pulmonary physiologic test of the month

Body Plethysmography in the Evaluation of Intrathoracic Airway Abnormalities*

Mauricio A. Reinoso, M.D., F.C.C.P.; James R. Jett, M.D., F.C.C.P.; and Kenneth C. Beck, Ph.D.

A patient with a previously unsuspected intrathoracic tracheal malignancy presented with symptoms suggestive of asthma and an unusual pattern seen by conventional PFTs. Reduced expiratory flows with a large difference between FVC and SVC, normal inspiratory flows and high MVV/FEV, were found. Body plethysmography using normal and panting efforts with increasing tidal volume and flow helped define the lesion as a variable intrathoracic obstruction and document its regression after palliative therapy.

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This article reports a patient with a previously unsuspected intrathoracic tracheal malignancy who presented with symptoms suggestive of asthma and an unusual PFT pattern.

CASE REPORT

A 43-year-old woman complained of persistent respiratory symptoms after an acute episode of a viral-like illness. She first developed nasal congestion and sinus tenderness three weeks earlier, followed by aching chest discomfort, shortness of breath and wheezing that required hospital admission. Despite the continued use of an inhaled β-agonist, prednisone and doxycycline, she had to be readmitted three days later due to exacerbation of her symptoms. The patient was then referred to our institution for further assessment.

She had a 16-pack-year smoking history, but no prior history of asthma, atopy, recurring respiratory infections or weight loss. Significant physical findings included the presence of expiratory wheezes. No respiratory distress, cyanosis, clubbing or lymphadenopathy were noted.

A chest roentgenogram and PFTs were ordered. On initial presentation to the pulmonary function laboratory, the expiratory flows were severely reduced during the FVC maneuver (FEV₁, 0.51 L; FVC, 1.22 L) with no improvement following use of an inhaled bronchodilator. The inspiratory flows were normal (Fig 1). The MVV also was severely reduced (MVV, 40 L/min), but the MVV/FEV₁ was 80. A large difference between the SVC (SVC, 4.16 L; 112 percent of predicted) and the FVC (FVC, 1.22 L; 33 percent of predicted) was noted. Carbon monoxide diffusing capacity was normal (DCO 23 ml·mmHg·min⁻¹·L⁻¹; 94 percent of predicted). Expiratory stridor was noted while the patient was performing the tests.

The large difference between FVC and SVC, the severely reduced expiratory flows with normal inspiratory flows and the high MVV/FEV₁ ratio were unusual findings that prompted further investigation. Airway resistance studies were performed in the body plethysmograph using panting with increasing tidal volumes to create Vm vs Pa loops. During normal panting maneuvers, Raw was at the upper limit of normal. During larger tidal volume panting, a dramatic plateau developed in expiratory flow, and calculated Raw was increased compared with values obtained during normal panting (Fig 2). Respiratory rate was not controlled but was probably between 1 and 3 breaths per second in all panting maneuvers.

*From the Division of Thoracic Diseases and Internal Medicine, Mayo Clinic and Mayo Foundation, Rochester, Minn.

Reprint requests: Dr. Beck, Mayo Clinic, Rochester, MN 55905

FIGURE 1. Spirometry obtained on the initial visit. Flow vs volume curves during forced expiration and inspiration (thick lines) and a slow expiration (thin line).
A chest roentgenogram revealed a right paratracheal mass and a small area of interstitial infiltrate in the right upper lobe. Subsequent bronchoscopy demonstrated a squamous cell carcinoma of the distal trachea that virtually obstructed the right main stem bronchus and obscured the carina, with no evidence of tumor in the remainder of the bronchial tree. Based on these changes, she was not thought to be a surgical candidate and radiation therapy was recommended. She developed respiratory distress requiring intubation before starting radiation therapy. At that point, repeat bronchoscopy was performed and a combination of Nd:YAG laser therapy and debridement with forceps opened the distal trachea to a 10-mm orifice and the right main stem bronchus to a 6-mm orifice.

A few days later the patient was extubated and repeat PFTs showed improvement in expiratory flows with little change in the inspiratory flows (FEV1, 1.5 L; FVC, 3.9 L). The patient was treated on a protocol with accelerated hyperfractionated external thoracic radiation (total, 6,000 cGy) and two courses of etoposide-cisplatinum. She completed this therapy uneventfully. Three months later she was asymptomatic and had resumed her normal activities; the expiratory flow limitation was completely reversed (Fig 3). Repeat plethysmography showed normal Raw and a change in shape of the Vm vs Pa loops to normal, even during large tidal volume panting (Fig 4). Bronchoscopy performed during a subsequent visit confirmed the patency of the airway and no evidence of any residual disease.

**Discussion**

This case illustrates the utility of plethysmography in evaluating cases of central airway abnormalities. Our patient presented with complaints consistent with hyperreactive airways, but results of PFTs suggested a variable intrathoracic upper airway obstruction which was confirmed later by flexible fiberoptic bronchoscopy.

Spirometry revealed an unusual pattern with a large difference between SVC vs FVC and MVV/FEV1 of 80, a ratio greater than the one observed in expiratory flow limitation due to COPD (35 to 40).1 As has been noted for variable intrathoracic obstructions,2,3 the shape of the maximal forced expiratory flow-volume loop was consistent with either severe COPD or a variable intrathoracic upper airway lesion. A large difference between FVC and SVC maneuvers has been described before in a study of main stem bronchial lesions.3 The reduced FVC in our patient suggests total obstruction of the airway during a forced maneuver, whereas less forceful expiration (ie, SVC) generating lower intrathoracic pressure allows more complete emptying. The larger than expected MVV also supports the concept of higher expiratory flows during the MVV effort compared with the FVC, which could occur with an intrathoracic upper airway lesion if intrathoracic pressure generation is less during the MVV compared with the FVC.4

Although determination of Raw can be a useful measure of airway function, the appearance of the Vm vs Pa loop can yield additional important information.5,6 In this case, during the initial visit (Fig 2),

**Figure 2.** Body plethysmography on the initial visit. Flow vs Pa curves during normal panting (top panel) and panting with increasing effort (bottom two panels). Note the relative normal Raw during normal panting and the plateau in flow during more vigorous panting. Calculated Raw values increased to 2.70 (center panel) and 10.4 cm H2O/L/s during more vigorous panting.

**Figure 3.** Spirometry obtained after three months, following Nd:YAG laser and radiation therapy. Flow vs volume curves during forced expiration and inspiration are within normal limits.
After treatment of the obstructing malignancy, the expiratory flow vs volume loop became virtually normal (Fig 3) and the Vm vs Pa loops also returned to normal (Fig 4). During normal panting, the loops were narrow and gave a resistance value of 0.7 cm H2O/L/s. During panting with larger tidal volumes and flows, the loop became wider, in part due to temperature and humidity changes in the plethysmograph caused by the larger tidal volumes, but there was no evidence of expiratory flow limitation as noted in the initial examination.

In summary, our case demonstrated the utility of body plethysmography using panting efforts with increasing tidal volume and flow in sorting out an atypical pattern of variable intrathoracic airway obstruction. A large difference between SVC and FVC and a high MVV/FEV1 ratio on the routine spirometry are clues that should prompt further investigation.

REFERENCES
6 Alpers JH, Guyatt AR. Significance of a looped appearance of the flow: alveolar pressure relationship of the lung as examined by the whole body plethysmograph. Clin Sci 1967; 33:1-10