Rancho Los Amigos National Rehabilitation Center
CARDIOLOGY SERVICE POLICY AND PROCEDURE

PURPOSE:

To standardize the testing procedure and interpretations and to ensure that the tests are carried out in a safe and effective manner.

POLICY:

I. Indications for testing

  A. To assess the risk before noncardiac surgery in patients with known CAD, diabetes mellitus, peripheral or cerebrovascular disease.
  B. To evaluate the patient's baseline (pre-treatment) physical work capacity.
  C. To assess the degree of aerobic capacity based on a comparison of a patient's performance with appropriate controls (matched for age, sex and activity level)
  D. To identify the cardiopulmonary mechanisms responsible for impaired gas transport capacity.
  E. To assist in the risk stratification of coronary artery disease (CAD) in patients with symptoms that are atypical for myocardial ischemia
  F. To assess functional capacity and to aid in assessing the prognosis of patients with known CAD
  G. To evaluate the prognosis and functional capacity of patients with CAD subacutely after an uncomplicated myocardial infarction (before discharge or early after discharge)
  H. To evaluate patients subacutely after coronary artery revascularization by surgery or coronary angioplasty
  I. To evaluate patients with symptoms consistent with recurrent, exercise-induced cardiac arrhythmias
  J. To evaluate functional capacity of selected patients with congenital heart disease
  K. To evaluate patients with rate-responsive pacemakers
  L. To evaluate the cardiopulmonary effects of various medications.

II. Contraindications to exercise testing

  A. High-risk unstable angina. However, patients with chest pain syndromes at presentation, who are otherwise stable and pain free, can undergo exercise stress testing.
  B. Decompensated or inadequately controlled congestive heart failure.
  C. Uncontrolled hypertension (blood pressure >200/100mm Hg).
  D. Uncontrolled cardiac arrhythmias (causing symptoms or hemodynamic compromise).
  E. Severe symptomatic aortic stenosis.
  F. Acute pulmonary or systemic embolism.

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Signature(s) on File.

G. Acute myocarditis or pericarditis.
H. Acute aortic dissection.
I. Severe pulmonary hypertension.
J. Acute myocardial infarction (less than 5 days for uncomplicated post MI for a low level test and less than 4 weeks for a maximal test).
K. Acutely ill for any reason (fever, vomiting, etc).
L. Incomplete screening data base (12-lead ECG, MD's history and physical and reason for referral).
M. Active endocarditis
N. Any musculoskeletal or neurological impairment which would prevent a complete evaluation of the patients cardiovascular response to exercise.

III. Relative contraindications for exercise stress testing

A. Known left main coronary artery stenosis
B. Moderate aortic stenosis
C. Hypertrophic obstructive cardiomyopathy or other forms of outflow tract obstruction
D. Significant tachyarrhythmias (greater than 120 beats/min) or bradyarrhythmias
E. High-degree atrioventricular block
F. Electrolyte abnormalities
G. Mental or physical impairment leading to inability to exercise adequately
H. Resting hypertension systolic BP greater than 180 mm Hg or diastolic greater than 100 mm Hg.
I. Resting hypotension (systolic BP less than 80 mm Hg).
J. Marked cardiomegaly
K. Uncontrolled metabolic disease such as diabetes thyrotoxicosis, etc.
L. Pre-exercise symptoms such as dizziness, nausea or pain.

IV. Preparatory procedures common to all testing protocols.

As indicated in the American College of Physicians/ACC/AHA task force statement on clinical competence in exercise testing, exercise testing in selected patients can be performed safely by properly trained nurses, exercise physiologists, physician assistants, physical therapists, or medical technicians working directly under the supervision of a physician, who should be in the immediate vicinity and available for emergencies.

A. Ensure all resuscitation equipment is available and functioning properly.
B. Check all equipment for calibration and mechanical function.
C. Review with physician all pertinent medical records with particular attention to possible contraindications and reasons for testing and interview the patient for recent history.
D. Verify that the electrodes are placed properly following proper skin preparation. (See Appendix A). Electrode and lead wire stability are then checked by breathing and tapping maneuvers.
E. Explain the purpose of the test to the patient.
F. Instruct the patient to report any chest discomfort or other bothersome symptoms during or after the test. The patient's severity of angina will be classified according to the following chest pain universal scale:
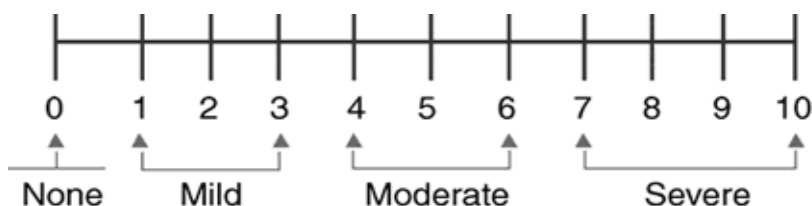
G. Demonstrate the proper use of the exercise equipment (treadmill or ergometer)

V. Standard evaluative procedures for pre-testing, testing and post-testing (common to all procedures including low level testing

A. Preliminary information (name, RLANRC#, age, diagnosis, ordering physician, reason for the test, medications, etc) are entered into the GE Case Exercise computer)
B. Pre-exercise procedures
   1. An ECG, heart sounds, blood pressure and symptoms are evaluated and recorded in the supine position for 2 consecutive minutes.
   2. **Special considerations**
      Non-ambulatory patients will not undergo supine positioning pre or post exercise. An ECG and blood pressure are recorded after 1 minute of sitting.

      Special considerations
      When expired air measurements are performed, the patients will remain seated at rest for 2-3 minutes to obtain baseline gas analysis and another 2-3 minutes of standing if the patient is exercising on the treadmill

   3. 10 second breath holding and 30 seconds of hyperventilation are performed by the patient sitting with continuous ECG recording for both maneuvers.
   4. An ECG and blood pressure are recorded after 1 minute of standing.

      Special considerations
      Standing measurements are not included in the ergometry protocols.

C. Exercise procedures

   1. An ECG and blood pressure are recorded after each minute of exercise.
   2. The time of onset of angina, as are changes in severity of discomfort, significant arrhythmia and significant ST segment changes are recorded on a minute by minute basis.

D. Post exercise procedures.

   1. Immediately post exercise the treadmill speed and grade or the ergometer workload is reduced over a 30-60 second period of time.
   2. An ECG and blood pressure are recorded immediately post exercise and the each minute during recovery.
   3. Post exercise recovery continues until the heart rate is within 15-25 beats/min of the resting rate and the systolic blood pressure is within 20 mm Hg at rest.
   4. Recording of angina, significant arrhythmias and ST segment changes are recorded in the on a minute by minute basis post exercise until the pain subsides, arrhythmias have stabilized and/or the ST segment depression or elevation has returned to less than 1 mm above or below the baseline measurements.
   5. When expired air is collected, gas sampling will continue for 3-4 minutes post exercise depending on patient comfort, symptoms, etc.

VI. Testing protocols

A. Choosing an exercise protocol utilizing either the treadmill or an ergometer will be dependent on the reason for the test, the patient's functional abilities and the clinicians best judgment regarding which protocol will provide the best assessment. The goal is generally to achieve an appropriate target heart rate for the patient (see the Appendix B for the various treadmill and ergometer protocols).

VII. Criteria for terminating a maximal exercise test (AML/AHA Practice Guidelines) 2002

A. **Absolute indications for termination of exercise testing**
1. Patient achieves symptom limited end point (subject desires to stop due to general fatigue, pain, dyspnea, etc.
2. Drop in systolic blood pressure of greater than 10 mm Hg from baseline blood pressure, despite an increase in workload, when accompanied by other evidence of Ischemia.
3. Moderate-to-severe angina (Level 6/10 or higher in the appropriate clinical setting)
4. Increasing nervous system symptoms (e.g., ataxia, dizziness, near-syncope).
5. Signs of poor perfusion (cyanosis or pallor).
6. Technical difficulties in monitoring ECG tracings or blood pressure
7. Sustained ventricular tachycardia
8. ST elevation (greater than 1 mm) in leads without diagnostic Q waves (other than V1 or aVR)
9. Equipment failure or poor ECG recording preventing accurate ECG interpretation.

B. **Relative indications for termination of exercise testing**
1. ST or QRS changes such as excessive ST depression (>2 mm of horizontal or downsloping ST-segment depression) or marked axis shift
2. Arrhythmias other than sustained ventricular tachycardia, including multifocal PVCs, triplets of PVCs, supraventricular tachycardia, heart block, or bradyarrhythmias
3. Fatigue, shortness of breath, wheezing, leg cramps, or claudication
4. Development of bundle-branch block or IVCD that cannot be distinguished from ventricular tachycardia
5. Increasing chest pain
6. Hypertensive response (SBP of 220 mm Hg or more and/or DBP of 115 mm Hg or more)

VIII. Criteria for terminating a low level exercise test
A. Achievement of a maximum heart rate of 120.
B. Systolic hypotension - 20 mm Hg or more drop in the blood pressure.
C. Hypertension (systolic blood pressure greater n 190 mm Hg or diastolic greater than 100 mm Hg).
D. Onset of level 1 angina.
E. Net change of 2 or more mm of horizontal or downsloping ST segment depression.
F. Frequent multimodal premature ventricular complexes (greater than 12/min), coupled PVCs, ventricular tachycardia (3 or more consecutive PVCs).
G. Patient request.
H. Equipment failure or poor ECG recording preventing accurate ECG interpretation
I. Any symptoms deemed by the tester to warrant termination, e.g. ataxia, dizziness, near-syncope, shortness of breath, wheezing, etc.

IX. Summary and Interpretation of test results

A. The test summary from the Philips StressVu or the GE Case Exercise system (which includes recorded exercise stages/workloads and minutes completed, heart rates, blood pressures, percent of predicted maximum heart rate, PVC counts for each stage, etc.), recorded 12 ECGs and rhythm strips and median complexes may all be printed out at the end of the test for filling in the patient and provided to the MD for review. The ECG technician will upload the ECG this data to the PACs system, where the MD will electronically sign the test

B. In the summary comments on the execise system summary, the following should be included:
1. Reason for termination of the test.
2. Level of effort (maximal or sub maximal, include Rating of Perceived Exertion, Appendix C)
3. Abnormal heart sounds if they are present, questionable or absent, (S4, S3, murmurs).

4. A description of angina/chest discomfort including the time onset of each level, time of resolution, if nitroglycerin was needed, and an assessment as to whether the discomfort was either definite, probable doubtful or definitely not.
5. A description of the arrhythmias, including the type, frequency, and time of occurrence. Also include the onset and description of any conduction disturbances.
6. Describe the type blood pressure response and time of occurrence:
    a. Flat response: failure to increase systolic blood pressure by at least 10 mm Hg during exercise.
    b. Drop in systolic blood pressure of greater than 10 mm Hg from baseline blood pressure or 20 mm Hg drop from the maximum systolic blood pressure attained during exercise, despite an increase in workload
    c. Adaptive: Steady progressive increase in the systolic blood pressure with increasing workloads, not to exceed 250 mm Hg.
    d. Systolic hypertension: Attaining near maximum systolic blood pressure in the early stages of exercise or exceeding the maximum allowed systolic BP of 250 mm Hg.
    e. Diastolic hypertension, 90 mm Hg or greater.
7. Summary of the ST-T changes, ST segment shifts should be described as to the type of change (see Appendix D) and the net from the resting level in mm. The leads where change occurred should be reported as well. Confounding factors regarding the interpretation of the ST segment shifts should be noted.
8. Describe the work capacity of the patient relative to individuals of the same sex and age (see Appendix E).

Appendix A: AHA Electrode Placement for Exercise Testing
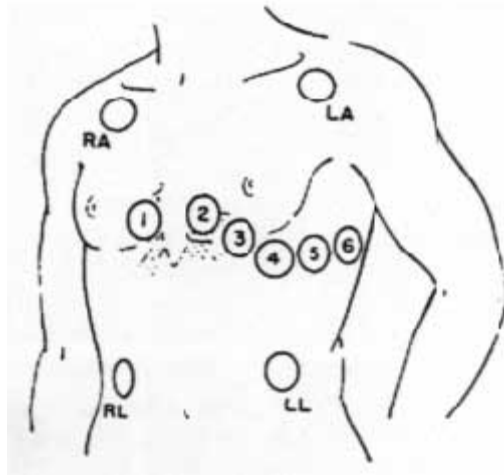
RA and LA electrodes should be placed just below the right and left clavicle.

RL and LL electrodes should be placed on the lower edge of the rib cage, or at the level of the umbilicus at the mid-clavicular line.

V1 Fourth intercostal space at the right border of the sternum

V2 Fourth intercostal space at the left border of the sternum

V3 Midway between locations V2 and V4

V4 At the mid-clavicular line in the fifth intercostal space

V5 At the anterior axillary line on the same horizontal level as V4

V6 At the mid-axillary line on the same horizontal level as V4 and V5

Skin Preparation for electrode attachment
- Dry clip to remove all hair from electrode sites.
- Scrub all electrode sites with alcohol wipes.
- Stretch skin and abrade each site with an abrasive pad.
- Skin should be red, with visible

Appendix B: Testing Protocols

EXERCISE PROTOCOLS USED IN THE RLANRC EXERCISE LAB:

TREADMILL PROTOCOLS

Bruce Protocol

Stage	Min	% grade	MPH	METS
1	3	10	1.7	4.7
2	3	12	2.5	7.0
3	3	14	3.4	10.1
4	3	16	4.2	12.9
5	3	18	5.0	15.0

Modified Bruce Protocol

Stage	Min	% grade	MPH	METS
0	3	0	1.7	2.0
½	3	5	1.7	3.0
1	3	10	1.7	4.7
2	3	12	2.5	7.0
3	3	14	3.4	10.1
4	3	16	4.2	12.9
5	15	18	5.0	15.0

Cornell Protocol

Stage	Min	% grade	MPH	METS
1	2	0	1.7	2.0
2	2	5	1.7	3.0
3	2	10	1.7	4.7
4	2	11	2.1	5.9
5	2	12	2.5	7.0
6	2	13	3.0	8.6
7	2	14	3.4	10.1
8	2	15	3.8	11.5
9	2	16	4.2	12.9

ERGOMETRY PROTOCOLS

All cycle ergometry protocols (Leg, arm or a combination of legs and arms include a 3 minute warm-up at an unloaded workload, followed by a fixed increment increase in the workload each minute. Increments can range between 5-50 Watts and are chosen by the testing personnel based on the age sex, size and disability of a given patient.

Approximate Energy Expenditure in METs During Bicycle Ergometry

Body weight		Exercise rate (kg · m · min⁻¹ and watts)						
kg	lb	300	450	600	750	900	1050	1200
		50	75	100	125	150	175	200
50	110	5.1	6.9	8.6	10.3	12.0	13.7	15.4
60	132	4.3	5.7	7.1	8.6	10.0	11.4	12.9
70	154	3.7	4.9	6.1	7.3	8.6	9.8	11.0
80	176	3.2	4.3	5.4	6.4	7.5	8.6	9.6
90	198	2.9	3.8	4.8	5.7	6.7	7.6	8.6
100	220	2.6	3.4	4.3	5.1	6.0	6.9	7.7

Approximate Energy Expenditure in METs During Arm Ergometry
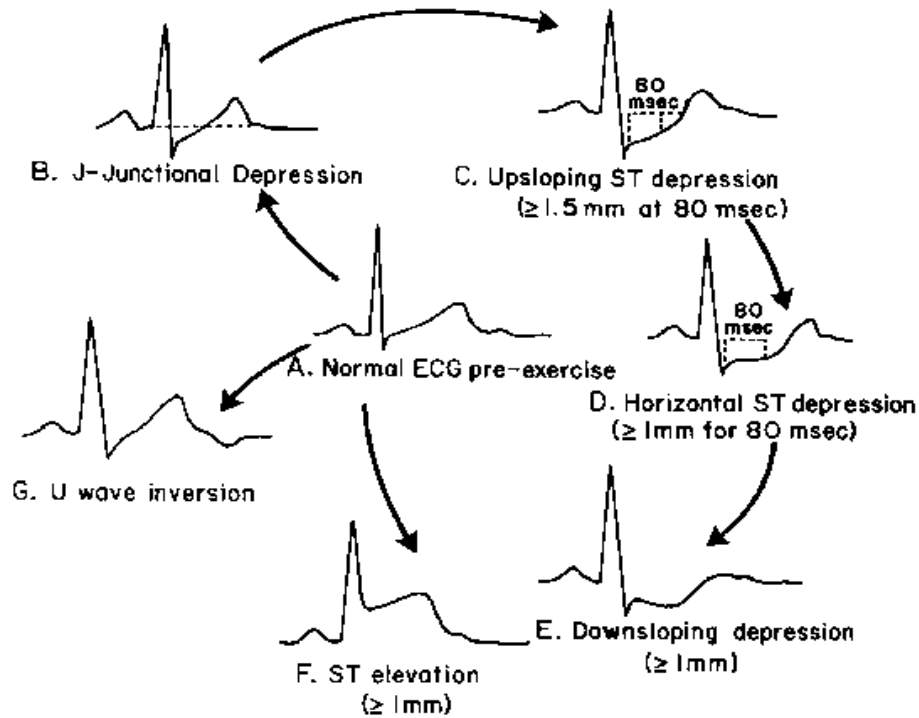
Body Wt kg (lb)	Power Output (W)					
	25	50	75	100	125	150
50 (110)	3.6	6.1	8.7	11.3	13.9	16.4
60 (132)	3.1	5.3	7.4	9.6	11.7	13.9
70 (154)	2.8	4.7	6.5	8.3	10.2	12.0
80 (176)	2.6	4.2	5.8	7.4	9.0	10.6
90 (198)	2.4	3.9	5.3	6.7	8.1	9.6
100 (220)	2.3	3.6	4.9	6.1	7.4	8.7

Appendix C: Rating of Perceived Exertion

Borg	Modified Borg
6	0–Nothing at all
7–Very, very light	0.5–Very, very weak
8	1–Very weak
9–Very light	2–Weak
10	3–Moderate
11–Fairly light	4–Somewhat strong
12	5–Strong
13–Somewhat hard	6
14	7–Very strong
15–Hard	8
16	9
17–Very hard	10–Very, very strong (almost maximum)
18	
19–Very, very hard	–Maximum
20	

The Borg RPE Scale_. From Borg GAV. *Borg's Scales of Perceived Exertion.* Champaign, Ill: Human Kinetics; 1999. Scales

Appendix D: SIGNIFICANT ST SEGMENT CHANGE TYPES SUGGESTIVE OF CAD

B. J-Junctional Depression

C. Upsloping ST depression
(≥1.5mm at 80 msec)

80 msec

A. Normal ECG pre-exercise

D. Horizontal ST depression
(≥ Imm for 80 msec)

80 msec

G. U wave inversion

F. ST elevation
(≥ Imm)

E. Downsloping depression
(≥ Imm)

Confounders of Stress ECG Interpretation:

Left Ventricular Hypertrophy With Repolarization Abnormalities: This ECG abnormality is associated with a decreased specificity of exercise testing, but sensitivity is unaffected.

Digoxin: Produces an abnormal ST-segment response to exercise. This abnormal ST depression occurs in 25% to 40% of healthy subjects studied and is directly related to age.

Left Bundle-Branch Block: Exercise-induced ST depression usually occurs with left bundle-branch block and has no association with ischemia. Even up to 1 cm of ST depression can occur in healthy normal subjects. There is no level of ST-segment depression that confers diagnostic significance in left bundle-branch block.

Right Bundle-Branch Block: Exercise-induced ST depression usually occurs with right bundle-branch block in the anterior chest leads (V1 through V3) and is not associated with ischemia (37). However, in the left chest leads (V5 and V6) or inferior leads (II and aVF), its test characteristics are similar to those of a normal resting ECG. The presence of right bundle-branch block does not appear to reduce the sensitivity, specificity, or predictive value of the stress ECG for the diagnosis of ischemia.

Atrial Repolarization: Atrial repolarization waves are opposite in direction to P waves and may extend into the ST segment and T wave. Exaggerated atrial repolarization waves during exercise can cause downsloping ST depression in the absence of ischemia. Patients with false-positive exercise tests based on this finding have a high peak exercise heart rate, absence of exercise-induced chest pain, and markedly downsloping PR segments in the inferior leads

Appendix E: Assessment of exercise capacity

VO₂Max Values – Men
ml/kg/min

Age	Poor	Fair	Average	Good	Excellent
< 29	≤24.9	25-33.9	34-43.9	44-52.9	≥ 53
30-39	≤ 22.9	25-30.9	31-41.9	42-49.9	≥ 50
40-49	≤ 19.9	20-26.9	27-37.9	39-44.9	≥ 45
50-59	≤ 17.9	18-24.9	25-37.9	38-42.9	≥ 43
60-69	≤ 15.9	16-22.9	23-35.9	36-40.9	≥ 41

McArdle, Katch, & Katch (2001)

Max MET Values - Men

Age	Poor	Fair	Average	Good	Excellent
< 29	≤6.9	7.1-9.7	9.7-12.5	12.6-15.1	≥ 15.1
30-39	≤ 6.5	7.1-8.8	8.9-12.0	12.1-14.3	≥ 14.3
40-49	≤ 5.7	5.7-7.7	7.7-10.8	11.1-12.8	≥ 12.8
50-59	≤ 5.1	5.1-7.1	7.1-10.8	10.9-12.3	≥ 12.3
60-69	≤ 4.5	4.6-6.5	6.6-10.3	10.3-11.7	≥ 11.7

McArdle, Katch, & Katch (2001)

VO₂ Max Values – Women
ml/kg/min

Age	Poor	Fair	Average	Good	Excellent
< 29	≤ 23.9	24-30.9	31-38.9	39-48.9	≥ 49
30-39	≤ 19.9	20-27.9	28-36.9	37-44.9	≥ 45
40-49	≤ 16.9	17-24.9	25-36.9	27-41.9	≥ 42
50-59	≤ 14.9	15-21.9	22-33.9	34-39.9	≥ 40
60-69	≤ 12.9	13-20.9	21-32.9	33-36.9	≥ 37

McArdle, Katch, & Katch (2001)

Max MET Values - Women

Age	Poor	Fair	Average	Good	Excellent
< 29	≤ 6.8	6.9-8.8	8.9-11.1	11.1-14.0	≥ 14.0
30-39	≤ 5.7	5.7-8.0	8-10.5	10.6-12.8	≥ 12.8
40-49	≤ 4.8	4.9-7.1	7.1-10.5	7.7-12.0	≥ 12.0
50-59	≤ 4.3	4.3-6.3	6.3-9.7	9.7-11.4	≥ 11.4
60-69	≤ 3.7	3.7-6.0	6.0-9.4	9.4-10.5	≥ 10.5

McArdle, Katch, & Katch (2001)

REFRENCES:

ACC/AHA Practice Guidelines: Gibbons et al. 2002

Schlant RC, Friesinger GC II, Leonard JJ. Clinical competence in exercise testing: a statement for physicians from the ACP/ACC/AHA Task Force on Clinical Privileges in Cardiology. J Am Coll Cardiol 1990;16:1061-5.

Principles of Exercise Testing and Interpretation: Including Pathophysiology and Clinical Applications; Waserman Karlman, Hansen, James. (2004)