"> 1. Kawasaki disease without giant aneurysms or known coronary stenosis 2. After repair of anomalous LCA 3. After arterial switch procedure 	Patients with Marfan syndrome and activity-related chest whom a noncardiac cause of chest pain is suspected
Routine monitoring in cardiac transplant patients not currently experiencing rejection	Patients suspected to have myocardial ischemia with exercise
Patients with palliated cardiac lesions without uncompensated CHF, arrhythmia, or extreme cyanosis	Routine testing of patients with Marfan syndrome
Patients with a history of hemodynamically stable SVT	Unexplained syncope with exercise
Patients with stable dilated cardiomyopathy without uncompensated CHF or documented arrhythmia	

CVS indicates cardiovascular system; ASD, atrial septal defect; VSD, ventricular septal defect; PDA, patent ductus arteriosus; PAPVR, partial anomalous venous return; TS, tricuspid stenosis; PS, pulmonary stenosis; ToF, tetralogy of Fallot; MS, mitral stenosis; AS, aortic stenosis; CoA, coarctation of a coronary artery; SVT, supraventricular tachycardia; CHF, congestive heart failure; and LVOTO, left ventricular outflow tract obstruction.

Figure 4 Relative Risks for Stress Testing taken from Paridon (2006) ¹²

Indications for Clinical Stress Testing Termination in the Paediatric Age Group

It is desirable to achieve a maximal study in most instances with care to be taken not to terminate a test too quickly. Test termination is usually indicated if the following occur:

- diagnostic findings have been established
- monitoring equipment failure
- decrease in heart rate or failure of heart rate to increase with increasing workload, associated with symptoms of insufficient cardiac output
- progressive fall in systolic blood pressure with increasing workload
- severe hypertension, > 250 mmHg systolic or 125 mmHg diastolic
- intolerable dyspnoea
- symptomatic tachycardia



- presence of > 3mm flat or downward sloping ST segment depression
- increasing ventricular ectopy with increasing workload
- patient requests termination of the study.

Following termination of the exercise test the patient should be monitored as outlined in section 4.6.2 *Performing the EST and Data Collection*

9. Suggested Readings and References

9.1. Suggested readings

- Ellestad, M. H. (2003). *Stress testing: principles and practice*. Oxford; New York, Oxford University Press. ¹³
- Gibbons, R. J., G. J. Balady, et al. (2002). *ACC/AHA 2002 guideline update for exercise testing: summary article*. ¹⁴
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9.2. References

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