Saudi Arabia. *Respir Med* 1994;**88**:519-22. http://dx.doi.org/10.1016/S0954-6111(05)80334-8
10. WHO. The energy access situation in developing countries: a review focusing on the least developed countries and sub-Saharan Africa. World Health Organization, 2009
11. Allwood BW, Myer L, Bateman ED. A Systematic Review of the Association between Pulmonary Tuberculosis and the Development of Chronic Airflow Obstruction in Adults. *Respiration* 2013;**86**(1):76-85. http://dx.doi.org/10.1159/000350917
12. Mehrotra A, Oluwole AM, Gordon SB. The burden of COPD in Africa: a literature review and prospective survey of the availability of spirometry for COPD diagnosis in Africa. *Trop Med Int Health* 2009;**14**(8):840-8. http://dx.doi.org/10.1111/j.1365-3156.2009.02308.x
13. Teklu B. Bronchial asthma at high altitude, a clinical and laboratory study in Addis-Ababa. *Thorax* 1989;**44**(7):586-7. http://dx.doi.org/10.1136/thx.44.7.586
14. Van Gemert F, van der Molen T, Jones R, Chavannes N. The impact of asthma and COPD in sub-Saharan Africa. *Prim Care Respir J* 2011;**20**:240-8. http://dx.doi.org/10.4104/pcrj.2011.00027

The flow-volume loop in inducible laryngeal obstruction: one component of the complete evaluation

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See linked article by Christensen *et al*. on pg 306

Since the initial description of the flow-volume loop (FVL) by Miller and Hyatt in the early 1970's as a clinical predictor of upper airway obstruction (UAO),[1] its utility in clinical practice has been debated. Early case series' suggested that the FVL might be a sensitive indicator of UAO.[2] Combining the FVL appearance with measurements of the forced mid-expiratory to mid-inspiratory flow ratios (FEF_{50}/FIF_{50}) was reported to separate upper airway lesions into fixed lesions (ratio of 0.85), variable extrathoracic obstruction (ratio of 2.20) with inspiratory limb truncation, and variable intrathoracic obstruction (ratio of 0.32) with expiratory limb truncation.[1] The 2005 guidelines on spirometry emphasise examination of the FVL for evidence of intrathoracic or extrathoracic UAO as an integral part of the interpretation.[3]

The diagnostic utility of the FVL can be variable. Since the FVL requires a maximal inspiratory and expiratory vital capacity manoeuvre, the most common cause of an abnormal FVL is submaximal patient effort or inadequate patient instruction in properly performing the required technique. Numerous conditions consistent with either a fixed or intermittent UAO can be considered for diagnosis or followed post-diagnosis using the FVL appearance and associated spirometric findings such as the FEF_{50}/FIF_{50}. Suspicion should be increased when abnormal test results occur in conjunction with symptoms such as dyspnoea and noisy breathing, or physical examination identifying stridor or wheezing. Diagnostic confirmation of an UAO can be made with airway imaging, laryngoscopy, or bronchoscopy. Anatomic obstructions such as airway tumors, tracheal stenosis, and bilateral vocal cord paralysis are specific disease processes where the FVL can be instrumental in raising suspicions for underlying disease if there is significant flow limitation.[4] However, imaging techniques such as computed tomography (CT) scanning can detect early anatomic lesions without significant flow limitation or FVL findings. Exterior compression of the trachea from goitres or anterior mediastinal masses may demonstrate FVL abnormalities depending upon patient positioning. Upright and supine spirometry with FVL was first advocated in 1984 to predict airway compromise in the supine position but limited combined data supported this approach.[5] After the 1983 publication of the initial series of vocal cord dysfunction (VCD) patients,[6] emphasis has shifted to using the FVL to identify symptomatic episodes of inducible laryngeal obstruction (ILO) due to upper airway disorders such as VCD and exercise-induced laryngeal obstruction (EILO).

Limited data exist on the predictive value of FVL appearance in determining the presence or absence of induced laryngeal obstruction. We previously reviewed inspiratory FVL appearance in our institution and identified 2.6% of properly performed spirometry with repeatable (two of three efforts) inspiratory FVL abnormalities. Of these 69 patients, only 17% had a documented follow-up evaluation. The cause of the abnormal FVL was identified in 52%, which consisted primarily of VCD patients.[7] For most ILOs, the FVL is likely to be normal when testing is performed in an asymptomatic patient. Due to the intermittent nature of VCD symptoms, corresponding inspiratory FVL abnormalities were described in approximately 25% of all reported patients.[8] Additional study of identification of VCD by FVL appearance was poorly predictive when examined by three pulmonologists blinded to patient history or examination.[9] It is very important to distinguish EILO from exercise-induced bronchospasm in elite athletes, and the FVL may be suggestive in these patients. McFadden first described "choking" in seven elite athletes who were eventually diagnosed with VCD after negative asthma bronchoprovocation testing; post-bronchoprovocation FVL abnormalities were seen in all seven patients.[10]

In the study by Christensen *et al*. in this issue of the *PCRJ*,[11] the authors attempted to demonstrate whether the FVL and associated measurements of several inspiratory flows and the FEF_{50}/FIF_{50} ratio

were predictive of EILO, either inspiratory closure of the vocal cords or arytenoid collapse. Pre- and post-exercise spirometry (done immediately after exercise) was done in 100 patients with exertional dyspnoea with 50 from a population-based sampling and 50 elite athletes. Patients with concomitant asthma were not excluded. Using continuous exercise laryngoscopy to evaluate laryngeal movement, 62.2% were reported to have EILO of a moderate/severe degree during exercise. The video laryngoscopic data were obtained from only the last 20 seconds of patients being exercised maximally. Single video frame analyses (the basis of the EILO calculations) do not identify the duration of the glottic closure. Most notably: 1) the FVL data and laryngoscopic findings did not agree; and 2) the agreement by four physicians was poor. Individual assessments also did not correlate with flow and laryngoscopic data (kappa value < 0.00). Laryngoscopy was not continued during the FVL testing and information was not provided on whether patients had either respiratory symptoms or physical examination findings of stridor/wheeze at peak exercise.

It is relatively easy to diagnose patients with intermittent respiratory symptoms when they are examined while symptomatic, have upper airway sounds on examination, a truncated inspiratory FVL, and laryngoscopy with near-complete inspiratory glottic closure persisting over repeated respiratory cycles.[8] What is more problematic is to evaluate the patient with exertional dyspnoea, with no audible wheezing or stridor during exercise, and demonstration of partial closure of the glottis during single video frame calculations. Christensen *et al.*'s study shows an extremely high percentage of "EILO" patients, considering 50% were from population-based screening, and it highlights several crucial problems related to defining and diagnosing EILO.[11] First, a prior study of symptomatic military personnel with exertional dyspnoea only identified VCD in 10% of the population.[12] Second, do the described laryngoscopic findings actually represent a disease process? Previous studies have suggested that abnormal glottic closure – especially in patients with known asthma – may be compensatory and not represent underlying pathophysiology.[13] Third, one would not expect to see FVL changes unless there is a high degree of airway obstruction. The degree of closure of the glottis or arytenoids that was required for "moderate" or "severe" closure (expressed mathematically) was not correlated to reduction in airflow or flow/volume relationship during tidal breathing during exercise. Fourth, correlation of timing of endoscopic findings with symptoms and wheezing/stridor on examination is an important piece of clinical information necessary to make a diagnosis of an EILO. If many of these patients only have incomplete closure, no symptoms, no airway sounds, and a lack of significant FVL findings, do the laryngoscopic findings as reported in the Christensen study represent the definitive cause of their symptoms? Additionally, normal subjects and elite athletes without underlying respiratory pathology undergoing maximal exercise may experience dyspnoea as a limiting symptom to exercise.

Spirometry with FVL measurement is a vital component of the patient evaluation for respiratory symptoms, and when a properly performed FVL test is abnormal it should prompt a thorough investigation. This finding may be helpful in raising awareness of both persistent, fixed anatomic obstructions and episodic inducible laryngeal obstructions. It should not be relied upon as a single diagnostic tool, but must be evaluated in the context of the clinical presentation, including symptoms and physical examination. Additional confirmatory testing such as radiologic imaging, laryngoscopy or bronchoscopy to establish the diagnosis is usually necessary.

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References

1. Miller RD, Hyatt RE. Evaluation of obstructing lesions of the trachea and larynx by flow-volume loops. *Am Rev Respir Dis* 1973;**108**(3):475-81.
2. Harrison BD. Upper airway obstruction – a report on sixteen patients. *QJM* 1976; **45**(180):625-645.
3. Pellegrino R, Viegi G, Brusasco V, *et al*. Interpretative strategies for lung function tests. *Eur Respir J* 2005;**26**(5):948-68. http://dx.doi.org/10.1183/09031936.05.00035205
4. Pavel CR, Morris MJ, Nicholson KL, Hayes JA. Inspiratory flow volume loops and diagnosis of upper airway obstruction. *Clin Pulm Med* 2008;**15**(5):274-82. http://dx.doi.org/10.1097/CPM.0b013e3181857e7c
5. Hnatiuk OW, Corcoran PC, Sierra A. Spirometry in surgery for anterior mediastinal masses. *Chest* 2001;**120**(4):1152-6. http://dx.doi.org/10.1378/chest.120.4.1152
6. Christopher KL, Wood RP, Eckert RC, Blager FB, Raney RA, Souhrada J. Vocal cord dysfunction presenting as asthma. *N Engl J Med* 1983;**308**(26):1566-70. http://dx.doi.org/10.1056/NEJM198306303082605
7. Sterner JB, Morris MJ, Sill JM, Hayes JA. Inspiratory flow volume curve evaluation for detecting upper airway disease. *Respiratory Care* 2009;**54**(4):461-6.
8. Morris MJ, Christopher KL. Diagnostic criteria for the classification of vocal cord dysfunction. *Chest* 2010;**138**(5):1213-23. http://dx.doi.org/10.1378/chest.09-2944
9. Watson MA, King CS, Holley AB, Greenburg DL, Mikita JA. Clinical and lung-function variables associated with vocal cord dysfunction. *Respir Care* 2009; **54**(4):467-73.
10. McFadden ER, Zawadski DK. Vocal cord dysfunction masquerading as exercise-induced asthma: a physiologic cause for "choking" during athletic activities. *Am J Respir Crit Care Med* 1996;**153**(3):942-7. http://dx.doi.org/10.1164/ajrccm.153.3.8630577
11. Christensen PM, Maltbæk N, Jørgensen IM, Nielsen KG. Can flow-volume loops be used to diagnose exercise-induced laryngeal obstructions? A comparison study examining the accuracy and inter-rater agreement of flow volume loops as a diagnostic tool. *Prim Care Respir J* 2013;**22**(3):306-11. http://dx.doi.org/10.4104/pcrj.2013.00067
12. Morris MJ, Grbach VX, Deal LE, Boyd SYN, Morgan JA, Johnson JE. Evaluation of exertional dyspnea in the active duty patient: the diagnostic approach and the utility of clinical testing. *Mil Med* 2002;**167**(4):281-8.
13. Collett PW, Brancatisano T, Engel LA. Changes in the glottic aperture during bronchial asthma. *Am Rev Respir Dis* 1983;**128**(4):719-23.