Paediatric and Adult Congenital Exercise Tolerance Testing Protocol

University Hospitals of Leicester NHS Trust

Trust Ref: B16/2023

1. Introduction and Who Guideline applies to

Exercise tolerance testing involves increasing oxygen demand via the use of a treadmill or bike and measuring the hearts response using continuous electrocardiograms (ECG), blood pressure (BP) monitoring and occasionally oxygen saturation monitoring. The test is used as a diagnostic tool in a variety of different settings (discussed under Indications).

Contents

2. Indications

The indications below are given in accordance with the Society for Cardiological Science & Technology (SCST) and American College of Cardiology (ACC)/ American Heart Association (AHA) guidelines for clinical practice.

Medically Supervised (High Risk)	Physiologist Led (Low Risk)
Provocation of arrhythmia in patients with known or suspected exercise induced arrhythmia.	Diagnosis of Ischemic Heart Disease (IHD) in those with a structurally and functionally normal heart and those with a background of congenital malformations.
As an adjunct in the assessment of congenital or acquired valvular disease, especially aortic valve stenosis, which has already been quantified as severe.	Post Myocardial Infarction (MI) for prognostic assessment and medication optimisation.
Screening for those with a family history of sudden cardiac death or genetically inherited cardiomyopathies.	Evaluation of exercise capacity in those with congenital disease as a baseline and as an indication for intervention.
Assessment of QTc intervals in suspected cases of LQTS.	Assessment of the response of an artificial pacing system to exertion.
Assessment of adequate beta-blockade in diagnosed and medicated cases of LQTS.	Follow up of cardiac abnormalities with late-coronary involvement e.g. Kawasaki's
Evaluation of atrial and ventricular premature contractions in otherwise healthy individuals	Evaluation of BP response, specifically after a coarctation repair.
	Assessment of desaturation in the presence of relatively well-balanced or palliated cyanotic congenital disease.
	As an adjunct in the assessment of congenital or acquired vavlular disease, especially aortic valve stenosis, which has been quantified as mild or moderate.
	Evaluation of chronotropic response in those with congenital AV blocks (including complete heart block).
	To assess fitness levels

Ischemic heart disease is extremely uncommon in a young population. This results in a much lower risk of routine testing as well as differences in the indications, usefulness, and interpretation of exercise laboratory data in the paediatric population. Applications of exercise testing in the young are most often related to measurement of exercise capacity, evaluation of known or possible abnormalities of cardiac rhythm, and evaluation of symptoms elicited by exertion. Exercise capacity may be diminished in children or adolescents with congenital heart disease, those who have had surgical treatment of congenital heart disease, and those who have acquired valvular or myocardial disease. Measurement of exercise capacity is often useful in evaluating subjective limitations in this age group (ACC/ AHA, 1997).

3. Contraindications

Medically Supervised (High risk)	Physiologist Led (Low risk)
Acute Stroke	Provocation of arrhythmia in patients with known exercise induced arrhythmia.
Acute PE	Patients with known severe aortic valve stenosis
Severe Pulmonary Vascular disease	
Recent DVT (discuss with Clinician regarding time-scale post anti-thrombolytic medical therapy)	Patients with a history of syncope.
Unstable angina	Patients with known or suspected LQTS.
Uncontrolled hypertension (BP at rest exceeding 180/110mmHg).	Patients with cardiomyopathies and other forms of LVOTO.
Any factors which prohibit the patients' physical ability to perform the test.	Presence of LBBB when performing test for the assessment of ischaemic changes.
Acute rheumatic fever with carditis	
Acute myocarditis or pericarditis	
Acute MI	
Uncontrolled, symptomatic heart failure.	
Acute aortic dissection	

All medically supervised contraindications also apply to physiologist led tests.

Nb. The contraindications listed are in agreement with the SCST guidelines; however during medically supervised tests the onus of assessing contraindications lies with the supervising Doctor.

4. Protocols

Bruce

The Bruce Protocol is the most commonly used.

Stage	Duration	Speed (MPH)	Gradient (%)
1	3	1.7	10
2	3	2.5	12
3	3	3.4	14
4	3	4.2	16
5	3	5	18
6	3	5.5	20
7	3	6	22

Modified Bruce

Used in suspected, but not diagnosed, LQTS and for patients who are unable to keep up with the Bruce Protocol.

Stage	Duration	Speed (MPH)	Gradient (%)
1	3	1.7	0
2	3	1.7	5
3	3	1.7	10
4	3	2.5	12
5	3	3.4	14
6	3	4.2	16
7	3	5	18
8	3	5.5	20
9	3	6	22

5. Pre-test considerations

Consent

There are two types of consent forms that are specific to physiologist led and medically led tests. For patients under the age of 16 the correct consent form must be signed by a parent or guardian. This form is not a medical risk assessment but simply highlights the responsibility of the physiologists / doctor during the test and documents that the parent/guardian agree for the patient to undergo the test.

Environment

The testing laboratory must be large enough comfortably fit all appropriate equipment and provide enough space in case of an emergency. An emergency pull alarm must be fitted and

accessible. It is essential that a congenital registrar or consultant can reach the exercise room within reasonable time of the emergency alarm being raised. Exercise tests will most likely be carried out on clinic days because of this requirement.

Equipment
A combined paediatric and adult cardiac arrest trolley with a manual defibrillator to be checked on a daily basis.

- Treadmill and exercise console
- Bed with adjustable sections
- Computer system with access to relevant databases to electronically store reports
- Blood pressure monitor- manual or automated.
- Stethoscope
- Range of appropriately sized cuffs
- Adult and paediatric electrodes
- Abrasive skin preparation tape
- Transpore tape
- Razors
- Spare exercise test paper
- Bed roll

Resuscitation equipment
Before starting an exercise session the cardiac arrest trolley (with defibrillator on top) must be checked in line with current Trust guidelines. A suction port and oxygen must also be available. Prior to testing, the patient must be weighed and the weight entered into the Paediatric Crash Sheet on Excel to provide accurate emergency drug dosages.

Appropriate defibrillation pads must be connected to the defibrillator prior to commencing the test and the defibrillator set to the correct energy charge- four times the patients weight in kilograms.

During the test the arrest trolley must be accessible to the exercise laboratory all times. The emergency pull alarm must be tested **daily.**

Referral form
Each exercise test requires a referral form; this form must be completed correctly and be signed by a doctor. Relevant patient information and history must be attached, including a mediation list.

Patient notes and/or most recent clinic letter must be available.

Medically supervised tests
For sessions which require medical supervision, ensure there is a physician present who is able to supervise the length of the exercise session prior to it starting.

Clinical background
The patient should be asked about their presenting symptoms to ensure there are no existing contra-indications. The physiologist/ physician should also ensure there are no significant changes in the patient's history since the exercise test referral; especially in physiologist led exercise tests where any changes might be a low risk contraindication requiring medical supervision (e.g. syncope).

The patient's physical suitability for the test should be assessed by physiologist/physician, ensuring they are able to walk on the treadmill safely.

The patient should be asked about their current medication. Ensure requests to stop/start medication on the referral form are met.

For patients who are diabetic, ensure blood sugars are stable. Diabetes can also increase pain thresholds.

6. Roles of lead, second and supervising doctor

Role of First Person

- Ensure patient safety throughout the test
- Ensure all contraindications for low risk exercise have been excluded
- Appropriately explain the test to patient ensuring they fully comprehend the requirements of the test.
- Primary analyser of ECG and BP
- Terminate test appropriately according to SCST/ AHA guidelines
- Write an accurate and concise report.
- Ensure all staff are suitably qualified
- Provide overall supervision of the test
- Must have up-to-date Adult ILS and paediatric BLS
- If appropriate ensure results are escalated to the relevant medical staff.

Role of Second Person

- To provide assistance throughout
- Prepare the testing environment
- To set the patient up on BP and ECG monitors
- To record the patient's blood pressure
- Provide secondary ECG and BP analysis
- To be competent with the use of ETT equipment
- Ensure patient safety throughout test, keeping vigilant for changes in the patient's appearance or gate- inform the First Person immediately of these changes.
- Must have up-to-date adult and paediatric BLS

Role of supervising physician

- Provide immediate clinical consultation when needed
- Monitor the patient
- Administration of appropriate pharmacological therapies and advanced life support if required.

NB. Under local guidelines anyone who has undertaken Paediatric BLS only (i.e. not ALS), including both first and second person roles, cannot defibrillate a paediatric patient. Therefore it is the responsibility of the supervising physician to defibrillate if required.

Physiologist led lists should be booked and carried out during a paediatric cardiology clinic where there will be suitable medical staff in the department. In the unusual event a physiologist led list had been booked and the cardiology clinic has been cancelled unexpectedly, the Ward 1/ on-call SpR must be informed of the list and on standby.

7. Performing an ETT

Patient preparation
The patient name, date of birth and first line of address should be confirmed. Each physiologist should introduce themselves.

The physiologist should be mindful of patient dignity and a gown should be given to patients if it is requested/ required.

Skin preparation
Skin preparation is often required to record the most accurate and reliable tracing by reducing impedance between the skin and the electrode.

If the patient has moisturising creams / oils on their skin, an alcohol wipe should be used to remove excess oils.

Abrasive skin preparation tape should then be used on the sites where the electrodes will be placed. Special care should be taken with those with sensitive skin.

Where appropriate a razor may be needed to remove hair that prevents adequate contact between the electrode and the skin.

Electrode positioning

V1- Fourth intercostal space, right sternal edge
V2- Fourth intercostal space, left sternal edge
V3- Midway between V2 and V4
V4- Fifth intercostal space, mid-clavicular line
V5- Left anterior axillary line, horizontally in line with V4
V6- Left mid-auxiliary line, horizontally in line with V4 and V5

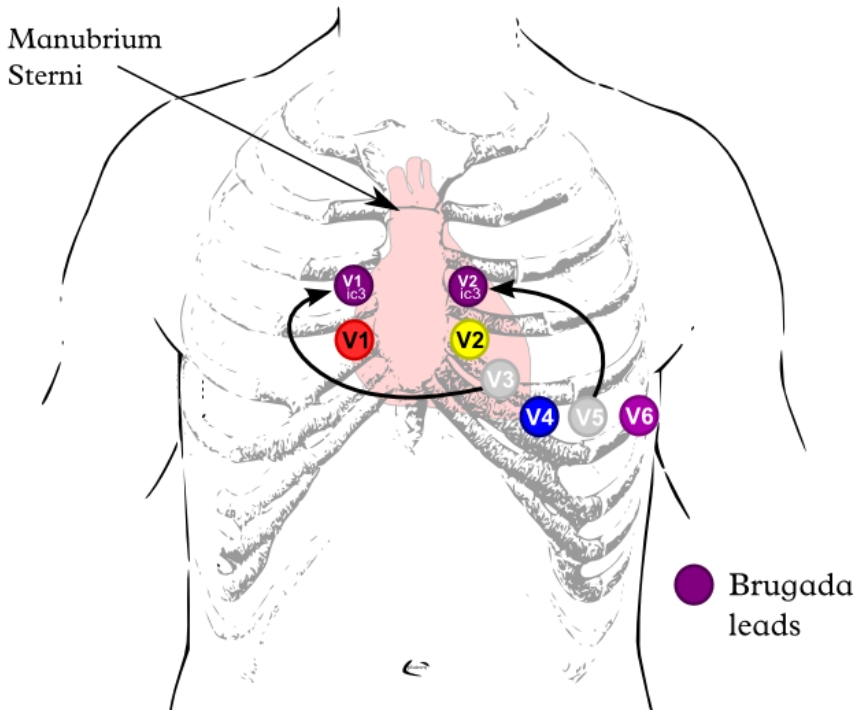
Chest electrodes should be placed as above. In many cases cables will be colour coded; the colours used above are the widely accepted standard colours.

The SCST gold standard practice for a resting twelve lead ECG requires electrodes to be positioned on the wrists and feet where possible. During an exercise test this is not possible and modified limb positioning is required. The modified Mason-Likar limb lead positions are stated below.

Upper left limb- upper right side of torso, 2 cm below clavical
Upper right limb- upper left side torso, 2 cm below clavicle
Lower right limb – lower right side of torso, half way between costal margin and iliac crest
Lower left limb- lower left side of torso, half way between costal margin and iliac crest

Dextrocardia

Dextrocardia refers to a form of cardiac malposition where the heart is positioned within the right side of the chest rather than the left. As the heart is in the right of the chest it is necessary to also move the electrodes to the right of the chest. V1 and V2 electrodes remain in the same position, but V2 becomes V1R and V1 becomes V2R. V3- V6 are positioned in mirror image positions on the right side of the chest, using the same landmarks. It is very important that these changes are annotated on an ECG as V1R, V2R, V3R, V4R, V5R, V6R. Limb electrodes remain in the standard positions.



Brugada Leads

Brugada syndrome is a disorder characterised by sudden cardiac death. The cardiac conduction system is affected in those with Brugada syndrome putting them at greater risk of ventricular arrhythmias. On occasion a patient may have an ETT with 'Brugada Leads', to monitor for ECG changes indicative of Brugada syndrome. V3 and V5 leads are moved respectively to electrodes placed one intercostal space above V1 and V2.

Monitoring
The patient should be attached to the ECG monitor using the specified positions.
Ensure the correct size blood pressure cuff is fitted to the patient. If the patient is known to have had a Coarctation of the Aorta repair, the cuff should be placed on the right arm.
If requested by the physician, a pulse oximeter should also be used.

Procedure explanation
The patient should be given a clear explanation of the test. The explanation should include the following information:

- The treadmill will get steeper and faster every three minutes (unless Mod Bruce is requested).
- Blood pressure will be taken every three minutes.
- Patient should keep hands on the bars at all times and to look forward.
- If the patient experiences any symptoms it is important they tell the physiologist
- If the patient wishes to stop, they must notify the physiologist and not stop themselves.
- The patient will be monitored throughout

The physiologist must be confident that the patient will tell them if they wish to stop. A demonstration should be offered to illustrate how to walk on the treadmill.

Pre-exercise requirements
A supine and standing 12 lead ECG should be recorded to show positional changes and labelled accordingly.
A resting blood pressure should be measured and recorded.
If the patient is following the *Long QT Protocol for Undiagnosed and Routine Screening* then they must be supine for ten minutes prior to exercise- see Long QT Protocol for further details.

During exercise

Bruce protocol should be used unless stated otherwise. During exercise the patient must rest their hands on the side or front bars of the treadmill at all times and should avoid turning their head backwards to talk to parent or guardian. Any cables/wires should be moved away so they are not a trip hazard.
The patient should give maximal effort, in paediatric cases encouragement should be given if necessary to reach maximal effort. Patients should be encouraged to walk for as long as possible to increase workload and heart rate.

- A 12 lead ECG will print at the end of every stage, print extra when necessary (e.g. ectopic). The ECG should be continuously monitored. The ST segment markers will be set at J point plus 80ms unless an alternative is specifically requested.
- Blood pressure should be taken during every stage unless it seems unsafe to do so. Immediately after terminating exercise a blood pressure should be recorded, please note that the patient can feel dizzy whilst doing this due to the immediate halt in exercise.

There are a total of seven stages in the Bruce Protocol; the treadmill will stop itself if Bruce Protocol is completed.

Recovery
The recovery phase must be a minimum of 6 minutes long. Blood pressure, heart rate and all significant ECG changes/ rhythms must have returned to baseline. Recovery can provoke arrhythmias, ischemic changes and changes to the Q-T interval not seen during exercise, therefore the patient must still be monitored closely.
Once this phase is complete, remove all electrodes and dispose of them in the clinical waste. Take the blood pressure cuff and ECG monitor from the patient and put away safely.

8. Terminating exercise (Paediatric and adult congenital)

End points of an exercise test as per the SCST/ AHA guidelines:

- Systolic BP >230mmHg
- Atrial or ventricular arrhythmia
- AV block with symptoms
- Sudden onset of Left bundle branch block
- 2mm ST depression with chest pain
- 3mm ST depression without chest pain
- Rapid ST elevation with or without pain.
- Hazardous symptoms which can associate with injury such as dizziness
- Signs of poor perfusion (cyanosis or pallor)
- Patient requests to stop
- Fatigue
- Severe chest pain or dysponea
- Heart rate reduction greater than 20% from resting baseline HR
- Systolic BP failing to increase by 20mmHg or a drop > 10mmHg from baseline recording despite increase in workload.
- 100% maximum heart rate maintained for one minute
- Technical difficulties monitoring the ECG or Blood Pressure.

9. Interpreting the results and writing a report

The following information must be included in the report

- Date of Test
- Indication for test
- Resting ECG
- Any deviations from pre-test instructions
- Exercise protocol used and duration of exercise
- Percentage of maximum heart rate achieved
- Reason for terminating test
- Symptoms reported by patient- note what and when they were and any associated ECG/BP changes.
- ECG changes/ arrhythmias- any associated symptoms
- Heart rate and blood pressure response to exercise
- Events during the recovery period
- Conclusions.

This report must be typed CRIS so that an electronic copy is available.

10. Post-test considerations

Once the test is finished, the patient should be notified that the results will go to their doctor and they should receive results in the post or in clinic. If the exercise test needs to be escalated the patient should be advised to stay until the exercise results and report are reviewed by a doctor.
After each exercise test Distel®/Clinell® wipes should be used to wipe down then bed, BP cuff and ECG cables. At the end of an exercise session Chlorclean should be used on the bed and chairs. Equipment should be cleaned and stored away safely and lights, A/C and equipment (e.g. Printer, ETT console and computer) should be turned off.
Any related incidents arising from testing which may involve a clinical error or near miss incidents must be reported using the Trust's incident reporting system.

11. Associations of congenital malformations

Lesion	Common Findings	Findings That Warrant More Concern
Aortic Stenosis	None	Ischaemic changes Blunted BP response Drop in systolic BP Dizziness, lethargy, SOB
Aortic Coarctation (Repaired)	Hypertension	Ischaemic changes Reduced exercise capacity Severe Hypertension
Palliated cyanotic heart disease	Poor chronotropic response Desaturation with progressive exercise	Severe desaturation Ischemia Symptoms associated with neurologic changes
Ventricular septal defect	May have reduced exercise capacity if shunt is large	Arrhythmias Desaturation

Mitral regurgitation	None	Reduced exercise capacity Ischemia
Mitral prolapse	False-positive ST changes associated with hyperventilation	Arrhythmia
Tetralogy of Fallot Repair	Right Bundle Branch Block Reduced exercise capacity	Arrhythmia Drop in systolic BP Desaturation
Post-op Mustards-Senning procedure for TGA	Reduced chronotropic response S-T changes in right precordial leads	Arrhythmia Desaturation
Post-op Arterial Switch procedure for TGA	None *Limited long term data*	Ischaemic changes Angina Symptoms associated BPA stenosis (SOB/ Dyspnoea/ desaturation). *Limited long term data*
Post-op Fontan procedure	Reduced exercise capacity Blunted BP response	Severe cyanosis Arrhythmia Drop in systolic BP
Kawasaki Disease		Angina Ischemic changes
Cardiomyopathy	Reduced exercise capacity	Dizziness, pre-syncope/ syncope Blunted BP response Arrhythmia
Post-op Cardiac Transplant	Slow rise in heart rate Slight reduction in peak heart rate	Ischaemic changes Reduced exercise capacity

12. In the Event of an Emergency

In the event of an Emergency, the emergency alarm should be activated and a 2222 call made as per Trust guidelines. Appropriate emergency care should be given to the patient by staff qualified to do so and if necessary cardio-pulmonary resuscitation delivered and appropriate use of the arrest trolley and defibrillator. Patient's family may be asked to step outside to allow emergency care to take place.

13. Education and Training

All clinical staff complete basic life support and resuscitation annual mandatory training.

14. Monitoring Compliance

What will be measured to monitor compliance	How will compliance be monitored	Monitoring Lead	Frequency	Reporting arrangements
Adverse incidents during exercise tolerance test	Review of datix submissions	Cardiology clinical risk lead	As occurs	Speciality quality & safety board

The Trust recognises the diversity of the local community it serves. Our aim therefore is to provide a safe environment free from discrimination and treat all individuals fairly with dignity and appropriately according to their needs.
As part of its development, this policy and its impact on equality have been reviewed and no detriment was identified.

CONTACT AND REVIEW DETAILS			
Guideline Lead (Name and Title) Author: Aine Noonan Co Author: Nichola Sutton Contact Name: Deborah Ip Reviewed by: Dr Shebani			**Executive Lead** Chief Medical Officer
Details of Changes made during review:			
Date	**Issue Number**	**Reviewed By**	**Description Of Changes (If Any)**
03/02/2022	2.0	Aine Noonan	Change made to specification of the location for the defib trolley.
June 2023	3.0	Aine Noonan	Added monitoring compliance