Clinical Guidance by Consensus

Recommendations for
Clinical Exercise Tolerance Testing

An approved method by
SCST – The Professional Body for Cardiac Scientists

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1. Change history

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2.0	2023	Alice Davis Harriet Walters Helen Twemlow Heather Herbert Pooja Raithatha Robyn Meyrick Sarah Cooper Suzanne Ramsay Vitor Morgado-Weaver	Review of Clinical Guideline in response to workforce modernisation and changes in clinical practice	Yes – SCST Council

2. Introduction

An electrocardiographic clinical exercise tolerance test (ETT) is a non-invasive investigation, which may provide diagnostic and prognostic information about a range of cardiac conditions. The test involves continuous monitoring of a 12-lead electrocardiogram (ECG) while the subject performs cardiovascular exercise to a specific protocol, which may be on a treadmill or bicycle ergometer. Blood pressure (BP) is also measured regularly, and the subject's symptoms are recorded.

ETT has been used for over 60 years and remains a relatively inexpensive and widely accessible investigation[1]. Calls to standardise ETT procedures in the United Kingdom (UK) began 25 years ago and since this time the Society for Cardiological Science and Technology (SCST), at times in conjunction with the British Cardiovascular Society (BCS) have produced guidance to facilitate high standards of service delivery[2, 3].
Within the UK, there has been a significant shift in the use of ETT over the past 15 years, due to the National Institute for Health and Care Excellence (NICE) recommending that ETT should not be used for the diagnosis of suspected coronary artery disease (CAD)[4]. Instead, alternative advanced imaging strategies were favoured as they provide higher diagnostic accuracy[4]. Therefore, there has been a significant decline in the number of ETTs performed nationally[5]. This has led to challenges in the maintenance of staff competence and the provision of training for new staff and students, both assisting and leading ETT.

Although ETT is non-invasive, by creating a state of increased metabolic demand in a

patient population with suspected or known cardiac disease it inevitably carries a risk of adverse events. This document will provide a review of the risks of ETT and provide standardisation of procedures and adherence to evidence-based guidelines.

3. Purpose

Numerous international standards and guidelines for the performance of ETT have been published. This document aims to make evidence-based recommendations for best practice within the UK but may be used to inform the work of those performing ETT elsewhere.

This document is intended for all healthcare professionals involved in ETT. It will provide recommendations for performing and reporting ETT in line with current best practice and guidance.

The recommendations presented within this document are intended for use in any environment where ETT is required, which may include but not be limited to clinical testing laboratories in publicly and privately funded hospitals, private clinics and clinical research laboratories.

This document provides guidance for ETT in adults. The following are beyond the scope of the document and will therefore not be discussed in detail:

- Paediatric ETT
- The use of pharmacological stress during ETT
- Cardiopulmonary exercise testing

It is recommended that individual testing laboratories produce a local standard operating procedure (SOP) for ETT, which should be followed by staff.

4. Indications and contraindications

4.1. Indications

The indications for performing ETT in the UK are summarised in Table 1.

Table 1. Indications for Exercise Tolerance Testing

	ETT for diagnosis?	ETT for ongoing management / prognosis / risk assessment?
Coronary Artery Disease	No (Unless alternative testing unavailable)[4, 6, 7]	Yes[8, 9]
Exercise-induced supraventricular arrhythmia	Yes (If symptoms clearly linked to exercise)[10, 11]	Yes (e.g. asymptomatic pre-excitation)[12]
Valvular Heart Disease	No[13, 14]	Yes (Unmasking symptoms, risk assessment, timing of intervention)[13]
Inherited cardiac conditions		
- **HCM**	No[15]	Yes[15]
- **LQTS**	No[16]	Yes[16, 20]
- **CPVT**	Yes[17, 18]	Yes[17, 18]
- **AVC**	No[10, 19]	Yes[10, 19]
Implantable cardiac rhythm management devices	No	Yes (chronotropic incompetence and rate response)[21]
Chronotropic Incompetence	Yes[22]	Yes[22]
Driving / pilot licence requirement	No	Yes[23]

(Table 1. Indications for exercise tolerance testing. ETT – exercise tolerance testing; HCM – hypertrophic cardiomyopathy; LQTS – long QT syndrome; CPVT – catecholaminergic polymorphic ventricular tachycardia; AVC – arrhythmogenic (ventricular) cardiomyopathy)

Coronary Artery Disease

ETT may be used to evaluate patients with known stable CAD, either to re-evaluate symptomatic patients for risk assessment[9], or to assess for ECG indicators of myocardial ischaemia as an alternative to functional imaging tests[7].

ETT should not be used for the diagnosis of CAD unless access to alternative testing modalities is limited or unavailable[7]. Non-invasive tests for the diagnosis of CAD should be chosen and interpreted using a Bayesian approach[24, 25]. The patient's pre-test probability will influence which diagnostic test is most suitable as different tests have different diagnostic performances depending on the patient population.

Historically, the most common use of ETT has been for the diagnosis of suspected stable CAD. Patients with stable CAD may exhibit ST segment depression on their 12-lead electrocardiogram (ECG) during exercise, suggesting myocardial ischaemia[26].

ETT has sub-optimal diagnostic performance for patients with either a high (>65%) or a low (<15%) pre-test probability of CAD, but has shown to perform better for patients with an intermediate probability between 15-65%[26]. However alternative non-invasive investigations such as Computed Tomography Coronary Angiography (CTCA) and stress imaging tests have better diagnostic performance than ETT, when performed in a centre with appropriate experience, availability and expertise[26]. Table 2. compares the performance of different testing modalities for the diagnosis of CAD[27]**.**

Table 2. The performance of different tests for anatomically and functionally significant coronary artery disease (Adapted from / Reproduced with permission from ESC[27]

Anatomically significant CAD			Functionally significant CAD		
Test	**Sensitivity (%) (95% CI)**	**Specificity (%) (95% CI)**	**Test**	**Sensitivity (%) (95% CI)**	**Specificity (%) (95% CI)**
			ICA	68 (60-75)	73 (55-86)
ETT	58 (46-69)	62 (54-69)			
Stress echo	85 (80-89)	82 (72-89)			
CTCA	97 (93-99)	78 (67-86)	CTCA	93 (89-96)	53 (37-68)
SPECT	87 (83-90)	70 (63-76)	SPECT	73 (62-82)	83 (71-90)
PET	90 (78-96)	85 (78-90)	PET	89 (82-93)	85 (81-88)
Stress CMR	90 (83-94)	80 (69-88)	Stress CMR	89 (85-92)	87 (83-91)

(Table 2. Comparison of the performance of different testing modalities for anatomically and functionally significant coronary artery disease. CAD – coronary artery disease; CI – confidence interval; CMR – cardiac magnetic resonance; CTCA – computed tomography coronary angiography; ETT – exercise tolerance testing; ICA – invasive cardiac angiography; PET – positron emission tomography; SPECT – single-photon emission computed tomography. Note ICA was used as a reference standard for anatomically significant CAD estimated but was included as a technique when fractional flow reserve was used as the reference. Adapted from / Reproduced with permission from ESC[27])

The addition of new non-invasive techniques in measuring coronary physiology such as Computed Tomography with Fractional Flow Reserve may add important incremental value to CTCA alone. This technique may be used in the pre-planning of revascularisation procedures and may help to avoid unnecessary revascularisation in some patients[28].

Exercise-induced supraventricular arrhythmias

An ETT can be used on patients that are suspected of having supraventricular ventricular arrhythmias during exercise[29]. This is especially useful when patients have had a normal ECG or ambulatory Holter monitor at rest but are experiencing symptoms during exercise. It can also be used in the management phase for patients with Wolff-Parkinson-White syndrome at low risk of rapid conduction over the accessory pathway, but are symptomatic with evidence of pre-excitation when in sinus rhythm[30].

Valvular Heart Disease (VHD)

VHD is diagnosed with cardiac imaging such as echocardiography[13], however, ETT is imperative to determine if a patient requires intervention by eliciting symptoms in patients who claim to be either asymptomatic, or who have non-specific symptoms. This is helpful in patients who are on the borderline for meeting the threshold for intervention[13, 14]. ETT has demonstrated its effectiveness in risk stratification for patients with aortic stenosis (AS)[13]. Surgical intervention in asymptomatic patients with severe AS is indicated if they have an abnormal ETT with symptoms in early exercise clearly related to AS (evidence I-C), or if during ETT the BP drops to below baseline (evidence IIa-C)[14]. ETT may also be used to assess operative risk in patients with valvular heart disease being considered for non-cardiac surgery[14] and as a form of risk assessment before pregnancy in patients with asymptomatic severe AS[14].

Hypertrophic Cardiomyopathy (HCM)

Exercise stress echocardiography is preferred in assessing HCM over ETT, with a second recommended assessment being cardiopulmonary exercise testing with simultaneous measurements of respiratory gasses. If ETT is used in the assessment of patients with HCM, close monitoring of BP is required, especially in patients with obstructive HCM (HOCM)[31, 32].

Ventricular Arrhythmias

Due to risk of provoking VT/VF, specialist knowledge of these conditions is essential. Medical supervision may be considered in these circumstances.

Long QT syndrome (LQTS)

ETT may be used in patients with known or suspected LQTS, predominantly to evaluate the QTc interval during recovery post-exercise. This can be a useful tool in the diagnosis and discrimination of LQTS[20].

Catecholaminergic Polymorphic Ventricular Tachycardia (CPVT)

ETT is useful in the study of patients with a clinical suspicion of CPVT and can be used to monitor the response of therapy in reproducible conditions. A key feature to look out for during the test is the presence of ectopy, especially bidirectional[18].

Arrhythmogenic Ventricular Cardiomyopathy (AVC)

Non-sustained ventricular tachycardia (NSVT) during ETT is an indication for implantable cardioverter defibrillator (ICD) implantation in patients with AVC. Continuing medical evaluation with repeat ETT every 2 years is also helpful[19].

Unexplained cardiac arrest and sudden cardiac death (SCD)

ETT may be used in the screening and risk stratification of patients with history of unexplained cardiac arrest and or risk of SCD[33].

Chronotropic incompetence

ETT can be used to diagnose and provide prognostic information for patients with suspected chronotropic incompetence. It can also be used in patients with documented or suspected symptomatic bradycardia or conduction disturbances, or a second or third degree atrioventricular[22].

Implantable cardiac rhythm management devices

ETT in patients who have ICDs and pacemakers (PPM) can continue their test as normal per conditions requested[33]. An individual with specialist knowledge in cardiac rhythm management should be present during the test. The parameters should be reviewed pre-test and understanding of the zones and therapy for ICDs is essential. If possible, the device should be interrogated and monitored wirelessly through the programmer, this is helpful in rhythm troubleshooting using the markers.

For requests to assess chronotropic incompetence or rate response algorithms adjustments to the parameters may be necessary. Follow local and national guidance for this.

Drivers / pilot license requirement

ETT may be recommended in drivers and pilots with particular cardiovascular disorders. Both the Driver & Vehicle Licencing Agency (DVLA)[23] and Civil Aviation Authority (CAA)[34] have published guidance to used when performing ETT in such patients.

SCST recommends users to refer to the guidance when asked to perform ETT on behalf of the DVLA and CAA.

4.2. Contraindications

There are certain situations and conditions where ETT should not be performed due to significant risk of adverse event/major complication. Individuals referring patients for ETT must ensure they have ruled out any absolute contraindications before requesting the test.

As there may be a time delay between referral and the test being performed, the

member of staff leading the test should review the patient's history immediately prior to testing to confirm no contraindications have arisen during the waiting list period and that it is still safe to perform the test. Table 3 lists the absolute contraindications for ETT.

Table 3. Absolute Contraindications to ETT
Recent or acute myocardial infarction (maximal ETT contraindicated <14-21 days post MI[35] or if the MI involved cardiogenic shock[36]
Ongoing unstable angina[35]
Uncontrolled cardiac arrhythmia with haemodynamic compromise
Active endocarditis
Symptomatic severe aortic stenosis
Decompensated heart failure
Acute pulmonary embolism, pulmonary infarction or deep vein thrombosis
Acute myocarditis or pericarditis
Acute aortic dissection
Physical or cognitive disability that precludes safe testing
Patient refusal

(Table 3. Absolute contraindications to exercise tolerance testing. ETT – exercise tolerance testing; MI – myocardial infarction)

Patients with HCM and severe resting gradient > 50mmHg shouldn't be exercised with the sole purpose of gradient assessment, however given the generally low risk involved in ETT, valuable and beneficial information regarding patient symptoms may be acquired[31].

Relative contraindications to ETT are to be considered if there is a slightly higher risk of an adverse event/complication, but the potential result outweighs the risk of harm from the test. In these situations, there must be clearly documented evidence of the specific indication and rationale for the test.

It would be prudent for the referring physician to obtain written informed consent, where there is clear documentation of discussion of the risks and benefits of the ETT with the patient. A physician with specialist knowledge of ETT as well as the particular condition should be present in the room during the test as well as the lead ETT staff member to ensure patient safety.

Local policies may deviate in regards to when to undertake an ETT on a patient with relative contraindications, the scope of this must be covered within a local SOP. Table 4 lists relative contraindications to ETT.

Table 4. Relative Contraindications to ETT
Known obstructive left main coronary artery stenosis
Moderate to severe aortic stenosis with uncertain relation to symptoms
Tachyarrhythmias with uncontrolled ventricular rates but without haemodynamic compromise
Acquired advanced or complete AV block
Hypertrophic obstructive cardiomyopathy with resting LVOT gradient < 50 mmHg[31]
Recent stroke or transient ischaemic attack
Cognitive impairment with limited ability to cooperate
Resting hypertension with SBP > 200 mmHg or DBP > 110mmHg (or both)
Uncorrected medical conditions such as significant anaemia, electrolyte imbalance or hyperthyroidism

(Table 4. Relative contraindications to exercise tolerance testing. ETT – exercise tolerance testing; AV – atrio-ventricular; LVOT – left ventricular outflow tract; SBP – systolic blood pressure; DBP – diastolic blood pressure)

5. Potential complications and risk of harm

Exercise in a population with known or suspected cardiovascular disease has the potential to lead to adverse cardiac events due to an increased metabolic demand, on a potentially inadequate cardiovascular system. The development of absolute and relative contraindications for ETT allow healthcare professionals to identify individuals who should not undergo ETT because of an underlying condition and those for whom extra considerations may be needed in terms of modified exercise protocol, alternative equipment or the presence of specialist staff.

ETT utilises continuous monitoring of both the patient and their ECG together with frequent BP measurements. This data allows the test operator to make real-time decisions regarding the ongoing safety of the test. Test end-points are discussed in section 13 of this guidance. Continuing to exercise a patient beyond a test end point poses an increased risk of complication.

Potential complications of ETT

Although ETT is a relatively low risk procedure, both cardiac and non-cardiac complications have been documented and are listed below:

- Angina
- Asystole
- Atrial fibrillation/flutter
- Atrioventricular blocks
- Cardiogenic shock
- Cerebrovascular event
- Claudication
- Congestive heart failure
- Dizziness
- Fatigue
- Hyper- and hypotension
- Injury (due to fall)
- Joint or muscle pains
- Myocardial infarction
- Pulmonary embolism
- Sinus bradycardia
- Sudden cardiac death
- Supraventricular tachycardias
- Syncope
- Ventricular tachycardias

Potential risks of harm from ETT

Studies on the incidence of major complications and death during ETT vary widely in terms of the health characteristics of the study population, exercise modality, protocol and staffing. Nevertheless, the overall data suggests a low risk of death or major complication during ETT. Table 5 summarises studies evaluating the risks of ETT. The overall risk of death may be considered as less than 1 in 10,000 tests and the overall risk of major complication is approximately 4 in 10,000 tests. However, it should be highlighted that the studies are outdated and there is a lack of recent data regarding the risks of ETT in the modern era.

Table 5. Incidence of Death and Major Complication during ETT

Study	Number of exercise tolerance tests	Death per 10,000 tests	Major complication per 10,000 tests
Rochmis and Blackburn (1971)[36]	170,000	1	2.4
Atterhög et al. (1979)[37]	50,000	0.4	5.2
Scherer and Kaltenbach (1979)[38]	712,285	0.23	1.3
Stuart and Ellestad (1980)[39]	518,448	0.5	8.36
Young et al. (1984)[40]	1377	0	0
Gibbons et al. (1989)[41]	71,914	0	0.85
Knight et al. (1995)[42]	28,133	0	3.19
Myers et al. (2000)[43]	75,828	0	1.2

(Table 5. Studies investigating the incidence of death and major complication during exercise tolerance testing. References included in table)

6. Personnel

The personnel involved in an ETT may not adhere to standardised job titles, professional classifications, or bandings. However, some departments have well-defined roles so it is imperative that SOPs consider local variations.

Two distinct staff roles have been identified as essential: a Lead and an Associate, which are explained below. However, the complexity and potential risks associated with specific ETT cases may require the presence of a Specialist Registrar (SpR) of level 3 or above, well-versed in cardiac care, for the entire duration of the test and subsequent recovery period. This additional medical presence should complement the two defined staff members performing the test.

6.1. Requirements for the Lead

The leading member of staff should have relevant level 6 qualifications to the field (i.e. Cardiac Physiology or equivalent) and hold current Immediate Life Support (ILS) training. They require a high level of knowledge and understanding in cardiac anatomy and physiology, ECG interpretation/reporting and the assessment of systemic BP. The Lead is responsible for evaluating the test referral against contraindications, conducting the ETT and reporting results.

Assessment of competency should be performed by an experienced and qualified member of staff. We recommend at least 50 tests performed as Lead, under supervision, should be carried out on a range of patients and preferably documented in a logbook (template suggestion in Appendix 1). As a minimum we recommend that the lead will have led at least 10 ETT's that have presented a range of positive findings. Thereafter ongoing and regular (at least monthly) clinical work in ETT should be performed. Medics, Nurse Practitioners and other registerable healthcare practitioners can also be considered as alternative acceptable staff should they have the proven theoretical and practical ETT skills. Further learning is encouraged, with many resources being available from the SCST (e.g. Foundation and Diploma ECG courses), HEE (Apprenticeships) and other cardiology organisations. Clinical examination and cannulation skills are advantageous, but not essential.

6.2. Requirements for the Associate

The Associate should have a current Basic Life Support (BLS) qualification and have been formally assessed as competent to use an automated electronic defibrillator (AED). They should also have knowledge of ETT protocols and ECG interpretation, but if this is not feasible then the individual must have undertaken an exercise module such as within the apprenticeship programme and have proof of over 20 tests on a range of patients as a supernumerary. The Associate must keep a logbook of these

tests to be deemed suitable for working in this area. Any individual not meeting the criteria must remain supernumerary and support the team as a third member until training in all areas are complete. For additional advice on personnel training and experience, please see Appendix 1 for an example competency logbook and assessment.

As for the Lead personnel, further learning by the Associate is encouraged as suggested in section 6.1.

6.3. Cardiac Implantable Electronic Devices (CIED) personnel

Staff competent in CIED should be present for all patients with an implantable device in-situ (with the exception of implantable loop recorders – ILRs). If this staff member is ETT trained then they can replace the associate for this procedure, otherwise they become an additional member to the team.

The CIED personnel will be responsible for the following:

- Identifying the device manufacturer / make / model and obtaining the appropriate programmer.
- Reviewing the programmed settings and algorithms, storing a report.
- Interpreting the device responses throughout the test.
- Contributing towards the final interpretation / diagnostic report.
- Produce report of the CIED review in addition to the ETT results.

An ETT should not be performed on CIED patients without a CIED-trained healthcare professional, and the appropriate programmer being present.

7. Resuscitation

It has been identified that ETT poses risk of acute illness (e.g. acute MI), loss of consciousness and even death[43], therefore it is compulsory to prepare the appropriate preventative and action measures.

For patient safety, there should be a minimum of two healthcare professionals present during the testing protocol. This enables one healthcare professional with enhanced life support training (ILS/ALS) to lead the arrest, whilst a second member can obtain the crash trolley/defibrillator. It should be mandatory for the Associate to be trained to at least Basic Life Support (BLS) level, and desirably to be additionally trained to ILS level.

RCUK Guidance states that in cases where the healthcare or medical professionals involved in carrying out ETT are trained in recognising cardiac rhythms, there should be a preference for the use of manual defibrillation over automated AED. This method,

using two healthcare professionals to perform manual defibrillation, has been proven to reduce the rates of “failure-to-rescue”[44].

For full details and information about life support courses and protocols, please visit the RCUK links as below:

- Adult basic life support (BLS)
- Adult advanced life support (ALS)
- Special circumstances
- COVID-19 statements and guidance

8. Infection control

An appropriate infection prevention and control strategy should be implemented during every ETT for the safety of patients and staff. The guidance provided should be followed in conjunction with local infection prevention and control policies.

ETT staff should have undertaken local infection prevention and control training. Staff have a responsibility to contact occupational health if they feel they are an infection risk or are vulnerable among a certain patient group. Prior to the ETT, patient records should be checked for transferable infections. If the patient has a known transferable infection then ETT staff should refer to local infection prevention and control policies or infection prevention and control team to determine if extra personal protective equipment (PPE), such as FFP3 mask and long sleeve medical gowns, are required.

ETT staff should adhere to national and local hand washing standards, whereby staff must wash their hands effectively before and after patients in conjunction with alcohol rub[45]. All ETT staff should consider wearing a disposable medical apron and gloves for every test. All equipment (treadmill, ECG cables, console etc.), must be cleaned between each patient using the cleaning solution/wipes stated by local policies. An auditable cleaning log should be implemented to ensure sufficient cleaning standards are achieved (see appendix 2)

All equipment and PPE should be handled and discarded as per local policies and recommendations.

8.1. Infection control during the COVID-19 pandemic

For guidance on infection control for patients with known or suspected COVID-19 refer to The SCST Consensus Recommendations for the use of PPE for procedures performed within cardiac physiology.

9. Equipment and environment

9.1. Exercise testing room

Located close to a medical setting, preferably within a Cardiology department or outpatients setting with advanced life support (ALS) providers on site. If this is not feasible, we strongly recommend the room is adjacent to a department with ALS providers.

Regulation 10 of the Workplace Health Safety and Welfare (HSW) Regulations 1992[46] states that the room should have the following for the purposes of health, safety and welfare:

- Total volume, when empty, that exceeds 11m^3, per person
- Minimum height of 2.4m to account for the gradients encountered on the treadmill and the tallest patient. When height is greater than 2.4m then a value of 2.4m should be used for the total volume calculation.
- Minimum floor area of 13.75m^2, (approx. example 3.5m x 4m room).
- Comply with local fire regulations
- Sink for clinical hand washing
- Height-adjustable couch
- Space for the patient to undress/change in relative privacy. Curtains / screens or room layouts should support patient dignity.

The room should be big enough to accommodate all the exercise stress testing equipment as well as emergency equipment. Adequate access to the patient in the case of an emergency is essential and the room must be large enough to accommodate a stretcher trolley. There should be a minimum of a door and half entry/exit for trolley and bed access. Should a non-life-threatening event leave the patient on the floor, space for a hoist or inflatable cushion should be available to comply with manual handling requirements. The location of these should be defined within your local SOP. Consider these restrictions when moving into pre-existing buildings or constructing new facilities.

9.2. Ventilation and temperature

The room should be well lit and have adequate ventilation. It is advised that the room should have a means of controlling temperature and humidity. Maintenance of an appropriate temperature is important as heart rate and perception of exertion increases with an increase in ambient temperature. Temperature in the range of 20^{o}C

- 22^{o}C is considered comfortable for exercise[47]. Whilst humidity above 60% can impact cardiovascular response.

A fan is often placed in front of patients for the sensation of air breeze, which supports patients' comfort. However, with the production of air droplets during an ETT, transmission of any infections must not remain air borne for the next patient to encounter. Ventilation can play a key role in limiting some infectious diseases, therefore, this should be considered within local departmental SOP.

9.3. Emergency and communications methods

The room must have a telephone to call the resuscitation team if required or contact the referrer if further clarification is required. Additionally, an alarm call system to initiate a call for help and the cardiac arrest team is valuable.

9.4. Equipment

Treadmill system

The treadmill should have the ability to increase speeds and gradients to meet the minimum of the Bruce Protocol stage seven (6mph at 22% gradient). The treadmill should have both front facing and side handrails for stability, although these are not for direct upper body support. Ideal performance requires minimal artefact from the upper extremities; therefore patients should be encouraged to use the lightest grip possible for suitable walking performance.

All treadmill machines have a weight limit within their specification. This should be clearly stated in the ETT room and/or departmental SOP. Patients who breach this weight should not be tested this may adversely affect the performance and accuracy of the equipment, as well as place the patient in danger.

It is recommended that staff familiarise themselves with the capabilities and controls of the equipment during their training period and should refer to the manufacturer's manual if necessary.

Treadmill PC communications

Where possible bi-directional communications should be set up from Trust electronic requesting systems, incoming worklists and exporting of data to improve data transfer, reduce data duplications and governance errors.

The procurement of any new exercise systems, should have the capability to export reports into the patients electronic records to meet the IT platform of future digital requirements required of the NHS[48].

ECG recording

ECG recording must be displayed on a real-time screen for visual review throughout the test. The recorder should have the simultaneous ability to print a 12-Lead ECG at any point (pre, during or post-test) as well as a continuous ECG recording onto graphic paper. Throughout the ETT, a minimum of 6 leads should be visible and all leads should be accessible.

BP recording

We recommend that manual BP systems, validated for specialist use, are located within the room and available for use. Office machines are not suitable. Please refer to the manufacturer and models recommended by the British and Irish Hypertension Society (BIHS)[49].

Automatic BP machines are common and well recognised but deteriorating clinical situations or fluctuating heart rates/ arrhythmias can cause rapid pressure change which may require the manual system.

9.5. Emergency equipment

A full resuscitation trolley including defibrillator with pacing module must be located within the exercise testing room or directly outside.

During the test there must be at least one clearly defined emergency button to terminate the treadmill belt. This is for staff use and should be located adjacent to handrails for a swift emergency stop if required.

Resuscitation team accessibility and drills.

The department SOP should dictate the requirements for testing the equipment above. Each department should have a set staffing group which carries out daily and weekly check of the crash trolley. ETT practise drills are recommended especially as the frequency of ETT are reducing. The UKCRF states[50]: *"All staff should be involved in at least one announced or unannounced emergency scenario training session annually."*

10. Patient preparation

10.1. Pre appointment preparation

Prior to the appointment date, sending the patient a list of pre-test instructions with the appointment letter is recommended. These instructions should include[51]:

- Wear comfortable clothing and footwear which are suitable for exercise.
- Clothing worn on the upper body should be easily removable for electrode positioning.
- Not to eat a heavy meal in the 3 hours prior to the test.
- Details regarding whether the patient should remain on any medications based on the physician's referral.

10.2. Patient identification

It is essential that the patient undergoing the procedure is correctly identified with at least two patient identifiers – name and date of birth. Additional identifiers may be used if deemed necessary, as per local policies. For patients unable to provide their own identifying details, confirmation of identity must be sought from carers/relatives or by using hospital wristbands.

The ECG recording must be checked to ensure it bears the correct patient details. Practitioners must be aware of potential sources of error if details are not entered digitally. Local policy and practice should be developed to ensure that errors do not occur in busy clinical environments. Where DICOM worklists are available, it is recommended they are used to prevent data errors.

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10.3. Informed consent

The patient should be given clear, precise information on the test in a format that is consistent with their needs and level of understanding. Information can be in the form of a booklet, information letter, oral explanation or a combination. As a minimum, SCST recommends the person performing the procedure should introduce themselves, explain their role and provide a brief overview of the procedure. If possible, this should include the level of undress involved and the use of adhesive electrodes, with a reassurance that the procedure is brief and painless. Informed consent is required in accordance with local policy before proceeding.

10.4. Clinical history

A patient's clinical history is obtained by the referring physician and clearly stated on the referral document, with emphasis that ETT contraindications have been considered. Special requirements, such as withholding medication for a test, should be noted on the referral document with reasoning. If a patient's clinical history is

incomplete or unclear the referring physician should be contacted for clarification. If this is not possible, request a review by a cardiology Registrar or Consultant.

It is the responsibility of the lead personnel to review the patient's clinical history to ensure clinical status is correct with no recent changes. This includes checking the test referral, electronic patient records and/or patient notes. Before conducting the ETT, the patient's clinical history should be discussed with the patient directly to confirm no recent changes e.g., new symptoms of angina, recent surgery or physical injury. Open-ended questions should be used by the lead personnel to establish the patient's clinical history, e.g., how would you describe your symptoms? If a contraindication is identified, the ETT should not be conducted and the patient should be referred back to the physician.

The lead personnel should review the referral to ensure the correct test protocol is selected to elicit the desired clinical information and results. Upon arrival, it must be clarified with the patient that they have withheld their medication, if required. The test should not be conducted if the patient has taken medication that the physician instructed to be withheld for the ETT. Any disabilities should be identified and evaluated prior to starting the test.

10.5. Pre-test explanation and demonstration

The test protocol should be explained, and patient instructed about how to inform the operator that they wish to stop, the importance of a maximal effort and that they will need to communicate symptoms during the test.

There should be clear descriptions on the walking technique especially if the patient is new to walking on a treadmill. If needed a staff member can demonstrate the correct technique with emphasis on the following key points:

- Normal length strides
- Looking ahead
- A light grip on the handrails for support and balance.

10.6. Chaperones

In accordance with good clinical practice, patients undergoing examinations that have the potential to be embarrassing or distressing should have the option of requesting a chaperone to be present.

A relative or carer can influence or interfere with the test, so their attendance is not recommended. However, in special circumstances, it may be beneficial to have a carer or a relative in the room (e.g., communication difficulties or other disabilities).

If English is not the patient's first language a chaperone may be a hospital organised interpreter. If the practitioner or the patient insists on a chaperone being present, or if

either is uncomfortable with the choice of chaperone, an offer may be made to defer the examination to a later date when a suitable chaperone would be available, if the delay would not adversely affect the patient's health[52].

10.7. Equality and diversity considerations

Practitioners should respect the cultural sensitivities of the patient and minimise embarrassment. Patients may feel uncomfortable when the chest electrode/leads are being applied; practitioners must act in a sympathetic, caring and compassionate manner[53].

Patients should be asked to remove all clothing impeding access to the correct chest electrode positions. Patients should be allowed to undress in a private environment with minimal risk of interruption. Once the cables have been attached to the electrodes the patient should be covered to preserve their modesty. The practitioner should make every effort to ensure the patient is comfortable and relaxed to minimise artefact on the ECG recording. Clinical discussions with the patient should only take place after re-dressing.

11. Patient electrode attachment

11.1. Skin preparation

Skin preparation is often required to help produce an artefact-free ECG. Care must be taken with patients who have sensitive or broken skin. There are various ways to minimise the skin-to-electrode impedance:

- Cleaning the skin with mild soap and/or an alcohol-based solution.
- Exfoliation - very light abrasion using a paper towel, gauze swab or proprietary abrasive tape designed for this purpose.
- Removing chest hair to ensure adequate electrode connection with the skin. Verbal consent must be obtained and a single use electric blade or razor should be used and disposed appropriately in a sharps bin.

11.2. Electrode positions

The correct anatomical positions for the chest electrodes have been defined (Figure 1) and must be used unless access is not possible. The centre of the active area of the electrode should be aligned with the relevant anatomical landmark[54].

Precordial (chest) electrode positions:

- V1, red (C1) – 4th intercostal space at the right sternal edge (RSE)
- V2, yellow (C2) – 4th intercostal space at the left sternal edge (LSE)
- V3, green (C3) – Midway between V2 and V4

- V4, brown (C4) – 5th intercostal space in the mid-clavicular line
- V5, black (C5) – Left anterior axillary line at the same horizontal level as V4
- V6, purple (C6) – Left mid-axillary line at the same horizontal level as V4 & V5

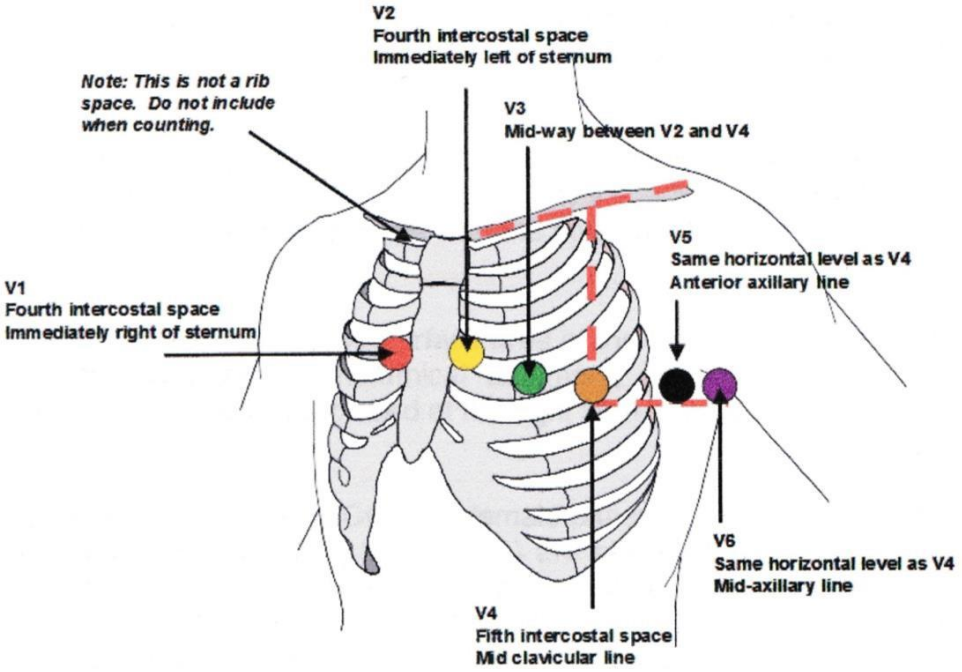

Figure 1: Standard ECG chest electrode positions[55].

Limb positions

To reduce movement artefacts during an ETT, a Mason-Likar modification is used which transposes the limb electrodes to the torso. As shown in Figure 2, right (RA) and left arm (LA) electrodes are placed in the infraclavicular fossae, medial to the deltoid muscle, 2cm below the lower border of the clavicle. The right (RL) and left leg (LL) electrodes are kept in the anterior axillary line, halfway between costal margin and iliac crest. As in a standard 12 lead ECG, the right lower electrode acts as the ground[56].

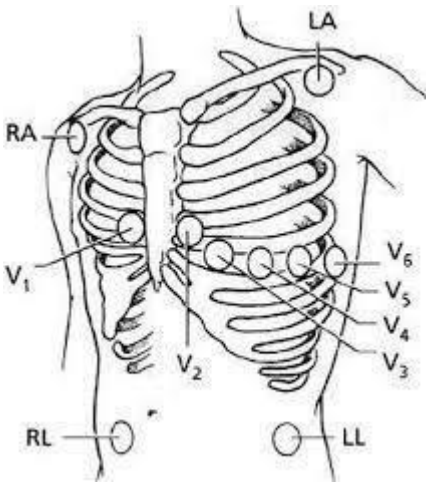

Figure 2: Limb lead positioning during exercise testing[57].

12. Exercise protocols

12.1. Treadmill protocols

Bruce protocol

The most common protocol used during treadmill exercise stress testing is the Bruce protocol. This protocol is divided into seven stages of 3-minutes which results in a total duration of 21 minutes. The speed and gradient increases at the end of each stage requiring the patient to gradually increase their exercise intensity. Stage 1 of the Bruce protocol starts at 1.7mph pace at a 10% gradient and Stage 7 ends at 6mph pace at a 22% gradient[58].

Modified *Bruce* protocol

There is a modified Bruce protocol for those who cannot exercise vigorously, which adds two lower workload stages to the beginning of the standard Bruce protocol, both of which require less effort than Stage 1[58].

Other protocols can be used in place of the *Bruce*:

- Accelerated protocols with 2-minute stages instead of 3 minutes are often used with athletes.
- The ***Cornell*** protocol reduces the workload increment between stages of the standard Bruce protocol by reducing stage duration to 2 minutes while interpolating additional half stages.
- The ***Naughton & Balke*** protocols also provide more modest increases in workload between stages and are useful choices for elderly, deconditioned patients.

A complete set of protocols can be found in the American College of Sports Medicine guide for exercise prescription and testing[59].

12.2. Bicycle protocols

For bicycle ergometry, the initial power output is usually 10W or 25W (150 kpm/min), usually followed by increases of 25W every 2 or 3 minutes until end points are reached. If arm ergometry is substituted for cycle ergometry, a similar protocol may be used, except that initial power output and incremental increases are lower. Two-minute stages are most popular with arm ergometry[51]. Most subjects who are unable to use their legs for treadmill or bicycle exercise generally undergo pharmacological stress testing with imaging[51].

12.3. Blood pressure measurement

BP must be taken prior to the test to ensure that the value is not a contra-indication for the ETT. If resting systolic BP (SBP) > 200 mmHg or diastolic BP (DBP) > 110mmHg then it should be repeated after a five-minute rest period. If it remains high the test should not be performed and the patient should be referred back to the referring clinician for re- referral once the BP is within a testing range.

If the BP is safe to commence the ETT, a repeat BP measurement should be obtained every two minutes into each three-minute stage, at peak exercise, immediately post exercise and at 1, 3 and 5 minutes into recovery. If the indication is for a driving or pilot licence, e.g., DVLA, then their latest requirements should be followed.

Prioritise SBP, particularly if challenging to obtain the measurements. If unsure about a reading, then retake and confirm, particularly if the patient is asymptomatic as stopping means the test is complete. If BP is high (Section 13) or you are unable to take a BP reading then always act on the side of safety as a patient can always return if needed for a repeat test.

13. Test endpoints

Unless specified on the referral, an ETT should end when the patient has reached maximum effort or become symptomatic. However, for the safety of the patient, tests should also be terminated if any of the following scenarios present:

Patient-led

- Patient request
- Moderate-to-severe angina with or without ST segment changes[51]
- Dyspnoea[58]
- Claudication[51]
- Central nervous system symptoms (e.g., ataxia, dizziness or near syncope)

Patient appearance

- Signs of poor perfusion (cyanosis or pallor)[60]
- Unsteadiness of gait
- Poor communication / lack of test understanding
- Sudden change in patient behaviour / cognitive ability

BP abnormalities

- Exaggerated hypertensive response (systolic BP > 230mmHg and/or diastolic BP > 115mmHg)[61]
- Blunted systolic BP response – failing to increase > 20mmHg[62]
- Drop in SBP > 20mmHg (consider repeating if subtle changes > 10 mmHg are noted)[62]

ECG abnormalities

- Sustained exercise-induced arrhythmias that alter cardiac output – Ventricular tachycardia (VT), second and third-degree atrioventricular (AV) block, supraventricular tachycardia (SVT) and new atrial fibrillation (AF)[63]
- Exercise induced arrhythmias with symptoms and BP drop – AF, frequent atrial premature beats (APBs), frequent ventricular premature beats (VPBs), ventricular triplets and bradyarrhythmia[64]
- ST depression in more than one lead (horizontal or downsloping of > 2mm, measured 60-80ms after the J point [the end of the QRS complex]), with no symptoms[51]
- Development of bundle branch block[58]
- Rapid ST elevation with or without chest pain 1mm in patients without pre-existing Q waves[58]
- Reduction of heart rate > 20% of starting rate[62]

Equipment faults

- Failure to obtain BP readings[64]
- Poor ECG signal quality[64]

14. Recovery period

The recovery period is a continuation of the test, staff must remain vigilant in their observation of the patient, measuring both ECG and BP during this stage. The BP and ECG should be taken at test termination or immediately after to obtain an artefact free ECG for interpretation.

An ECG should be taken at 1 minute then every two minutes into recovery until the test is complete. Should any arrhythmia arise, or ongoing changes occur, additional recordings should be obtained.

The BP should be taken again at test termination, and repeated every two minutes until it recovers to within a normal range, or to the patient's baseline, whichever occurs first.

Five minutes is the recommended minimum recovery time, but this should be extended should abnormalities remain. Where departments require a longer recovery for all or complex cases they should ensure this is documented in the SOP. Many licensing authorities (e.g., CAA, DVLA) require an ECG every minute for a 10-minute recovery period, please see the licensing section and most up to date websites for requirements.

15. Final report

All written reports will include features obtained throughout the test and should include but not only be limited to:

- The protocol used
- The resting ECG appearances
- Exercise time
- % of predicted maximum heart rate achieved if this is a parameter of the departmental SOP.
- Reason for termination
- Maximum ST changes; which lead(s) and when (and resolution)
- Patient's cardiac symptoms – what, when, associated ECG changes, where on ECG.
- Patient's other symptoms – claudication, dizziness, fatigue
- BP response - fundamentally systolic reaction
- Some machines report METS, RPP and ectopic activity
- Recovery phase. A record of time taken for ECG and BP to return to baseline values.
- Comment about the patient's appearance before, during and after the exercise.
- Describe findings when a CIED in situ such as the predominant rhythm, percentages of pacing, details on inhibition.
- Reports, arrhythmias, tables and ectopic activity if not described previously should mentioned if applicable.

IT interfacing for digital reports and back-up systems

Reports, arrhythmias, tables and ectopic activity can be stored, if digital technology allows, within your exercise system. The report, test graphs, tables and tracings should be saved in the patients' electronic records within the machine and transferred to the patient's main hospital records.

16. Post-test patient information

Once the patient is recovered, disconnected, dressed and composed, information about the test and its findings may be relayed. If a Cardiologist or applicable medic is in attendance discussions may occur on the day. For many individuals the technical service will not have a medic and they will be informed later either in writing, via the GP or at a later hospital visit.

The test day must be encouraged to be a positive hospital experience, whatever the patient's performance or findings the team should be supportive to the efforts achieved. Obvious significant findings may lead to admission so if this is not the outcome the patient must be told who, how and when the results and findings should arrive. If waiting times are long guidance on signs and symptoms can be educational, to support the patient seeking further help if needed in the interim.

17. Quality assurance (QA) and audit

Not following a standardised safe protocol for ETT has the potential to lead to harm or unnecessary complications for patients. Also, misinterpretation or incorrect reporting of the test findings can have serious consequences for the diagnosis and subsequent treatment of the patient. It is therefore recommended that ETT procedures undergo systematic QA to ensure standards of testing and reporting are continually maintained and inconsistencies are highlighted and addressed in a timely manner where necessary.

Regular formal audit is a useful quality improvement tool to ensure the service provided meets the required standards set by departmental policy and as laid out in this guidance. An audit checklist is available in Appendix 2, which may be used or adapted for this purpose.

It is recommended that any QA scheme for ETT addresses qualifications in ECG interpretation and performing / assisting in ETT; spot checking of the test procedure to ensure compliance with the departmental standard operating procedure; and audit of the ETT report and associated handling of documentation / appropriate and timely feedback of results.

A representative sample of the service output should be reviewed for quality assurance, this should equate to at least 5% of the total procedures performed and may be increased periodically if the department has highlighted any areas to be improved through a specific quality improvement project or structured audit.

18. Conclusion

Consideration of the patient undergoing any diagnostic investigation must be at the centre of all clinical pathways. Meticulous patient preparation, precise electrode placement and the other factors described in this document are essential in the provision of accurate diagnostic information.

It has been recognised the requirements for exercise test services has diminished in a wide range of departmental environments. Hence, it is of paramount importance that the procedure is undertaken by appropriately trained and qualified practitioners to ensure that high-quality consistent care and patient safety are upheld irrespective of where and by whom the procedure is performed, supporting throughout the personnel following good scientific practice.

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20. Appendices

20.1. Appendix 1 – Example of competency logbook

ETT Competency Logbook

Recommended Knowledge Base

- Cardiac and Cardiovascular Anatomy and Physiology.
- ETT protocols, aims and troubleshooting.
- Physics of ECG, ECG interpretation and ECG reporting relevant to the indications, contraindications and potential complications of ETT.
- BP assessment (competency in manual BP assessment during ETT is ideal).
- Comprehensive knowledge and understanding of the relevant cardiac and non-cardiac conditions relating to the indications, contraindications and possible complications of ETT.

No.	Date	Age	Indication	Presenting rhythm	ECG changes during test	Reason for stopping	Test outcome	Supervisor Initials

ETT Lead Assessment

- **Aim:** To assess the competency of prospective Lead Personnel in all aspects of exercise ECG testing.

- **Method:**

- Prior to the assessments, the assessee should have completed 50 ETTs under supervision as the lead.

- The assessee is to complete a minimum of 5 assessed ETTs, demonstrating a high level of performance & understanding. At least 3 of these must be positive tests.

It is recommended that the candidate is assessed by a healthcare professional with at least two years' experience as the Lead.

Personnel being assessed: _____

(Name)

Summary of Assessments Performed:

Stop filling in form for negative/equivocal tests after 4 have been done.
Save 3 slots for Positive tests.

Date	Age	Indication	Presenting rhythm	ECG changes during test	Reason for stopping	Positive / Negative

PRACTICAL ASSESSMENT

Tick the boxes if the assessee has competently completed that section. Cross box if not competent.
If an assessment point does not apply, please enter N/A in the column.

Preparation	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1. Reads the referral form and patient notes. Understands the requested end points for the test. (Ask them to explain this to you)							
2. Does not proceed if any contra-indications.							
3. Introduces themselves to the patient							
4. Reminds patient to inform them of any symptoms during the test.							
5. Checks baseline ECG with the clinic ECG for any changes.							
6. Measures a baseline BP.							

During the Test	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1. Regularly asks how the patient is feeling.							
2. Is watching the ECG monitor.							
3. Records a BP after 2 minutes into each stage, more if necessary.							
4. Encourages the patient appropriately.							
5. Observes patient for signs of distress.							
6. Adequately documents onset of patient symptoms.							
7. Monitors patient symptoms for increasing severity.							
8. Checks the ECG when symptoms occur. Records extra ECG's to monitor increasing ST changes.							
9. Questions the patient regarding symptoms if ECG changes occur.							
10. Stops the test at the appropriate time.							

Recovery Stage	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1. Takes a BP on recovery (if was not recorded during the last stage)							
2. Questions patient regarding current symptoms.							
3. Questions patient regarding symptoms that they had during the test.							
4. Gives GTN spray and oxygen as appropriate.							
5. Writes a report including: a) Duration of test and if target HR met. b) Haemodynamic response. c) ECG changes.							

d) Cardiac and non-cardiac symptoms. e) Recovery status							
6. Ensures ECG changes and symptoms have resolved before ending the test.							
7. Explains to the patient that they discuss the test result with the doctor.							

This section is assessed during Q&A session.

Cardiac Arrest during test:	
1. Safely gets patient onto the floor (If still on treadmill).	
2. Pushes arrest call button.	
3. Commences CPR until crash team arrives.	
4. Understands importance of early defibrillation in VF arrests and can describe pad placement, and energy levels for defibrillation.	

Practical Assessment Comments:

Stop filling in form for negative/equivocal tests after 4 have been done.
Save 3 slots for Positive tests

Date	Comments:
	Assessment # __1___ Competent / Not yet Competent **signature:** _____
	Assessment # _2____ Competent / Not yet Competent **signature:** _____
	Assessment # _3____

	Competent / Not yet Competent **signature:** _____
	Assessment # _4____ Competent / Not yet Competent **signature:** _____
	Assessment # _5____ Competent / Not yet Competent **signature:** _____
	Assessment # _6____ Competent / Not yet Competent **signature:** _____
	Assessment # _7____ Competent / Not yet Competent **signature:** _____

Oral Assessment Comments:

Date:	Comments: Competent / Not yet Competent

FINAL REPORT

Practical Assessment: **Competent / Not yet Competent**

Oral Assessment: **Competent / Not yet Competent**

I find that _____ is partially competent and has a good understanding in all aspects of the role of an ETT Supervisor.

_____

(Supervisor signature)

_____

(Date)

20.2. Appendix 2 – ETT audit document

Exercise Tolerance Test Audit criteria			
Hospital Number	**Date**		
Audit performed by (Name)			
(Job Title)			
Task		**Yes**	**No**
(1) Qualification & Training	Are the Lead and Associate trained in the exercise test system?		
	Did the Lead personnel member have the required qualifications?		
	Did the Lead personnel member have a proven logbook of over 39 cases?		
	Did the associate personnel member have a recognised ECG certificate?		
	Did the associate member have a logbook of proven exposure?		
	Have team members had applicable resuscitation training in last 12 months?		
(2) Identification of patient	Were at least 2 identifiers and /or Trust protocol followed for patient identification?		
(3) Consent	Was the procedure explained before proceeding?		
	Was consent (verbal or written) properly obtained?		
(4) Patient experience, privacy and dignity	Did the operator communicate with clarity and accuracy?		
	Did the information meet the correct level /deemed appropriate to meet the patient's needs?		
	Was level of clothing appropriate?		
	Was the patient treated with dignity, respect and the cultural sensitivities respected?		
	Were there any difficulties with communication?		
	Was the patient aware / asked if they wanted a chaperone?		
(5) Environmental considerations	Is the Exercise room of correct minimum dimensions (3m x4m x 2m) high as minimum, if not has this been ratified in Trust SOP		
	Was the environment private (curtained, walled, screened)?		
	Was the procedure conducted with no interruptions?		
	Was the environment comfortable and warm?		
	Did the area have hand-cleaning facilities?		
	Did the area have clinical waste disposal facilities?		
	Was a height-adjustable couch available?		
(6) Equipment specification	Was a crash trolley located within or immediately outside the room?		

	Was the room checked for equipment & consumables prior to the test		
	Was there an electrocardiograph meeting standards available?		
	Was the ETT system up-to-standard and checked by medical electronics team?		
(7) Infection control	Did the lead and Associate follow hand hygiene protocols?		
	Did the team wear appropriate PPE?		
	Was there provision for disposal of clinical waste? Black/orange & sharps bin.		
	Was the equipment adequately cleaned prior and post ETT? (as per IC guidance)		
(8) Patient preparation	Was appropriate skin preparation performed		
(9) Electrode Placement	Were the precordial (chest) leads in the correct anatomical positions in accordance with SCST guidelines?		
	Were the leads connected correctly to the electrocardiograph?		
(10) Recording Quality	Was a reasonably artefact-free recording obtained?		
	Was the initial recording at appropriate settings for paper speed (25mm/sec) and gain (10mm/mV)?		
(11) Documentation, processing and storage	Did 3 identifiers appear on the printout / stored recording?		
	Was the ECG recording forwarded appropriately according to local policy (eg for medical review, electronic storage, copy in notes etc)?		
	Was the report/ entire recording forwarded appropriately according to Local policy (eg stored electronically, submitted to referring clinician, paper copy to notes in not paperweight.?		
	Has the patient's information been treated in a confidential and secure way?		
	Was the report completed with the minimum sections required for local policy?		