Patient Testing – Cardiopulmonary Exercise Test (CPET or MVO2)

Audience All personnel in the Pulmonary Function Clinics.

Purpose Tests designed to assess ventilation, gas exchange, and cardiovascular function during exercise can provide information not obtainable with the patient at rest. Cardiopulmonary exercise testing allows for evaluation of the heart and lungs under conditions of increased metabolic demand. Limitations to work are not entirely predictable from any single resting measurement of pulmonary function. To define work limitations, a cardiopulmonary exercise test is necessary. Cardiopulmonary variables are assessed in relation to the workload (i.e., the level of exercise). The patterns of change in any particular variable (e.g., heart rate) are then compared with the expected normal response.

Indications The primary indications for performing exercise tests are dyspnea on exertion, pain (especially angina), and fatigue. Other indications include exercise-induced bronchospasm and arterial desaturation.

Exercise testing can also detect the following:

- The presence and nature of ventilatory limitations to work.
- The presence and nature of cardiovascular limitations to work.
- The extent of conditioning or deconditioning.
- The maximum tolerable workload and safe levels of daily exercise.
- The extent of disability for rehabilitation purposes.
- Oxygen desaturation and appropriate levels of supplemental oxygen therapy.

Contraindications The following are contraindications for performing cycle exercise tests:

Absolute	Relative
Acute myocardial infarction (3–5 days)	Left main coronary stenosis or its equivalent
Unstable angina	Moderate stenotic valvular heart disease
Uncontrolled arrhythmias causing symptoms or hemodynamic compromise	Severe untreated arterial hypertension at rest (200 mm Hg systolic, 120 mm Hg diastolic)
Syncope	Tachyarrhythmias or bradyarrhythmias
Active endocarditis	High-degree atrioventricular block
Acute myocarditis or pericarditis	Hypertrophic cardiomyopathy
Symptomatic severe aortic stenosis	Significant pulmonary hypertension
Uncontrolled heart failure	Advanced or complicated pregnancy
Acute pulmonary embolus or pulmonary infarction	Electrolyte abnormalities
Thrombosis of lower extremities	Orthopedic impairment that compromises exercise performance
Suspected dissecting aneurysm	
Uncontrolled asthma	
Pulmonary edema	

Respiratory failure
Acute non-cardiopulmonary disorder that may affect exercise performance or be aggravated by exercise (i.e. infection, renal failure, thyrotoxicosis)
Mental impairment leading to inability to cooperate
Right Heart Catherization (femoral access) within 24 hours
Right Heart Catherization (jugular access) within 4 hours
Systolic pressure > 200 and/or Diastolic pressure > 120
Room air desaturation at rest </= 85 %(per ATS guidelines)

Therapist performing test will review patient chart for any contraindications. In-patients needing testing will also need to be reviewed. Therapist may contact Pulmonary Fellow or Medical Director for any concerns of acute issues.

Protocol

Cardiopulmonary exercise tests can be divided into two general categories: progressive multistage tests and steady-state tests.

Progressive multistage tests examine the effects of increasing workloads on various cardiopulmonary variables, without necessarily allowing a steady-state to be achieved. Often used to determine the workload at which the subject reaches a maximum oxygen uptake (VO_{2max}). Can also determine maximal ventilation, maximal heart rate, or a symptom limitation (i.e., chest pain) to exercise.
The Pulmonary Function Clinic uses the following progressive multistage exercise protocol:

Cycle Ergometer	Workload	Interval (min)	Comment
"RAMP"	10W/min to exhaustion	Continuous	Requires electronically braked ergometer: different work rates may be used to alter ramp slope.

Steady-state tests are designed to assess cardiopulmonary function under conditions of constant metabolic demand. Conditions are usually defined in terms of HR, oxygen consumption (VO_2) or ventilation (V_E). If the HR remains unchanged for 1 minute at a given workload, a steady-state may be assumed. Steady-state tests are useful for assessing responses to a known workload. They may be used to evaluate the effectiveness of various therapies or pharmacologic agents on exercise ability.

Variables Measured

A number of cardiopulmonary exercise variables may be used depending on the clinical questions to be answered.

Variables Measured	Uses
ECG, BP (pre/post only), SpO_2	Limited to suspected or known coronary artery disease; pulse oximetry may be misleading if used without blood gases.

All of the above plus ventilation, VO_2, VCO_2, and derived measurements	Noninvasive estimate of ventilatory threshold (AT), quantify workload, discriminate between cardiovascular and pulmonary limitation to work.
All of the above plus arterial gases	Detailed assessment of gas exchange abnormalities; calculation of V_D/V_T; titration of O_2 in exercise desaturation; measurement of pH and lactate possible.

Mandatory Guidelines

The following are mandatory guidelines that must be followed when performing a gas exchange study:

- A pulmonary physician, faculty or fellow, must be present for all CPET Cardiopulmonary Exercise testing done on cardiac transplant candidates.
- For invasive testing, a radial arterial catheter will be placed for serial blood gas determination during the test.
- All patients will have a 12 lead ECG performed prior to testing and will not be tested until a pulmonary physician has seen and approved the results of the 12 lead ECG.
- A code cart will be close proximity to the PF clinic when Cardiopulmonary Exercise testing takes place on cardiac transplant candidates.
- Patients will have pretest vitals done by therapist prior to ECG, and will be monitored throughout the test by pulse oximetry and ECG monitors.
- All heart patients require an IV access during testing. IV may be placed on any CPET patient for safety precautions.
- Termination of testing will occur when one of the following criteria has been met:
  - The patient voluntarily requests termination.
  - For CPET tests on cardiac transplant candidates, when heart rate reaches 80-85% of predicted maximal rate.
  - When any life threatening or injury threatening cardiac rhythm abnormalities (as determined by supervising physician) occurs.
  - Failure of testing equipment.
  - When the subject is not able to maintain current workload.
  - Any other reason deemed as a threat to the patient's safety.

Start-Up

The following steps are required for the initial start-up of the CPX Ultima:

- Ensure the power cords are connected to the Ulitma system and PF Module. These in-turn need to be plugged into a power conditioner which is plugged into a wall outlet before turning power on. Ensure all

communication cables are securely attached between the Ultima and PF Module along with tubing connections.

- Push the Main Power switch on, then the computer, then login once Windows has loaded.
- Open then Breeze, and that should open Mortara and Breeze, one program should be on each monitor.
- Press and hold the standby light on the front of the Ultima. The light will be solid amber when warming up and solid green when ready for calibration and testing. If blinking, then press and hold for several seconds until light is solid. The system will turn from amber to green when the system is completely warmed up (~30 minutes). Do Not calibrate or test while system is in warmup.
- Once Breeze loads, make sure gas time clock is counting down for warmup.
- Open all gas tanks (turn gas cylinder top pressure valve to the left). Calibration and Reference gas for the Ultima should be set to deliver 15 psi. Ultima WD tanks are preset to 15 psi and have only one adjustment knob to open and close
- Calibrate the pneumotach (see pneumotach calibration procedure).
- Calibrate the gas analyzers (O2 and CO2) before each test using the auto calibration option.

Procedure The following is the correct procedure for performing a Gas Exchange test on a patient:

- Notify rotating Pulmonary Fellow a minimum of 24 hours prior to patient testing via email including patient name and MRN.
- Have all supplies and consent forms ready and before patient is brought to testing area.
- Perform AutoGas Cal before testing patient.
- Patient must have correct height and weight for the study and can sit in sturdy chair. Explain procedure to patient, ensuring their understanding.
- At this time, an FVC should be performed. At least three efforts should be obtained, with the best two FVC efforts within 150 ml of each other and the two best FEV1's within 150 ml of each other. The efforts should also meet the ATS acceptability criteria.
- Place the SpO2 monitor on patient's finger and turn on pulse oximeter.
- Obtain a blood pressure and document in the comments.
- Properly place the 12 leads of the ECG on the patient. Right lead placed on rear hip or on sternum. Left lead placed on hip or on rib under Lead 5 or 6. At this time, run a baseline ECG on the patient. Arm leads should be placed on clavicles. Make sure that patient is very still. You will have to turn on the remote ECG module. Print one ECG report for fellow to initial. Contact the assigned Pulmonary fellow during this time, patient is ready for testing.

- IV can be done before or after FVC and ECG.
- Pulmonary fellow is to go over consent form with patient in full. Once consent is signed, fellow needs to review and initial ECG report.
- Carefully have patient move to the bike. Adjust the seat accordingly.
- Be sure to instruct the patient hold bike handles lightly with SpO2 finger as that could prevent blood-flow to their fingers.
- Instruct patient to signal when they need to stop the test.
- Before beginning the test, click Zero Flow to zero the pneumotach. There must be no flow through the pneumotach during this procedure.
- Have the patient place the mouthpiece and pneumotach setup in their mouth. Take a folder piece of gauze and place it between their chin and the mouthpiece. Place nose clips on the patient.
- Instruct the patient to begin breathing normally for their two-minute pre-exercise phase. There should be no pedaling during this time. Press the appropriate start buttons on both the Breeze/ Mortara software.
- Once their two minutes has passed, instruct the patient to start pedaling at a steady pace making sure to keep the bike speed at the RPM of 60. Prompt program to go to exercise phase.
- During testing therapist and fellow will monitor patient and data for any physical signs of distress or abnormalities and that software is recording data accurately.
- Patient will pedal until they feel they can no longer continue exercising. At that time, they will stop pedaling and their two-minute cool down phase will begin. They are to leave the mouthpiece and nose clips on during this time. Prompt program to go to the recovery phase.
- Once their two minutes of cool down has finished, they can remove the mouthpiece and nose clips. Prompt program to end testing and save/exit ECG program.
- Carefully assist patient to sturdy chair. ECG leads and SpO2 monitor can be removed. Physician may leave once patient is in chair with no adverse events or symptoms.
- If an IV was placed, Therapist will remove and hold pressure until bleeding subsides. A band-aid will be placed over IV site.
- Ask the patient their reason for terminating the test and make note of their comments on the final report. Save all changes.
- Obtain patients vitals (HR, SpO2) including blood pressure. If all have returned to baseline and patient is not symptomatic, patient can be released. Document in comments.

Reporting Therapist can print and email GX report to the current reading Pulmonary Fellow. The signed consent form and initialed ECG will be scanned and emailed HIM team to upload to patients' MRN in the Pulmonary Function Report section under Results Review.

This form documents the approval and history of the policies and procedures for the Pulmonary Function Laboratory. The Medical Director signs all policies verifying initial approval. Annually thereafter, the Director and/or designee may approve reviews and revisions.

Date	Approved by:	Signature
11/07	**V. Cardenas, MD** **Medical Director Pulmonary Laboratory**	
6/09	**V. Cardenas, MD** **No changes to the policy**	
7/08	**V. Cardenas, MD** **No changes to the policy**	
2/12	**A. Duarte, MD** **Medical Director Pulmonary Laboratory** **No changes to the policy**	
5/14	**A. Duarte, MD** **Medical Director Pulmonary Laboratory** **Changes to policy**	
8/16	**A. Duarte, MD** **Medical Director Pulmonary Laboratory** **Changes to policy**	
11/17	**A. Duarte, MD** **Medical Director Pulmonary Laboratory** **Changes to policy**	
8/19	**A. Duarte, MD** **Medical Director Pulmonary Laboratory** **Changes to policy**	
9/21	**A. Duarte, MD** **Medical Director Pulmonary Laboratory** **Changes to policy**	
8/23	**A. Duarte, MD** **Medical Director Pulmonary Laboratory** **No changes to policy**	