Figure 1. $V_{O_2}$ versus time as an analog of work output in a normal subject and a patient with heart failure.

Figure 2. Work rate (Watts) $\dot{V}O_2$ relationship in normal subjects and patients with heart failure. A: Normal slope is $\sim 10$ ml $\dot{V}O_2$ per Watt. B: At high work rates, the $\dot{V}O_2$/Watts slope may plateau in HF patients. C: In severe LV dysfunction, $\dot{V}O_2$ may decline as blood pressure and cardiac output are reduced.

Jeffrey Dwyer, PhD, Clinical Specialist in Cardiology at Kaiser Permanente.
Figure 3. Identification of the ventilatory threshold (VT) by the V-Slope method. Patients with heart failure demonstrate a change in the V-Slope at a lower $\dot{V}O_2$.

Jeffrey Dwyer, PhD, Clinical Specialist in Cardiology at Kaiser Permanente.
Figure 4. Ventilatory response ($V_E$) as a function of $VCO_2$ ({$V_E/VCO_2$} slope) during incremental exercise in normal and patients with mild or moderate heart failure.

Figure 5. Response of heart rate and oxygen-pulse (analog of stroke volume) to progressively increasing work rate in a normal subject (left panel) and in a patient with hypertrophic cardiomyopathy (HCM; right panel).

Figure 6. Profile of the ventilatory response as a function of $\dot{V}CO_2$ during incremental exercise in a normal subject and a patient with heterotrophic cardiomyopathy (HCM). Note the high slope in the patient.

Figure 7. Kaplan-Meier analysis for one-year cardiac-related hospitalization using \( \dot{V}E/\dot{V}CO_2 \) slope threshold of 34.

Cardiac Hospitalization

Event Free Status

Months

Figure 8. Flow-Volume loops measured at peak exercise in a normal trained subject (A). Patient B reported limiting dyspnea and ventilated low in the FVC where forced expiratory efforts encountered increasing resistance from progressively collapsing smalls airways. Patient C reported dyspnea described as inability to get a full breath. He ventilated high in the FVC and performed a high degree of elastic work, terminating inspiration near TLC.

Jeffrey Dwyer, PhD, Clinical Specialist in Cardiology at Kaiser Permanente.
Figure 9: Exercise responses in normal subjects (N) and patients (P) with respiratory chain deficiency myopathy (RCM). Patients have: (A) lower peak $\dot{V}O_2$, work capacity, and slope of $\triangle \dot{V}O_2/\triangle$ work; (B) reduced slope of $\dot{V}O_2$/HR; (C) ventilation threshold (anaerobic threshold) at a lower $\dot{V}O_2$; and (D) steeper $\dot{V}E/\dot{V}CO_2$ slope.

Jeffrey Dwyer, PhD, Clinical Specialist in Cardiology at Kaiser Permanente.