Cardiopulmonary Exercise Testing
An Idea Whose Time Has Almost Come

Cardiopulmonary exercise testing (CPX) is rooted in a classic view of the heart, lungs, and circulation functioning together during exercise to accomplish gas exchange while maintaining the internal milieu. Disorders of this integrated unit are distinguished by analysis of expired gases, which has become practical with the advent of computerized metabolic carts. By virtue of simultaneous assessment of ventilatory and circulatory reserves, CPX is unique in its ability to identify the mechanism of limitation in patients with exercise intolerance.1,2

It is noteworthy that this interdisciplinary field is emerging in the present era of subspecialization. Cardiologists have come to take a rather narrow view of exercise testing, engulfed as we are in the explosion of technology for evaluation and treatment of ischemic heart disease. However, interest in CPX is growing, particularly among students of heart failure, which has been re-examined during the past decade in its own classic terms, as a disorder of gas transport.2

The problem with CPX today is that diverse groups have brought a variety of methods and biases to the field, with no universally accepted guidelines for testing and interpretation. We have numerous treadmill and bicycle protocols, with 1, 2 and 3 minute stages or continuous ramping. Wasserman and colleagues1 suggest that the protocol should be flexible, aiming for a test duration of 8 to 12 minutes, but many laboratories cling to standardized protocols that clearly are not suitable for all subjects. We have varying definitions of key parameters. For example, VO2max can be identified with or without various plateauing criteria, and can be corrected for body size in several ways. Normal values vary from laboratory to laboratory. Does this reflect inherent biologic variability, true differences between local populations, or disparate methodologies?

Which test parameters are most useful in differential diagnosis? In the comprehensive and well-reasoned approach of Wasserman’s group,1 three primary variables are considered in sequence. Low peak VO2 (with evidence of lactic acidosis), low anaerobic threshold (AT) and normal breathing reserve (BR) reflect circulatory limitation, whereas a low VO2-normal AT-low BR pattern indicates ventilatory limitation. Various secondary parameters are then used to confirm and extend the diagnosis. For example, elevation of Ve/Vco2 distinguishes pulmonary vascular disease (and congestive heart failure) from other circulatory disorders. Similarly, a low O2-pulse separates structural heart disease, pulmonary vascular disease and anemia from chronotropic incompetence and peripheral vascular disease. Among ventilatory disorders, indices of ventilation-perfusion mismatching set lung diseases apart from chest wall deformities, respiratory muscle weakness and chronic metabolic acidosis. Likewise, a high Ve/Vco2 distinguishes lung disease and metabolic acidosis from the other disorders.

These principles appear straightforward, at least for analysis of isolated lesions, but a number of questions remain. What are the implications of mixed results (low VO2-low AT-low BR pattern) in patients with concurrent heart and lung disease? Some of these patients may have true ventilatory limitation, but others potentially could respond to cardiovascular therapy if their anaerobic threshold can improve or if chronic pulmonary congestion contributes to their high Ve/Vco2.1 Does the pattern of gas exchange at maximal exercise always explain the symptoms experienced during daily activities? Which test parameters best predict the response to therapy and what is their sensitivity and specificity? To what extent is the analysis of ventilation weakened by our inability to measure the work of breathing?

In this issue (see page 263) Eschenbacher and Mannina present a new algorithm for test interpretation. They have added Ve/Vco2, O2 saturation, heart rate response and ischemia as primary decision points and they have rearranged the other variables. The authors are to be commended for presenting a new algorithm which, hopefully, will stimulate further discussion. A detailed critique cannot be accommodated here, but a few general observations should be made. First, the proposed algorithm considers circulatory and ventilatory defects separately. This scheme seems less powerful than Wasserman’s unified approach. In addition, Eschenbacher and Mannina do not fully exploit the diagnostic potential of individual parameters. As a result, their overall approach lacks the focus of the older method and their diagnostic
categories remain comparatively vague.

Beyond these general and partly subjective comments, it is actually difficult to judge with confidence the relative merits of the two algorithms. The problem here is that we lack an adequate database (or any gold standard) with which to determine the predictive value of the test parameters. Furthermore, the variability of normal values clouds the detection of mild disease. Thus, I would contend that no algorithm can be properly validated at the present time.

Clearly, it is time for a concerted interdisciplinary effort to develop a reasonable and consistent approach to CPX. Selection of a common methodology should be followed by collection of whatever data are needed to establish prospectively the diagnostic potential and limitations of the technique. Such a consensus would be the product of much work and compromise, but it would be well worth the price. Without such an effort, CPX will continue to flourish at selected centers, but it may never gain widespread acceptance as a modern clinical tool.

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REFERENCES

State of the Art of Spirometric Instrumentation

Of the several pulmonary function tests available for identifying and evaluating patients with lung diseases, simple spirometry is one of the most practical and useful. The American College of Chest Physicians, the American Thoracic Society (ATS), and the Association for the Advancement of Medical Instrumentation (AAMI) have all published recommendations for spirometry performance and instrumentation. The obvious impact of these attempts to standardize spirometry has been to improve the quality of the spirometry. With a clear definition of the instrumentation need for spirometry, spirometry manufacturers have developed and modified their instruments to conform with these standards. Initial recommendations came at a particularly opportune time just prior to the proliferation of computerized spirometry systems.

Several studies have evaluated spirometers. In 1980 Gardner et al reported that eight of 12 volume type spirometers and none of seven flow type spirometers performed without any performance difficulties for a total of 8 (42 percent) of 19. Less than half of the spirometers tested in 1980 were computerized. In comparison, in this issue Nelson and colleagues (see page 288) report that only 35 (56.5 percent) of 62 spirometers, 95 percent of which were computerized, performed acceptably. Some of the differences between these two studies can be explained by slightly different testing methods and limits of acceptability.

A comparison of these studies suggests that while there has been a significant increase in the availability of computerized spirometry systems from 1980 to 1989, there has not been an expected corresponding marked increase in quality of these systems. While Gardner et al have demonstrated a significant number of major measurement errors associated with hand measurements, Nelson et al have found that 25 percent of spirometers had software problems, indicating that one cannot assume that the use of computers will eliminate these problems. However, considering that a relatively large number of spirometers that originally failed their tests were later found to be acceptable after software revisions, it is likely that most manufacturers had not rigorously and thoroughly tested their spirometers prior to submitting them to Nelson et al. Therefore, comprehensive performance testing and use of the American Thoracic Society's 24 standard waveforms to test spirometry software should be encouraged and may be critical to the improvement of spirometers available to users. The fact that most spirometers are now able to pass the readily available syringe check procedure is an example of the impact of available testing technology.

There are several potential problems with concluding that the results of Nelson et al completely represent the current performance of spirometers available or in use: (1) the tests conducted by Nelson et al were performed on spirometers specifically selected by the manufacturers and therefore may represent the best instruments rather than the typical newly purchased spirometer or one that has been in use for a number of years; (2) the tests were conducted using room air, whereas a patient's exhaled values must be corrected to BTPS — values as much as 10 percent greater than those using room air. Thus, the results of Nelson et al do not reflect potential spirometer errors in BTPS correction. Errors larger than those reported by Nelson et al can be expected, particularly in the measurement of FEV₁, for which standard BTPS.