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REVIEW

Defining hyperinflation as 'dynamic': Moving toward the slope

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Summary
Measuring the severity of dynamic hyperinflation is a useful clinical approach to assess the effect of therapeutic interventions and explain their impact on exercise tolerance. Dynamic hyperinflation is typically quantified by the change in end expiratory lung volume from rest to the end of exercise. The result may be inconsistent with disease severity and does not clearly explain how exercise tolerance improves with therapy. Using a re-examination of selected studies, we suggest an operational definition of dynamic hyperinflation using the slope derived from serial measures of inspiratory capacity expressed as a linear function of ventilation that clearly differentiates whether therapies affect static or dynamic hyperinflation or affect lung volume only as a consequence of reducing ventilation. With this approach, the magnitude of the result is consistent with disease severity and is a more reliable outcome as it uses serial measures rather than a single time point estimate. The therapies re-evaluated are breathing helium or hyperoxic gas mixtures, bronchodilation and exercise training. A clear definition of dynamic hyperinflation will assist clinicians in assessing the impact of therapeutic interventions.

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Introduction

Measuring the presence and severity of dynamic hyperinflation (DH) is a useful clinical approach to assess the impact of therapeutic interventions on exercise tolerance. Patients with airflow obstruction and consequent gas trapping breathe at high lung volumes (hyperinflation) which requires a greater inspiratory effort to offset threshold and elastic loads.[1] During the increased ventilation in response to exercise, the operational lung volume dynamically increases intensifying exertional dyspnea until it becomes disabling.

It is common practice to identify and quantify DH from the maximum change in end expiratory lung volume (EELV). However, the maximum change in EELV may be inconsistent with the severity of the disease. Moreover, a second step of determining the EELV measured at a single point such as iso-time or iso-ventilation is often necessary to evaluate the intervention under the same physiological condition. Limiting the analysis to one data point diminishes the precision of the estimated effect.

Another approach is to use an operational definition of DH as the slope of the regression of lung volume as a function of ventilation.[1–3] The idea that EELV is a function of ventilation is one of the basic cornerstones of respiratory physiology and has been known for a number of years.[4,5] Using the slope of this regression line has the advantage of: i) being consistent with disease severity; ii) enabling both the qualification of whether DH is present and the quantification of how much of a change has occurred; iii) helps clinicians distinguish interventions that reduce ventilation or resting lung volumes from those that directly affect DH. Nevertheless, in the absence of guidelines for standardization of IC measurement and interpretation, DH summarized by a point estimate prevails in the interpretation of research studies and the directions given for analyzing clinical exercise tests.[6]

We have previously reported the use of the 'slope method' to identify static (defined by the intercept) and dynamic (defined by the slope) hyperinflation to show that improved exercise performance after lung volume reduction surgery may be attributable to static (change in the intercept) as well as dynamic (change in the slope) effects.[7] In the present communication, we discuss the measurement of DH using a re-examination of published clinical examples such as breathing helium and hyperoxic gas mixtures, bronchodilation and exercise training that support using multiple data points to identify DH from a regression of EELV against ventilation.

Measuring dynamic hyperinflation

A sample recording of a patient's breathing is shown in Fig. 1. At rest inspiratory capacity (IC) was obtained by the patient inspiring from EELV to total lung capacity (TLC). A reduced inspiratory reserve volume (IRV) of 600 ml was observed. During exercise, both tidal volume and EELV increased thereby further reducing the IRV such that little remained at end exercise. The operational lung volume increased as ventilation increased during exercise.

Dynamic hyperinflation has typically been defined as an increase in EELV derived from a single independent measure of IC, usually near the end of exercise.[3] To compare results between tests, investigators often endeavor to qualify these findings based on a different point such as iso-time or iso-ventilation. Defining DH as a single time-dependent point estimate makes it difficult to compare DH between tests in which exercise time or peak ventilation might vary and measurements at iso-time are less precise.[2] Hyperinflation during exercise is only time dependent inasmuch as ventilation increases with time; otherwise, DH is independent of time. For example, Weigt et al. noted that if ventilation was increased and kept constant at a higher level with metronome paced breathing, EELV increased only while minute ventilation increased and did not progress when ventilation was constant.[8]

Alternatively, in the slope method to assess DH, the slope is derived from serial measures of IC expressed as a linear function of ventilation.[1–3] Ventilation is chosen as the independent variable over other parameters such as breathing frequency, as it represents the overall response i.e. EELV depends on the components of frequency, tidal volume and duty cycle.[9] This method improves precision because it is based upon multiple samples. It has the advantage of not requiring the subject to reach the same exercise time, power output or ventilation on each occasion in order to assess the effect of an intervention or disease progression.[2] Another advantage is that it is concordant with disease severity. For example, a patient with mild COPD who exercises to 100% predicted power during incremental exercise may increase ventilation from