Benefits and Barriers of Invasive Cardiopulmonary Exercise Testing (iCPET) and the Diagnosis of Exercise Induced Pulmonary Arterial Hypertension

David Systrom, MD
Director, Advance Cardiopulmonary Exercise Program
Assistant Professor of Medicine, Harvard Medical School
Department of Pulmonary and Critical Care Medicine
Center for Pulmonary Heart Disease
Brigham and Women’s Hospital,
Boston, Massachusetts

Jeff Voner, MSHS, MPH, PA-C
Lead Physician Assistant
Program Coordinator
Department of Pulmonary and Critical Care Medicine
Center for Pulmonary Heart Disease
Brigham and Women’s Hospital,
Boston, Massachusetts
Disclosures

Jeff Voner, MSHS, MPH, PA-C has no financial interests to disclose.
David M Systrom, MD has no financial interests to disclose.

This continuing education activity is managed and accredited by Professional Education Services Group (PESG) in cooperation with the Pulmonary Hypertension Association (PHA). Neither PESG, nor PHA, nor any accrediting organization support or endorse any product or service mentioned in this activity.

PESG and PHA staff have no financial interests to disclose.

Commercial Support was not received for this activity.
Learning Objectives

At the conclusion of this activity, the participant will be able to:
1. Describe the iCPET procedure
2. Interpret the data obtained in an iCPET report
3. State the importance of the early diagnosis of eiPH
4. Explain how iCPET can differentiate several diagnoses
5. Cite barriers to the referral of patients to specialized dyspnea centers and use of iCPET
6. Recognize the cost effectiveness of iCPET
7. Describe the patient satisfaction with iCPET at our institution
Invasive Cardiopulmonary Exercise Testing

David M Systrom, M.D.
Brigham & Women’s Hospital
Boston, MA
Invasive Cardiopulmonary Exercise Testing

- What is it?
- Exercise-Induced PH
- Exercise-Induced HFpEF
- Preload Failure
- Skeletal Muscle Mitochondrial Dysfunction
Harvard Fatigue Lab

- 1927-47
- Morgan Hall
iCPET

- Hb
- Ca-vO2
- Lactate
- Ph
- PA O2 sat

- Peak Vo2
- VE/VCO2
- AT

- mPAP
- PCWP
- RAP
- CO
- Compliance

Echocardiography
Exercise Testing

MUSCLE ACTIVITY

O\textsubscript{2} & CO\textsubscript{2} DELIVERY

VENTILATION (\dot{V}\textsubscript{A} + \dot{V}\textsubscript{D} = \dot{V}\textsubscript{E})

PERIPH. CIRC.

PULM. CIRC.

CO\textsubscript{2} PROD. Creat - PO\textsubscript{4}

Pyr \rightarrow Lac

O\textsubscript{2} CONSUM

O\textsubscript{2} FLOW

CO\textsubscript{2} FLOW

Heart Blood

EXPIRED

INSPIRED

Lungs

\dot{Q}\textsubscript{CO\textsubscript{2}}

\dot{Q}\textsubscript{O\textsubscript{2}}
Non invasive CPET Dx Algorithm

Impairment
VO2max < 80%

Pulmonary Mechanical
VEmax/MVV > 0.7

Central Cardiac
VE/VCO2@AT
PETCO2
Oscillatory Ventilation

O2 Flux
AT < 40%
OUES

Peripheral
?

Left Heart
?

Right Heart
?

Preload Failure
?
Invasive CPET Dx Algorithm

Impairment
VO2max < 80%

Pulmonary Mechanical
VEmax/MVV > 0.7

O2 Flux
AT < 40%

Central Cardiac
Qtmax < 80%

Peripheral
Ca-vO2 < [Hb]

Left Heart
PCWPmax > 20 mmHg

Right Heart
mPAPmax > 30 mmHg and
PVRmax >120 dynes .s.-5

Preload Failure
RAPmax < 9mm Hg
All else normal
Invasive Cardiopulmonary Exercise Testing

• What is it?
• Exercise-Induced PH
• Exercise-Induced HFpEF
• Preload Failure
• Skeletal Muscle Mitochondrial Dysfunction
Exercise Induced PAH
Invasive CPET Dx Algorithm

Impairment
VO2max < 80%

Pulmonary Mechanical
VEmax/MVV > 0.7

O2 Flux
AT < 40%

Central Cardiac
Qtmax < 80%

Peripheral
Ca-vO2 < [Hb]

Left Heart
PCWPmax > 20 mmHg

Right Heart
mPAPmax > 30 mmHg and
PVRmax >120 dynes .s.-5

Preload Failure
RAPmax < 9mm Hg
All else normal
Exercise-Induced Pulmonary Arterial Hypertension
James J. Tolle, Aaron B. Waxman, Teresa L. Van Horn, Paul P. Pappagianopoulos and David M. Systrom
*Circulation* 2008;118;2183-2189; originally published online Nov 3, 2008;
DOI: 10.1161/CIRCULATIONAHA.108.787101
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal (n=16)</th>
<th>Exercised-Induced PAH (n=78)</th>
<th>Resting PAH (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>45.9±14.9</td>
<td>58.8±15.1*</td>
<td>58.5±15.7*</td>
</tr>
<tr>
<td>Female gender, %</td>
<td>68.8</td>
<td>65.8</td>
<td>46.7</td>
</tr>
<tr>
<td>Body mass index</td>
<td>25.5±4.2</td>
<td>30.2±5.3*</td>
<td>28.1±6.2</td>
</tr>
<tr>
<td>Work max, W</td>
<td>155.5±43.1</td>
<td>90.3±41.7*</td>
<td>70.0±41.5*</td>
</tr>
<tr>
<td>$\dot{V}_{O_2}$ max, mL/min</td>
<td>2022±468</td>
<td>1284±58*</td>
<td>1127±507*</td>
</tr>
<tr>
<td>$\dot{V}_{O_2}$ max, % predicted</td>
<td>91.7±13.7</td>
<td>66.5±16.3*</td>
<td>55.8±20.3*†</td>
</tr>
<tr>
<td>P(A-a)$_{O_2}$ max, mm Hg</td>
<td>14.7±7.6</td>
<td>32.0±18.0*</td>
<td>52.7±17.3*†</td>
</tr>
<tr>
<td>$Ca_o_2$, mg/mL</td>
<td>19.0±1.2</td>
<td>18.0±2.5</td>
<td>16.8±3.3</td>
</tr>
<tr>
<td>Paco$_2$ max, mm Hg</td>
<td>32.9±4.4</td>
<td>35.1±6.1</td>
<td>37.1±7.6</td>
</tr>
<tr>
<td>$\dot{V}_{CO_2}$ max, mL/min</td>
<td>2380±722</td>
<td>1561±705*</td>
<td>1310±626*</td>
</tr>
<tr>
<td>mPAP rest, mm Hg</td>
<td>13.9±2.9</td>
<td>18.6±3.2*</td>
<td>30.9±8.9*†</td>
</tr>
<tr>
<td>mPAPmax, mm Hg</td>
<td>27.4±3.7</td>
<td>36.6±5.7*</td>
<td>48.4±11.1*†</td>
</tr>
<tr>
<td>PCWPmax, mm Hg</td>
<td>14.8±4.5</td>
<td>15.0±2.4</td>
<td>15.2±3.1</td>
</tr>
<tr>
<td>$Q_t$max, L/min</td>
<td>15.5±3.2</td>
<td>11.4±3.0*</td>
<td>10.4±3.6*</td>
</tr>
<tr>
<td>$Q_t$max, % predicted</td>
<td>99.4±11.1</td>
<td>83.1±18.9*</td>
<td>71.8±22.4*†</td>
</tr>
<tr>
<td>PVR rest, dyne · s · cm$^{-5}$</td>
<td>154±61</td>
<td>223±82*</td>
<td>352±141*†</td>
</tr>
<tr>
<td>PVRmax, dyne · s · cm$^{-5}$</td>
<td>62±20</td>
<td>161±60*</td>
<td>294±158*†</td>
</tr>
<tr>
<td>RAPmax, mm Hg</td>
<td>9.1±3.5</td>
<td>9.6±3.0</td>
<td>11.0±6.1</td>
</tr>
<tr>
<td>RVEFmax</td>
<td>0.58±0.06</td>
<td>0.53±0.08*</td>
<td>0.43±0.11†</td>
</tr>
<tr>
<td>$\dot{V} <em>{O_2}$, $\dot{V}</em>{CO_2}$ at anaerobic threshold</td>
<td>36.0±8.9</td>
<td>37.8±8.9</td>
<td>43.1±6.9*</td>
</tr>
<tr>
<td></td>
<td>Normal (n=16)</td>
<td>Exercised-Induced PAH (n=78)</td>
<td>Resting PAH (n=15)</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------</td>
<td>-------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Age, y</td>
<td>45.9±14.9</td>
<td>58.8±15.1*</td>
<td>58.5±15.7*</td>
</tr>
<tr>
<td>Female gender, %</td>
<td>68.8</td>
<td>65.8</td>
<td>46.7</td>
</tr>
<tr>
<td>Body mass index</td>
<td>25.5±4.2</td>
<td>30.2±5.3*</td>
<td>28.1±6.2</td>
</tr>
<tr>
<td>Work max, W</td>
<td>155.5±43.1</td>
<td>90.3±41.7*</td>
<td>70.0±41.5*</td>
</tr>
<tr>
<td>( \dot{V}O_2 \text{max}, \text{mL/min} )</td>
<td>2022±468</td>
<td>1284±58*</td>
<td>1127±507*</td>
</tr>
<tr>
<td>( \dot{V}O_2 \text{max}, % \text{predicted} )</td>
<td>91.7±13.7</td>
<td>66.5±16.3*</td>
<td>55.8±20.3†</td>
</tr>
<tr>
<td>P(A-a)(O_2)\text{max}, mm Hg</td>
<td>14.7±7.6</td>
<td>32.0±18.0*</td>
<td>52.7±17.3*†</td>
</tr>
<tr>
<td>CaO(_2), mg/mL</td>
<td>19.0±1.2</td>
<td>18.0±2.5</td>
<td>16.8±3.3</td>
</tr>
<tr>
<td>Paco(_2)\text{max}, mm Hg</td>
<td>32.9±4.4</td>
<td>35.1±6.1</td>
<td>37.1±7.6</td>
</tr>
<tr>
<td>( \dot{V}C_0 \text{max}, \text{mL/min} )</td>
<td>2380±722</td>
<td>1561±705*</td>
<td>1310±626*</td>
</tr>
<tr>
<td>mPAP rest, mm Hg</td>
<td>13.9±2.9</td>
<td>18.6±3.2*</td>
<td>30.9±8.9*†</td>
</tr>
<tr>
<td>mPAP(\text{max}, \text{mm Hg} )</td>
<td>27.4±3.7</td>
<td>36.6±5.7*</td>
<td>48.4±11.1*†</td>
</tr>
<tr>
<td>PCWP(\text{max}, \text{mm Hg} )</td>
<td>14.8±4.5</td>
<td>15.0±2.4</td>
<td>15.2±3.1</td>
</tr>
<tr>
<td>Q(_1)\text{max}, L/min</td>
<td>15.5±3.2</td>
<td>11.4±3.0*</td>
<td>10.4±3.6*</td>
</tr>
<tr>
<td>Q(_1)\text{max}, % \text{predicted} )</td>
<td>99.4±11.1</td>
<td>83.1±18.9*</td>
<td>71.8±22.4†</td>
</tr>
<tr>
<td>PVR rest, dyne \cdot s \cdot cm(^{-5})</td>
<td>154±61</td>
<td>223±82*</td>
<td>352±141*†</td>
</tr>
<tr>
<td>PVR(\text{max}, \text{dyne} \cdot \text{s} \cdot \text{cm}^{-5} )</td>
<td>62±20</td>
<td>161±60*</td>
<td>294±158*†</td>
</tr>
<tr>
<td>RAP(\text{max}, \text{mm Hg} )</td>
<td>9.1±3.5</td>
<td>9.6±3.0</td>
<td>11.0±6.1</td>
</tr>
<tr>
<td>RVEF(\text{max} )</td>
<td>0.58±0.06</td>
<td>0.53±0.08*</td>
<td>0.43±0.11*†</td>
</tr>
<tr>
<td>( \dot{V} \dot{\overline{V}}C_0 \text{, at anaerobic threshold} )</td>
<td>36.0±8.9</td>
<td>37.8±8.0</td>
<td>43.1±6.9*</td>
</tr>
</tbody>
</table>
Novel Metabolic Signatures of Human Exercise Performance

Gregory D. Lewis,1,2,3,4 Laurie Farrell,1 Amanda Souza,4 Elaine Yang,4 Maryann Martinovic,1 Xu Shi,4 Rahul Deo,1,5 Frederick P. Roth,5 Aarti Asnani,1,2,4 David M. Systrom,6 Marc J. Semigran,1 Malissa J. Wood,1 Steven A. Carr,4 Marc S. Sabatine,1,3,7 Clary B. Clish,4 and Robert E. Gerszten1,2,3,4

Sci Transl Med 26 May 2010 2:33ra37
Arginine/Nitric Oxide Metabolism in eiPH

Plasma NOx

- Controls Radial arterial
- Controls Mix Venous
- EIPH Radial arterial
- EIPH Mix Venous

Plasma NOx

- EIPH
- Controls

CIT/ARG

- EIPH
- Controls

Release by lung
Uptake by lung
D Dimer Levels Discern Two Distinct Subsets of Patients with PH

D dimer was measured in plasma (PA, and arterial) during rest and exercise in subjects with either EIPAH, EICHF or in normals (n = 10/group)
Soluble Tissue Factor Ag Discern Two Distinct Subsets of PH

- Soluble TF was measured in plasma (PA, and arterial) during rest and exercise in subjects with either eiPAH, eiCHF or in normals (n = 10/group)
Event-Free Survival in eiPH

n = 56 followed for > 3 years
Mean f/u 6.7 years

HR = 2.0, p = 0.007
Invasive Cardiopulmonary Exercise Testing

• What is it?
• Exercise-Induced PH
• Exercise-Induced HFpEF
• Preload Failure
• Skeletal Muscle Mitochondrial Dysfunction
Invasive CPET Dx Algorithm

Impairment
VO2max < 80%

Pulmonary Mechanical
VEmax/MVV > 0.7

Central Cardiac
Qtmax < 80%

O2 Flux
AT < 40%

Peripheral
Ca-vO2 < [Hb]

Left Heart
PCWPmax > 20 mmHg

Right Heart
mPAPmax > 30 mmHg and
PVRmax > 120 dynes .s. -5

Preload Failure
RAPmax < 9 mm Hg
All else normal
Misclassification of the Cause of Dyspnea by Resting Right Heart Catheterization: The Impact Of Invasive Cardiopulmonary Exercise Testing

Santos M, Opotowsky AR, Shah AM, Tracy J, Waxman AB, Systrom DM.
Central cardiac limit to aerobic capacity in patients with exertional pulmonary venous hypertension: implications for heart failure with preserved ejection fraction. Circ Heart Fail. 2015 Mar;8(2):278-85
Invasive Cardiopulmonary Exercise Testing

- What is it?
- Exercise-Induced PH
- Exercise-Induced HFpEF
- Preload Failure
- Skeletal Muscle Mitochondrial Dysfunction
Invasive CPET Dx Algorithm

Impairment
VO2max < 80%

Pulmonary Mechanical
VEmax/MVV > 0.7

O2 Flux
AT < 40%

Central Cardiac
Qtmax < 80%

Mt Myopathy
Ca-vO2 < [Hb]

Left Heart
PCWPmax > 20 mmHg

Right Heart
mPAPmax > 30 mmHg and
PVRmax >120 dynes .s.-5

Preload Failure
RAPmax < 9mm Hg
All else normal
Preload Failure

![Graph showing pressure (mmHg) over time points]

- mPAP
- PAWP
- TPG
- RAP
Unexplained exertional dyspnea caused by low ventricular filling pressures: results of clinical invasive cardiopulmonary exercise testing
William M. Oldham¹, ², ³, Gregory D. Lewis³, ⁴, ⁵, Alexander R. Opotowsky², ³, ⁶, Aaron B. Waxman¹, ², ³, David M. Systrom¹, ², ³
Under review.
Invasive Cardiopulmonary Exercise Testing

• What is it?
• Exercise-Induced PH
• Exercise-Induced HFpEF
• Preload Failure
• Skeletal Muscle Mitochondrial Dysfunction
Invasive CPET Dx Algorithm

- Impairment
  - VO2max < 80%

  - Pulmonary Mechanical
    - VEmax/MVV > 0.7

  - O2 Flux
    - AT < 40%

- Central Cardiac
  - Qtmax < 80%

- Peripheral
  - Ca-vO2 < [Hb]

- Left Heart
  - PCWPmax > 20 mmHg

- Right Heart
  - mPAPmax > 30 mmHg
  - PVRmax > 120 dynes .s.-5

- Preload Failure
  - RAPmax < 9mm Hg
  - All else normal
Systemic O$_2$ Extraction is Impaired in PAH & HFpEF (vs. HFrEF)

Ca-vO$_2$/CaO$_2$

$^{31}$P Magnetic resonance spectroscopy

3T whole body MR magnet

- Gradient coils
- 4 cm rf coil (centered)
- 120 cm I. D. magnet
- To pneumotachograph
- To gas analyzers
- Heating pad
- Blood sampling
- To NMR spectrometer
- 1.4 kg lead bricks
Normal

PCr Recovery

\[ \tau_{\text{PCr}} = 30 \text{ s} \]

PAH

\[ \tau_{\text{PCr}} = 62 \text{ s} \]
An open label, uncontrolled study of ambrisentan in patients with exercise induced pulmonary arterial hypertension
Aaron B. Waxman, Alexander R. Opotowsky, Laurie Lawler, David M. Systrom
Brigham and Women’s Hospital and Harvard Medical School. Boston. MA. USA
An open label, uncontrolled study of ambrisentan in patients with exercise induced pulmonary arterial hypertension
Aaron B. Waxman, Alexander R. Opotowsky, Laurie Lawler, David M. Systrom
Brigham and Women’s Hospital and Harvard Medical School. Boston. MA. USA
iCPET Diagnoses
(\%, n=225)
Thanks To…….

• Jeff Voner PAC
• Charlie Lee PAC
• Julie Tracy MS
• Abbey Karin MS
• Sasha Opotowsky MD
• Aaron Waxman MD PhD
Why aren’t more iCPETs done?

1. “iCPET is way too expensive. It’s not worth it.” (cost)

2. “My patients would never agree to such an invasive test.” (anxiety)
Wei Huang MD, PhD, Stephen Resch, MPH, PhD, David M. Systrom, MD, Aaron B. Waxman, MD, PhD; **Diagnostic Efficacy and Economic Evaluation for Unexplained Dyspnea with Invasive Cardiopulmonary Exercise Testing In Specialized Dyspnea Center; Abstract**

- Review of 864 patients referred to the Brigham and Women’s Hospital Dyspnea Clinic over 3 ½ years (3/2011 – 10/2014)
- 530 patients underwent iCPET (61.3%)
- iCPET Cohort:
  - Mean age: 55 ± 17 (range 16-88)
  - 67.4% women
  - 32.6% were referred from outside of our state (Massachusetts)
Wei Huang MD, PhD, Stephen Resch, MPH, PhD, David M. Systrom, MD, Aaron B. Waxman, MD, PhD; **Diagnostic Efficacy and Economic Evaluation for Unexplained Dyspnea with Invasive Cardiopulmonary Exercise Testing In Specialized Dyspnea Center;** Abstract
asthma, bronchitis, chronic obstructive pulmonary disease, cystic fibrosis, emphysema, pneumonia, fibrosing alveolitis, atelectasis, hypersensitivity pneumonitis, lung cancer, pleural effusion, interstitial lung disease, pneumoconiosis, pneumothorax, pulmonary edema, pulmonary hypertension, sarcoidosis, pulmonary emboli, pulmonary veno-occlusive disease, superior vena cava syndrome, laryngeal cancer, pharyngeal pulmonary aspiration, epiglotitis, laryngeal phrenic nerve lesion, polycystic liver ankylosing spondylisis, rib fracture, costochondritis, pectus excavatum, cardiomyopathy, congenital heart heart failure, ischemic heart disease, pericarditis, pericardial effusion, hypothyroidism, adrenal leukemia, holocarboxylase lateral sclerosis, Guillain-Barre myasthenia gravis, Parsonage Syndrome, Chronic Fatigue medication reaction, central neuropathy, dysautonomia, cancer, empty nose syndrome, edema, vocal cord dysfunction, disease, diaphragm tumor, spinal kyphosis, obesity, scoliosis, aortic dissection, disease, CREST syndrome, malignant hypertension, valvular heart disease, anemia, insufficiency, metabolic acidosis, sepsis, synthetase deficiency, amyotrophic syndrome, multiple sclerosis, Turner Syndrome, Eaton-Lambert Syndrome, anxiety, panic attacks, hyperventilation syndrome, small fiber mitochondrial myopathy, etc., etc., etc.
Current Diagnostic Model for Dyspnea Patients

- All patients with dyspnea
  - Primary doctor visit
    - Conventional Diagnostic tests
      - Wrong diagnosis
        - Treatment
      - Correct diagnosis
        - Treatment

- Unexplained dyspnea
  - Keep searching
    - Repeat diagnostic tests
    - Frequently visits
      - Dysspnea Center
      - ICPET

- Stable
  - Give up
- Wrong diagnosis
- Correct Diagnosis
  - Until Progress or severe

Source: Wei Huang MD, PhD, Stephen Resch, MPH, PhD, David M. Systrom, MD, Aaron B. Waxman, MD, PhD; Diagnostic Efficacy and Economic Evaluation for Unexplained Dyspnea with Invasive Cardiopulmonary Exercise Testing In Specialized Dyspnea Center; Abstract
REFERRALS

- Pulmonologist (174)
- Cardiologist (165)
- General Medicine MD (103)
- Neurologist (28)
- Rheumatologist (13)
- Other (47)

Other: Family Medicine, Lung Transplant, GI, ID, Thoracic Surgery, Pediatrics, Renal, Hematology, Oncology, Allergy/Immunology, Self Referred

Source: Wei Huang MD, PhD, Stephen Resch, MPH, PhD, David M. Systrom, MD, Aaron B. Waxman, MD, PhD; Diagnostic Efficacy and Economic Evaluation for Unexplained Dyspnea with Invasive Cardiopulmonary Exercise Testing In Specialized Dyspnea Center; Abstract
Difference in Number of Tests Ordered Before and After Referral to our Dyspnea Center

* Other Tests include imaging, stress testing, and noninvasive and invasive tests
Number of Times Test Repeated Prior To DC Referral

Costs based on Medicare reimbursement rate per diagnosis-related outpatient tests in 2014

Source: Huang, W, Waxman AB, Systrom DM; Efficacy and Economic Assessment of Invasive Cardiopulmonary Exercise Testing versus Conventional Diagnostic Testing for Unexplained Dyspnea in a Dyspnea Center; Abstract
% of Patients Getting Expensive Tests Prior To DC Referral

- Chest CT ($167.46)
- Noninvasive CPET ($2269)
- ETT ($432.59)
- Cardiac SPECT ($947.80)
- Cors ($3634.29)
- Stress Echo ($526.01)
- RHC ($3341.32)
- Abdominal u/s ($311.45)
- Cardiac MRI ($624.05)

Costs based on Medicare reimbursement rate per diagnosis-related outpatient tests in 2014

Source: Huang, W, Waxman AB, Systrom DM; Efficacy and Economic Assessment of Invasive Cardiopulmonary Exercise Testing versus Conventional Diagnostic Testing for Unexplained Dyspnea in a Dyspnea Center; Abstract
**Difference in Cost of Testing Before and After Referral to our Dyspnea Center**

Costs based on Medicare reimbursement rate per diagnosis-related outpatient tests in 2014

- **Cost Before DC**: $7302 (Range: $3963 - $13114)
- **Cost After DC**: $5438 (Range: $4061 - $5567)

* Compared with diagnostic time before DC, $P < 0.0001.*

Source: Wei Huang MD, PhD, Stephen Resch, MPH, PhD, David M. Systrom, MD, Aaron B. Waxman, MD, PhD; Diagnostic Efficacy and Economic Evaluation for Unexplained Dyspnea with Invasive Cardiopulmonary Exercise Testing In Specialized Dyspnea Center; Abstract
Difference in Time to Diagnosis Before and After Referral to our Dyspnea Center

* Compared with diagnostic time before Dyspnea Clinic, \( P < 0.0001 \).

Source: Wei Huang MD, PhD, Stephen Resch, MPH, PhD, David M. Systrom, MD, Aaron B. Waxman, MD, PhD; *Diagnostic Efficacy and Economic Evaluation for Unexplained Dyspnea with Invasive Cardiopulmonary Exercise Testing In Specialized Dyspnea Center*; Abstract
Proposed Standardized Diagnostic Algorithm for Unexplained Dyspnea

Source: Wei Huang MD, PhD, Stephen Resch, MPH, PhD, David M. Systrom, MD, Aaron B. Waxman, MD, PhD; Diagnostic Efficacy and Economic Evaluation for Unexplained Dyspnea with Invasive Cardiopulmonary Exercise Testing In Specialized Dyspnea Center; Abstract
“What’s worse; iCPET or going to the dentist?”
Patient Satisfaction Survey

• 42 patients surveyed

• Asked to rate: 1 (excellent), 2 (very good), 3 (good), 4 (fair), to 5 (poor) for 15 different aspects of the iCPET procedure and leave comments

• These aspects included the patient’s satisfaction with:
  - The procedure as a whole
  - Comfort level with pain
  - Attention to discomfort
  - Privacy
  - Check in
  - Wait time
  - Procedure explanation
  - Friendliness/courtesy of staff
  - Caring/concern shown by staff
  - Staff listening
  - Staff ability to answer questions
  - Instructions during the procedure
  - Safety during the procedure
  - Adequacy of post procedure explanation
  - Overall rating of the staff

Simon, BB, A Patient Satisfaction Survey of 42 Patients Undergoing iCPET at the Brigham and Women’s Hospital, Poster Presentation (PHPN)
### Key Patient Satisfaction Survey Results

<table>
<thead>
<tr>
<th>Overall Ratings</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey Completion</td>
<td>100%</td>
</tr>
<tr>
<td>Overall Procedure Visit</td>
<td>95.3% very good to excellent (73.8% excellent).</td>
</tr>
<tr>
<td>Comfort Level</td>
<td>93.5% good to excellent (70% excellent).</td>
</tr>
<tr>
<td>Felt Safe</td>
<td>95.3% very good to excellent (78.6% excellent)</td>
</tr>
<tr>
<td>Privacy</td>
<td>92.3% very good to excellent (76.9% excellent)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Staff Ratings</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>97.6% very good to excellent (85.7% excellent)</td>
</tr>
<tr>
<td>Average of 9 staff related areas*</td>
<td>92.8% very good to excellent (75.1% excellent)</td>
</tr>
</tbody>
</table>

| Logistics Ratings**                   | 85.7% very good to excellent (61.9% excellent)                  |

* Attention to discomfort, procedure explanation, friendly/courteous, caring, listening, ability to answer questions, instructions during procedure, post procedure explanation, discharge.

** Ease of check in and wait time

Simon, BB, *A Patient Satisfaction Survey of 42 Patients Undergoing iCPET at the Brigham and Women’s Hospital*, Poster Presentation (PHPN)
173 (32.6%) patients were referred from outside of MA:
- 47 New Hampshire
- 36 Maine
- 24 Rhode Island
- 17 New York
- 14 Connecticut
- 10 Florida
- 4 Vermont
- 3 California
- 3 Georgia
- 2 New Jersey
- 2 Indiana
- 2 Pennsylvania
- 1 Delaware
- 1 Kentucky
- 1 Maryland
- 1 Mississippi
- 1 Missouri
- 1 Nebraska
- 1 North Carolina
- 1 Tennessee
- 1 Norway
Conclusions

1. iCPET has a 100% success rate of obtaining a treatable diagnosis
2. The average cost of iCPET (post dyspnea clinic referral) is about $1900 less compared to the extensive pre-dyspnea clinic referral work up.
3. iCPET dramatically reduces the time it takes to arrive at an accurate diagnosis in unexplained dyspnea patients: Within a month; AND 1 year and 4 months FASTER than a conventional workup leads to a referral.
4. The excess expense and time with the traditional work up appears to be the result of a lack of a standardized diagnostic approach. This approach leads to multiple physician referrals, repeat testing, and ultimately ordering more expensive tests as prior tests are inconclusive.
5. The proposed standard algorithm including iCPET could limit expense and accelerate time to diagnosis.
6. Our institution has a greater than 90% patient satisfaction rate for all major indices of this procedure showing patient’s and referring clinicians should not let anxiety about the invasive nature of iCPET prevent the use of this highly successful test.
THANK YOU !!

QUESTIONS
Obtaining CME/CE Credit

If you would like to receive continuing education credit for this activity, please visit:

http://pha.cds.pesgce.com