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운동부하 심폐기능 검사의 해석

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The Interpretation of Cardiopulmonary Exercise Testing

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지금까지 수많은 운동 부하 심폐기능 검사의 해석 방법이 제시되었음에도 불구하고, 단지 운동 부하 심폐기능 검사 하나로만 어떤 질병(특히, 심폐질환)을 정확하게 진단내리기란 그리 쉬운 것은 아니다. 그 이유는 운동 부하를 시키면서 발생할 수 있는, 원인을 규명하기 힘든 어떤 요인들 중 하나가 운동 부하 검사 해석을 전혀 엉뚱한 방향으로 인도할 수 있기 때문이다. 가장 중요한 것은 우선 임상증상을 정확하게 파악하고, 그 증상을 이해한 후 검사 결과에 연계시켜서 종합적인 해석을 해 나가는 것이 가장 중요하다. 그러기 위해서는 개념적이면서 여러 가지 인자들을 하나하나 살펴보면서 감별진단 할 수 있는 알고리듬(algorithm) 형태의 분석이 중요하다. 그러나 알고리듬만 가지고 접근하다보면, 초기 또는 복합적인 심폐질환을 평가할 때 부족한 면이 있기 때문에 임상적 판단을 할 때는 운동 부하 심폐기능 검사의 여러 요소들 간의 상호관계에 현상학적인 면을 반복하는 경험을 통해 해석해 나가는 것이 가장 현명한 방법이다.

Table 1(Am J Respir Crit Care Med, 2003; 167:211)에서는 운동 부하 심폐기능 검사를 해석해 나가는 순서를 정리하였다.

Figure 1에서는 운동 부하 심폐기능 검사의 경향에 따른 해석으로 감별진단을 할 수 있는 알고리듬을 정리해 보았다.

Table 2는 몇 가지 질환에 따른 전형적인 운동 부하 심폐기능 검사 반응 형태를 요약한 것이다. 서로 다른 질환 간에 중복된 결과를 보일 뿐 아니라 환자들은 종종 몇 가지 질환을 동시에 가지고 있기 때문에, 정확한 해석을 위해서는 그러한 중복과 다양성을 잘 고려해야 한다.

Table 3에서는 정상 범위로 받아들여지는 몇 가지 운동 부하 심폐기능 검사 수치를 나타내었다. 이를 바탕으로 다음에 나오는 증례를 해석해보자.

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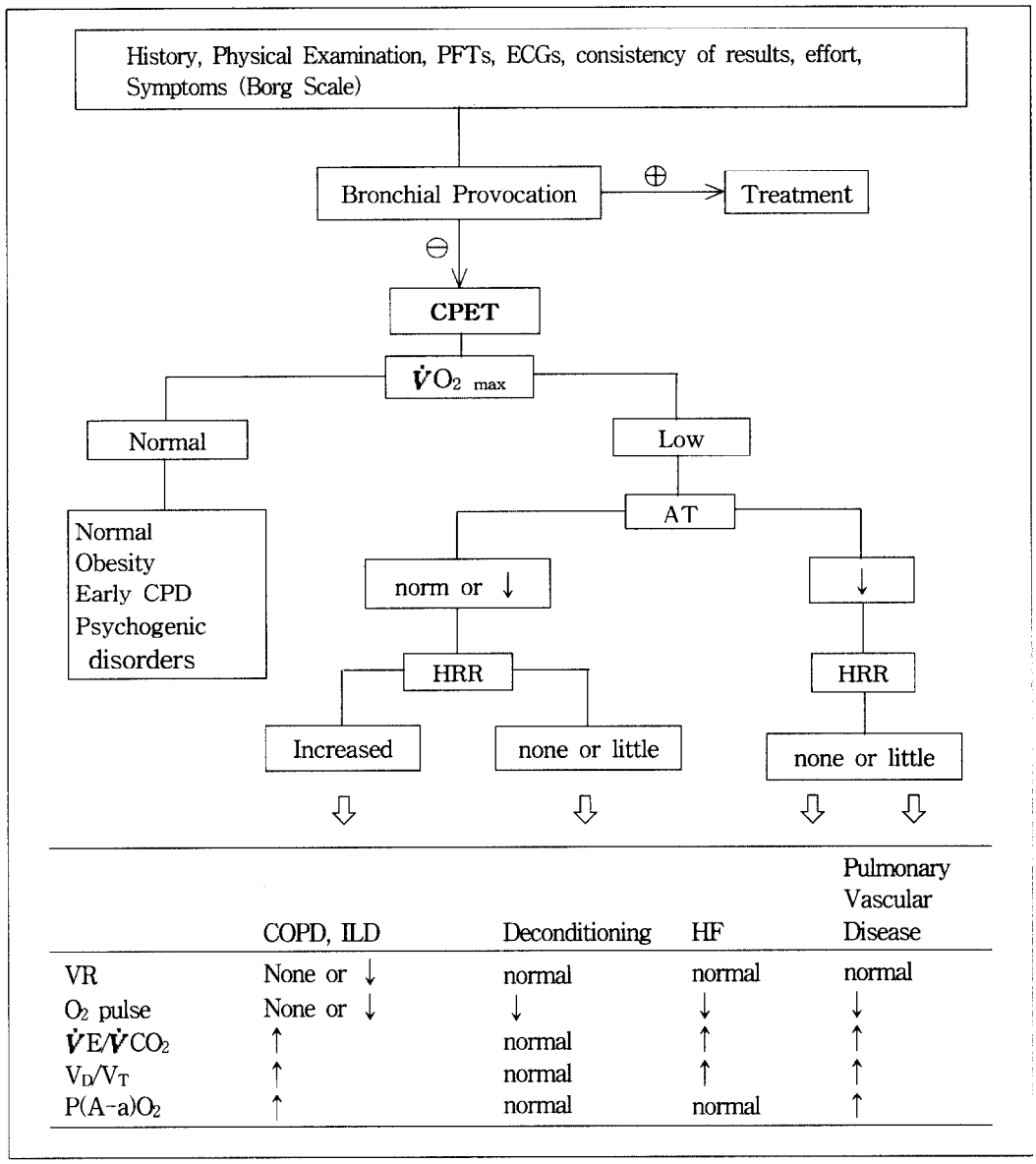
Table 1. Integrative approach to the interpretation of cardiopulmonary exercise testing results

1. Determine reason(s) for CPET
2. Review pertinent clinical and laboratory information (clinical status)
3. Note overall quality of test, assessment of subject effort, and reasons for exercise cessation
4. Identify key variables: initially $\dot{V}O_2$, and then HR, $\dot{V}E$, Sa_{O2}, and other measurements subsequently
5. Use tabular and graphic presentation of the data
6. Pay attention to trending phenomena: submaximal through maximal responses
7. Compare exercise responses with appropriate reference values
8. Evaluate exercise limitation: physiologic versus nonphysiologic
9. Establish patterns of exercise responses
10. Consider what conditions/clinical entities may be associated with these patterns
11. Correlate CPET results with clinical status
12. Generate CPET report

Table 2. Usual Cardiopulmonary exercise response patterns

Measurement	Heart Failure	COPD	ILD	Pulmonary Vascular Disease	Obesity	Deconditioned
$\dot{V}O_2$max or $\dot{V}O_2$peak	⇓	⇓	⇓	⇓	⇓ for actual, normal for ideal weight	⇓
Anaerobic Threshold	⇓	Norm/⇓/ indeterminate	Norm or ⇓	⇓	Noraml	Noraml or ⇓
Peak HR	Variable, usually normal in mild	⇓, normal in mild	⇓	Norm/ slightly ⇓	Norm/ slightly ⇓	Norm/ slightly ⇓
O_2 pulse	⇓	Norm or ⇓	Norm or ⇓	⇓	Normal	⇓
($\dot{V}$/MVV)×100	Normal or ⇓	⇑	Norm or ⇑	Normal	Normal or ⇑	Normal
$\dot{V}_E/\dot{V}_{CO2}$ (at AT)	⇑	⇑	⇑	⇑	Normal	Normal
V_D/V_T	⇑	⇑	⇑	⇑	Normal	Normal
Pa_{O2}	Normal	Variable	⇓	⇓	Normal/ may ⇑	Normal
$P(_A-a)o_2$	Usually normal	Variable, usually ⇑	⇑	⇑	may ⇓	Normal



	COPD, ILD	Deconditioning	HF	Pulmonary Vascular Disease
VR	None or ↓	normal	normal	normal
O_2 pulse	None or ↓	↓	↓	↓
$\dot{V}E/\dot{V}CO_2$	↑	normal	↑	↑
V_D/V_T	↑	normal	↑	↑
$P(A-a)O_2$	↑	normal	normal	↑

Definition of abbreviations: PFT=pulmonary function test, ECG=electrocardiogram, CPET= cardiopulmonary exercise testing, AT=anaerobic threshold, CPD=cardiopulmonary disease, HRR=Heart rate reserve, COPD=chronic obstructive pulmonary disease, ILD=interstitial lung disease, HF=heart failure, VR=ventilatory reserve.

Fig. 1. Basic strategy for the interpretation of peak CPET results.

Table 3. Suggested normal guidelines for interpretation of CPET results

Variables	Criteria of Normality
$\dot{V}O_2$max or $\dot{V}O_2$peak	> 84% predicted
Anaerobic threshold	> 40% $\dot{V}O_2$max predicted; wide range of normal (40-80%)
Heart rate (HR)	HRmax > 90% age predicted
Heart rate reserve (HRR)	HRR < 15 beats/min
Blood pressure	< 220/90
O_2 pulse ($\dot{V}O_2$/HR)	> 80%
Ventilatory reserve (VR)	MVV - $\dot{V}_E$max: >11 L or $\dot{V}_E$max/MVV × 100: <85% Wide normal range: 72 ± 15%
Respiratory frequency (fR)	< 60 breaths/min
$\dot{V}_E/\dot{V}CO_2$ (at AT)	< 34
V_D/V_T	< 0.28; < 0.30 for age > 40 years
Pa_{O_2}	> 80 mm Hg
$P(_A-a)O_2$	< 35 mm Hg

Case 1. Normal CPET response

Table 4. Results of maximal cardiopulmonary exercise testing for a healthy person

62-year-old male; white; height, 175 cm; weight, 84 kg; ideal weight, 78 kg
Clinical Dx: Exertional dyspnea
Medications: None
Reason for testing: Shortness of breath on exertion

Resting Pulmonary Function Tests

Variable	Actual	% Pred	Variable	Actual	% Pred
FVC, L	4.50	99	TLC, L	6.52	103
FEV_1, L	3.10	88	RV, L	2.54	109
FEV_1/FVC, %	69		DLco, mℓ/min per mm Hg	26.3	91
MVV, L/min	124				

Cardiopulmonary Exercise Test

Protocol: Maximal, symptom limited, incremental cycle ergometry, 10 W/min
P_B, 656 mm Hg, P_{IO_2}, 128 mm Hg

Variable	Peak	% Pred	Variable	Rest	Peak
Work rate, W	170	109	SaO_2, %		
$\dot{V}O_2$, L/min	2.1	98	SPO_2, %	95	96
$\dot{V}O_2$, mℓ/kg per min	25.6	91	PaO_2, mm Hg		
AT, L/min	1.05	N (>0.86)	$PaCO_2$, mm Hg		
$\Delta\dot{V}O_2/\Delta$WR, mℓ/min/W	10.3	N (>8.6)	pH		
HR, beats/min	166	98	HCO_2^-, mEq/L		
O_2 pulse, mℓ/beat	2.6	100	$P(A-a)O_2$, mm Hg		
BP, mm Hg	176/90		V_D/V_T		
$\dot{V}_E$, L/min	90.7	73	Lactate, mEq/L		
fR, breaths/min	33	N			
$\dot{V}E/\dot{V}CO_2$, at AT	34	N	**Stop** : Dyspnea, 7/10;		
RER	1.21		leg fatigue, 5/10		

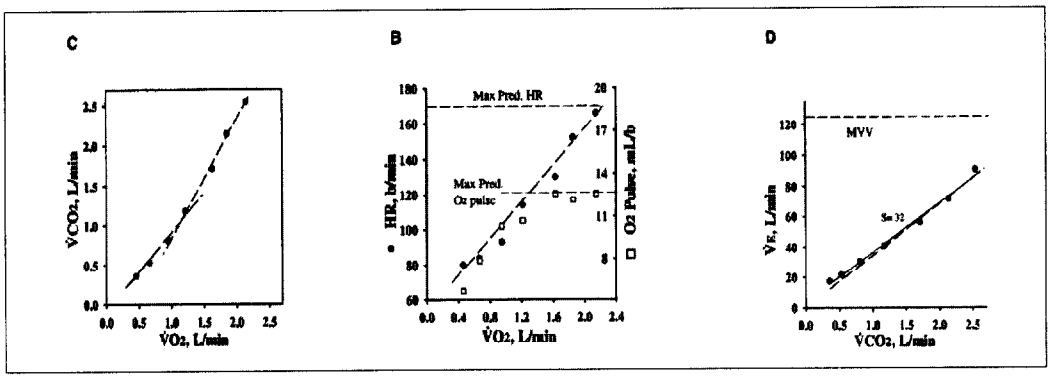


Fig. 2. Graphic representation of the maximal, incremental, cardiopulmonary exercise response of a healthy aged person.

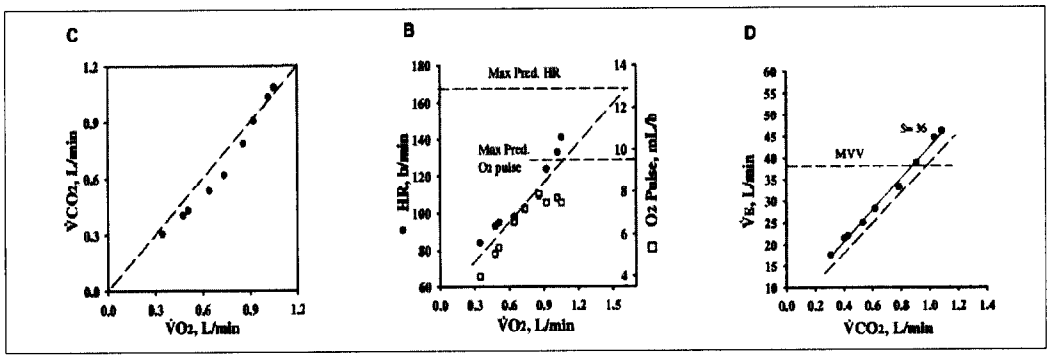


Fig. 3. Graphic representation of the maximal, incremental, cardiopulmonary exercise response of a patient with COPD.

Case 2. COPD CPET response

Table 5. Results of maximal cardiopulmonary exercise testing for a patient with COPD

66-year-old male; white; height, 175 cm; weight, 61 kg; ideal weight, 77.5kg
Clinical Dx: Severe COPD
Medications: Ipratroprium bromide, budesonide, salmeterol, as-needed Proventil, Tagamet
Reason for testing: Evaluation of functional capacity and worsening of dyspnea

Resting Pulmonary Function Tests

Variable	Actual	% Pred	Variable	Actual	% Pred
FVC, L	2.44	55	TLC, L	9.45	139
FEV_1, L	0.88	25	RV, L	7.01	303
FEV_1/FVC, %	36		DLco, ml/min per mm Hg	16.5	51
MVV, L/min	38				

Cardiopulmonary Exercise Test

Protocol: Maximal, symptom limited, incremental cycle ergometry, 10 W/min
P_B, 656 mm Hg, P_{IO_2}, 128 mm Hg

Variable	Peak	% Pred	Variable	Rest	Peak
Work rate, W	70	65	Sa_{O_2}, %	92	83
$\dot{V}O_2$, L/min	1.06	66	Sp_{O_2}, %	90	85
$\dot{V}O_2$, ml/kg per min	17.4	66	Pa_{O_2}, mm Hg	65	55
AT, L/min	0.75	N (>0.64)	Pa_{CO_2}, mm Hg	38	46
$\Delta\dot{V}O_2/\Delta WR$, ml/min/W	9.3	N (>8.6)	pH	7.413	7.279
HR, beats/min	141	84	HCO_3^-, mEq/L	24	21
O_2 pulse, ml/beat	7.5	79	$P(A-a)_{O_2}$, mm Hg	20	27
BP, mm Hg	166/72		V_D/V_T	0.45	0.42
$\dot{V}_E$, L/min	46	121	Lactate, mEq/L	1.4	6.9
fR, breaths/min	36	N			
$\dot{V}E/\dot{V}CO_2$, at AT	44	H			
RER	1.03		**Stop** : Dyspnea, 10/10		