Providence HEALTH CARE	**RESPIRATORY SERVICES**	DATE CREATED: August 2010 DATE REVIEWED/REVISED: **October 2015**
PROCEDURE	TITLE: Pulmonary Diagnostics: Cardiopulmonary Exercise Test (CPX) NUMBER: B-00-12-12125	RELATED DOCUMENTS:

SITE APPLICABILITY:

ST. PAUL'S HOSPITAL

GENERAL INFORMATION:

Cardiopulmonary exercise testing (CPX) is performed in the Cardiology ECG Lab at St. Paul's Hospital under close supervision of a Cardiologist. A Respiratory Therapist conducts testing while an ECG technician is present to assist in cardiac and hemodynamic monitoring.

Many clinics and physicians refer to the CPX lab, including the Pacific Lung Health Centre and many of the Heart Centre clinics (i.e. Healthy Heart, Pre-Heart Transplant, Pacific Adult Congenital Heart, Heart Function).

CPX testing is performed for the following reasons:

i. To obtain an objective assessments of a subject's Functional Capacity
ii. To determine a subject's Fitness Level
iii. To determine a subject's Level of Impairment
iv. To determine the Cause of Impairment (I.e. pulmonary, cardiac, circulatory, obesity, deconditioning, or malingering)
v. To determine appropriate Methods of Intervention

CPX tests generally take 45 minutes to complete.

EQUIPMENT:

- Sensor Medics Vmax Metabolic Cart
- Cycle Ergometer or Treadmill
- Pulse Oximeter
- 12 lead ECG machine
- Blood pressure monitor
- Crash Cart
- Silicone Mouthpiece
- Microgard Filter
- Nose Clips
- Mass Flow Sensor
- Head Gear (if necessary)

INDICATIONS:

- Evaluation of exercise tolerance
- Evaluation of undiagnosed exercise intolerance
- Evaluation of patients with respiratory diseases/symptoms
- Preoperative evaluation
- Exercise evaluation and prescription for pulmonary rehabilitation
- Evaluation of impairment/disability
- Evaluation of lung, heart, and heart-lung transplantation

CONTRAINDICATIONS:

- Acute MI
- Unstable Angina
- Uncontrolled arrhythmias causing symptoms
- Syncope
- Active endocarditis
- Acute myocarditis
- Symptomatic severe aortic stenosis
- Uncontrolled Heart Failure
- Acute PE
- Thrombosis of lower extremities
- Suspected dissecting aneurysm
- Uncontrolled Asthma
- Pulmonary Edema
- Room air desaturation at rest less than 85%
- Respiratory Failure
- Acute non-pulmonary disorder that may affect exercise performance or be aggravated by exercise
- Mental impairment leading to inability to cooperate

PROCEDURE:

Start Up:

a. Dock Laptop computer onto Vmax metabolic cart.
b. Power on metabolic cart, computer and cycle ergometer.
c. Open calibration tanks.
d. Attach a clean mass flow sensor to the grey cable and place the sensor in the grey plastic holder.
e. Attach the gas sample cable and direction sensing cable to the mass flow sensor in their respective ports.

NOTE: All Calibrations/Verifications are performed a minimum of once daily.

Mass Flow Sensor Calibration:

a. Select **Flow Sensor Calibration** from the Program Manager Main Menu screen to access the Flow Volume Calibration screen.
b. Adjust the barometric pressure: Choose **Setup** from the top menu, change the BP to the daily reading, and choose **F3** to save.
c. Attach the calibration syringe to the mass flow sensor. Excessive movement of the mass flow sensor or the sensor cable during calibration may affect the accuracy and success of the procedure.
d. Select **F1** to display the Mass Flow Sensor Zero box.
e. Stroke the syringe twice and then press the space bar.
f. A 15 second timer will count down to zero before continuing on to allow for stabilization of the mass flow sensor.
g. Another timer will automatically begin to count down to allow for zero gas flow to occur.
h. Calibration Strokes:
   - Once the Zero screen disappears, move the piston in and out to simulate inspiration and expiration. There should be one stroke for each of 8 horizontal fields of differing flow rates.

- A minimum of 50% of each stroke must remain in their respective yellow fields.
- Pause after each stroke allowing the flow to return to zero before continuing.
- The thin vertical yellow bar on the right side indicates a successful stroke when it turns from yellow to green. All fields must turn green for the verification strokes to begin.

i. Verification Strokes:
   - Perform 10 inspiratory and expiratory strokes at varying flow rates (the first 2 strokes are discarded). At least one set of inspiratory and expiratory strokes should be less than 0.5 L/s and another set of strokes should be greater than 3.0 L/s.
   - Target percentage must be between 97 – 103% and the correction factor between 0.9-1.1. Check each stroke to ensure that there are no unusually high or low readings (each stroke should be between 2.9 – 3.1L).
   - If calibration has passed, press F3 to save and exit.

Gas Analyzer Calibration:

a. Assure that the calibration gas tanks are open.
b. Connect the breath by breath (BXB) line to the calibration port on the front of the Vmax analyzer module.
c. Press F1 to start calibration.
d. If calibration does not pass and an "O_2 Outside Accuracy Range" message appears, repeat calibration (F1). Several attempts may be required.
e. If other warnings are displayed, check the troubleshooting guide attached to this procedure.

*** The B x B line (permeable Nafion tubing) should be changed regularly and hung to dry out as needed. These should be dated and replaced every 3 months as they can affect response time and transit time.

f. A green "Calibration Complete" message will appear in the lower right corner of the screen when successful. Verify that the results are acceptable (+ / - 0.05%).
g. Press F3 to save.
h. Reconnect the B x B sample line to mass flow sensor.

Ergometer Calibration:

a. From the Main Menu > Exercise/Metabolic Test > F10
b. From the Metabolic Protocol Setup screen, double click on "7 – Work" from the "Analog In" list in the lower right-hand corner.
c. From the Analog Channel Setup screen, highlight "7 – Work" from the Analog Channel menu.
d. Press F1 to enter Ergometer Calibration.
e. Calibration Level 1 – The work rate field should default to 50. Have an assistant (not the patient) pedal the bicycle at 60-80 rpm. Note the wattage on the bike. Enter this reading in the "Ergometer Reading" field and press "Accept". Cal will automatically enter Level 2.
f. Calibration Level 2 – Continue to pedal bike at 60-80 rpm. Work rate should default to 100. Note the wattage reading on the bike and enter this reading in the "Ergometer Reading" field. Cal will automatically enter verification.
g. Ergometer Verification – Work rate field should default to 50. Work value should gradually decrease to match work rate field (50). Press F3 to save. Press F3 again to exit Analog Channel Setup. Press F3 again in Metabolic Protocol Set-up screen to save changes and exit.

Patient Information:

Previous Patients

- Select "Find Patient" from the Vmax main menu.
- Enter patient's last name or the first few letters of it and press F1. A list of patients with that last name will appear.
- Choose the desired patient and press F2 to obtain the patient's previous demographics only.
- Enter the patient's current height and weight and any other information that may have changed.
- Press F3 to save and exit.

New Patients

- Choose “New Study’ from the Main Menu.
- Enter pt.’s information using the PHN as the “ID Number”.
- Press F3 to save and exit.

Spirometry:

a. Select “Pulmonary Function” from the Vmax Main Menu, followed by “Flow Volume Loop”.
b. Explain the spirometry procedure to patient (refer to FVL procedure RTD7300) and complete spirometry as per ATS criteria.
c. Press F1 to start each maneuver.
d. To ensure the correct trial is recorded in the final report, delete all but the best trial before exiting. Choose F2 and select trials to be deleted then press “Esc” to exit.
e. Exit from spirometry by choosing “Exit” from the top menu and select “Reports” from the drop down menu. Data will be saved automatically on exit.
f. From the Reports screen, select “Spirometry Report” and print 2 copies.

Patient Preparation:

a. ECG technician:
   i. May measure patient’s height and weight.
   ii. Applies 12-lead ECG electrodes.
   iii. Applies automatic BP cuff.
   iv. Once HR and rhythm are stable, will toggle the Marquette into “Pre-Test” mode.
   v. Obtains a resting BP and prints out a baseline 12-lead ECG.
b. Adjust cycle ergometer seat/handlebar height for patient. This may be re-adjusted to better suit the patient once on the bicycle.
c. Place oximeter probe on finger. Turn on oximeter.
d. Explain the test procedure to the patient and establish proper had signals. Emphasize the importance of maximal patient effort and remind patient to pedal between 55-80rpm.
e. To assist the RT in anticipating the end of testing, remind the patient to signal approximately 1 minute before having to stop.
f. Fit the patient with headgear or adjust the height of the pull-down mass flow sensor clip.

Selecting Vmax Bike Protocol:

a. Select “Exercise/Metabolic Test” from main menu.
b. “Metabolic Study” screen should default to “St. Paul’s - CPX”.
c. If desired, select F2 to bring up a set of reference values for the current patient.
d. From the “Metabolic Study” screen select F10 to set up testing parameters.
e. From the “Metabolic Protocol Setup” screen, select the bike protocol. Use your own clinical judgment in choosing Work Rate (ramp), keeping in mind that the Exercise Phase should last between 8 – 12 minutes. Typical Work Rates range from 5 – 25 watt/minute ramps.
f. Default Values on Metabolic Protocol Setup screen:

Left Graph : V_E vs. VO_2	ECG : CASE (COM1)
Text : EZ-View I	Deadspace : 0.050L
Signal Out : Analog Group 3	Analog In : 1-Work
Right Graph : HR vs. VO_2	

g. Select F3 to save and exit.

Starting the Test:

a. Record subjective baseline BORG measurements of dyspnea and leg fatigue and continue monitoring throughout testing.
b. Place the mouthpiece in the patient’s mouth and the nose clips on.
c. From the Metabolic Study screen, select **F1 Start Test**.

d. The O_2 and CO_2 Analyzer Calibration screen is displayed and you have the option to perform this calibration at this point if this has not already been performed.
e. Choose F3 to continue on with testing.
f. From the St. Paul's CPX screen, verify that the Vmax is measuring the patient's values. Press F7 to make the CO_2 waveforms visible at the top of the screen. VO_2, RQ, VE and the other parameters should appear and ideally be within normal (green) range. Values may normalize once the Warm Up phase begins.
g. Assure that the Heart Rate is displayed in the upper left corner and the SpO2 values are displayed. SpO2 may be manually entered if necessary.
h. Toggle Vmax system into Baseline phase by choosing the green "Start" box in the lower right corner twice. Alert ECG tech of phase change. Collect one minute of Baseline data.
i. Record Baseline SpO2 by selecting the F2 button at the bottom left of the screen. Tab to the SpO_2 field and enter value from oximeter. Select F3 to save.
j. After 1 minute in Baseline phase the computer will need to be switched into the warm up phase by pressing the "Baseline" box once. This will switch the program into the Warm Up phase. Have the patient start pedaling, maintaining a speed between 55 and 80 rpm.
k. After 1 minute in Warm Up, the computer will automatically switch into the Exercise phase. Alert the ECG tech as exercise phase begins.

During the Test:

a. ECG tech is responsible for measuring the patient's blood pressure every two minutes with an automatic monitor, and for monitoring the heart rate and rhythm for abnormalities.
b. Coach and encourage the pt. throughout the test. Maximal pt. effort ensures accurate results.
c. Every two minutes:
    i. Perform Exercise Flow Volume loops on all Respiratory patient's and any patient with abnormal spirometry. Select F1 at the bottom left of the screen. After several tidal breaths, instruct the patient as follows: "At the end of a normal breath, take a deep breath all the way in and let it out normally". A force exhalation is not necessary. Select F3 to save and exit this screen. (It is recommended that Flow Volume Loops are not done after the pt. has reached an RQ of 1.1 as they will be quite difficult to perform after this point.)
    ii. Record SpO_2 using the F2 button.
d. When the patient signals that he/she is ready to stop, encourage them to continue pedaling for a little longer. Patients are often able to pedal for at least 30 seconds more. Ideally, the Exercise phase should last between 8 – 12 minutes.
e. Put the Vmax system into Recovery Phase by clicking the green Exercise phase button on the lower right of the screen. The patient may continue to pedal for another minute (with mouthpiece in place) to cool down.

Ending the Test:

a. After one minute in Recovery phase, Choose Exit from the top menu bar and choose "Y to end test" from the dropdown menu. Turn oximeter off and remove probe. Remove nose clips and mouthpiece and have the patient sit for a minimum of 3 minutes with ECG leads on as the Marquette is still collecting data. The patient may dismount the bicycle and sit in a chair at this time.
b. Once the pt. has recovered, ECG leads may be removed and the patient may change back into his/her clothes. A shower is available if desired.
c. On the Metabolic End of Test Comments screen, choose a comment from the pre-formatted comments as to why the test was ended (leg muscle fatigue, dyspnea, etc.) Double click on "A – Subject achieved peak VO_2 plateau criteria" (if this was the case) and double click again on reason "A", "B" or "C" as they apply. Record the BORG scale (0-10) for dyspnea and leg fatigue. Add comments about patient effort, or any other relevant information. Select F3 to save and continue.
d. The "Exercise Summary Graphic Edit" screen appears. The computer selects the peak VO_2 based on a 10 second average, however, you may be able to find a higher VO_2 manually. Select the "Peak" tab near the top of the box. Move the striped vertical bar at the end of the exercise phase on the graph until you find the highest value for VO_2 (in the exercise phase only). Select F3 to save and exit.
e. The "Anaerobic Threshold Graphic Edit" screen appears. AT may be selected from this screen. In most cases, the computer will determine an AT; however, this value often needs to be re-adjusted.

f. To change AT: Choose the AT tab and then click the portion of the graph where you deem the AT to be. Any changes to AT must be saved by clicking F3 before proceeding to the next screen. AT should then be verified on the "Plot View" screen (choose Plot View from the Metabolic Study screen). Choose "Dual Criteria Plot" from the Graph menu of the Plot View Screen for the clearest view of AT. The Plot View Screen is used for visual confirmation of the AT only. To change the AT you must exit this screen (press ESC) and then return to the Anaerobic Threshold screen to re-adjust AT if necessary. Press F3 to save any AT changes.

g. Select Tabular Edit from the Metabolic Study page. Change the "Average" to 20 seconds and print 2 copies (press F5 twice). Press F3 to save and exit.

h. Return to the Vmax Metabolic Study screen and select "Comments/Interpretation". Click on "C – Summary Exercise" in the Category box near the top of the box. Then, click on "A – A cardiopulmonary stress test was performed on (patient's name)". A summary report should appear on the screen. Scroll through this report and add the following information:

   i. Protocol used (e.g. 5 watt/min. ramp)
   ii. Resting BP and Maximum BP

   Examine the rest of the report to ensure that all values have been reported correctly. Note the maximum Watts and the MVO_2 and record them on the ECG worksheet. Select F3 to save and exit.

i. To print report: Choose F8 Reports from the bottom of the Metabolic Study screen. Highlight "ST Paul's X1 new" from the reports menu. Press Print at the top of the screen for each copy needed.

Reports:

Respirologist Report: Top sheet is CPX requisition, then Page 4 (Summary Report), Page 1, Page 2, Page 3, Exercise FV Loops, Spirometry and lastly, the Tabular Report.

Heart Clinic Reports: Top sheet is Page 1, then Page 2, Page 3, Page 4, Spirometry and then the Tabular Report.

PACH Clinic Reports: Dr. Kiess receives a full clinic report delivered to her mailbox in her office across the hall from the Cardiology Lab.

The PACH clinic receives a copy of Page 4 Summary Report only, which is sent to 5C via pneumatic tube system.

Health Records Copy: Photocopy the Respirologists report (without the requisition), assembled Page 4, 1, 2, 3, Exercise FV Loops, Spirometry and Tabular Report.

	Respirologist Copy	Clinic Copy	Health Records Photocopy	Page 4 Summary	Total # of Copies
Heart Clinics	✓	✓	✓		3
Pacific Lung Health Clinic	✓	✓	✓		3
PACH Clinic	✓	✓ **To Dr. Kiess**	✓	✓ **To PACH**	4
Outside Doctors	✓		✓		2

REFERENCES:

1. Vmax Instructional Manual

2. ATS/ACCP Statement on Cardiopulmonary Exercise Testing. Am J Respir Crit Care Med Vol 167. pp 211-277, 2003.

REVIEWED BY:

1. RRT