Patient Testing – Gas Exchange on CPX

**Audience**
All personnel in the Pulmonary Function Clinic.

**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.

**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$_{2\text{max}}$). 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:

<table>
<thead>
<tr>
<th>Cycle Ergometer</th>
<th>Workload (min)</th>
<th>Interval</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>“RAMP”</td>
<td>10W/min to exhaustion</td>
<td>Continuous</td>
<td>Requires electronically braked ergometer; different work rates may be used to alter ramp slope.</td>
</tr>
</tbody>
</table>
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 ($\text{VO}_2$) or ventilation ($\text{VE}$). 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.

<table>
<thead>
<tr>
<th>Variables Measured</th>
<th>Uses</th>
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<tbody>
<tr>
<td>ECG, B/P, SpO$_2$</td>
<td>Limited to suspected or known coronary artery disease; pulse oximetry may be misleading if used without blood gases.</td>
</tr>
<tr>
<td>All of the above plus ventilation, VO$_2$, VCO$_2$, and derived measurements</td>
<td>Noninvasive estimate of ventilatory threshold (AT), quantify workload, discriminate between cardiovascular and pulmonary limitation to work.</td>
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<tr>
<td>All of the above plus arterial gases</td>
<td>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.</td>
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**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 MvO2 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 in the PF clinic when MvO2 Cardiopulmonary Exercise testing takes place on cardiac transplant candidates.
- Subjects will be monitored throughout the test by pulse oximetry and ECG monitors.
- All heart patients require an IV access during testing.
- Termination of testing will occur when one of the following criteria has been met:
  - The patient voluntarily requests termination.
For MvO2 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 Ultima 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. The power light on the front of the Ultima system will turn from amber to green when the system is completely warmed up (~15 minutes).
- Open then Breeze, find patient, click GX tab. Breeze should open Mortara and Breeze, one program should be on each monitor.
- Turn the Gas Exchange (GX) vacuum pump.
- Wait for the system to warm-up and stabilize: 15 minutes for the system, 2 minutes for the vacuum pump.
- 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.
- Once calibration of the pneumotach and gas analyzers have been successfully completed, print the calibration report and file in appropriate binder.

### Procedure

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

- Have all supplies and consent forms ready and before patient is brought to testing area.
- 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.
• Properly place the 12 leads of the ECG on the patient. The two leg leads should be placed on either side of the lower back. At this time, run a baseline ECG on the patient. Make sure that patient is very still. You will have to turn on the remote ECG monitor. Print two ECG reports. Page the assigned Pulmonary fellow, patient is ready for testing.

• 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 not to grip the bike handles too tight, as that could prevent blood-flow to their fingers.

• 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 a certain value. Prompt program to go to exercise phase.

• 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. Physician may leave once patient is in chair with no adverse events or symptoms.

• Carefully assist patient to sturdy chair. ECG leads and SpO2 monitor can be removed.

• Ask the patient their reason for terminating the test and make note of their comments on the final report. The GX report should be printed immediately. Make sure that the AT is appropriately placed for the test and save all changes.

• Patient can be released.

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.

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<thead>
<tr>
<th>Date</th>
<th>Approved by:</th>
<th>Signature</th>
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<tbody>
<tr>
<td>11/07</td>
<td>V. Cardenas, MD</td>
<td>Medical Director Pulmonary Laboratory</td>
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<td>Date</td>
<td>Name</td>
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<td>6/09</td>
<td>V. Cardenas, MD</td>
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<td>7/08</td>
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<td>2/12</td>
<td>A. Duarte, MD</td>
<td>Medical Director Pulmonary Laboratory</td>
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<td>5/14</td>
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