Normal appearance of a flow-volume loop.

A flow-volume loop is generated by having the patient inhale deeply to total lung capacity (TLC), forcefully exhale until the lungs have been emptied to residual volume (RV), and rapidly inhale to reach TLC. Flow is plotted on the Y axis and the volume on the X axis; a typical loop is shown below. The upper portion of the curve reflects the expiratory portion of the forced vital capacity (FVC) maneuver and is also referred to as the maximal expiratory flow-volume (MEFV) curve. Unlike the flow in the inspiratory portion, the flow during the maximal expiratory maneuver diminishes at the end of the MEFV curve due to shrinking lung volumes. This happens because a decreasing lung volume causes a corresponding decrease in the lung's elastic recoil forces, which keep the airways open during exhalation. This fact has important implications for the flow-volume contour in patients with COPD, where small-airway narrowing secondary to loss of elastic recoil leads to a coved appearance in the terminal portion of the MEFV curve.
Miller and Hyatt defined three classic patterns of flow-volume loop contours in patients with UAO, depending on the location of the obstruction and depending on whether the obstruction was fixed or variable.\textsuperscript{10,11} Fixed lesions are characterized by lack of changes in caliber during inhalation or exhalation and produce a constant degree of airflow limitation during the entire respiratory cycle. A fixed lesion may be extrathoracic or intrathoracic. Its presence results in similar flattening of both the inspiratory and expiratory portions of the flow-volume loop (Figure 3a). Its causes include postintubation strictures, goiters, and tracheal tumors.\textsuperscript{5} Variable lesions are characterized by changes in airway lesion caliber during breathing. Depending on their location (intrathoracic or extrathoracic), they tend to behave differently during inhalation and exhalation. Airway lesions located above the thoracic inlet are not affected directly by changing thoracic pressures during the respiratory cycle. Instead, during inspiration, there is acceleration of airflow from the atmosphere toward the lungs, and the intraluminal pressure decreases with respect to the atmospheric pressure due to a Bernoulli effect. This effect is exaggerated in the presence of an extrathoracic obstructing lesion, resulting in the limitation of inspiratory flow seen as a flattening in the inspiratory limb of the flow-volume loop (Figure 3b). During expiration, the air is forced out of the lungs through a narrowed (but potentially expandable) extrathoracic airway. Therefore, the maximal expiratory flow-volume curve is usually normal. Causes of variable extrathoracic lesions include glottic strictures, tumors, and vocal-cord paralysis.\textsuperscript{5}

Variable intrathoracic constrictions expand during inspiration, causing an increase in airway lumen and resulting in a normal-appearing inspiratory limb of the flow-volume loop. During expiration, compression by increasing pleural pressures leads to a decrease in the size of the airway lumen at the site of intrathoracic obstruction, producing a flattening of the expiratory limb of the flow-volume loop (Figure 3c). Causes of variable intrathoracic lesions include malignant tumors and tracheomalacia.\textsuperscript{5}

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Schematic representation of an extrathoracic variable obstruction. The solid lines represent actual curves, while the dashed line represents a normal inspiratory pattern. Note that with the extrathoracic variable obstruction, exhalation induces a positive intratracheal pressure, which in turn results in little or not resistance to flow past the narrowed segment (top figure). Conversely, inhalation generates negative intrathoracic pressure, which in turn induces negative pressure in the trachea below the point of obstruction. This negative pressure will induce further obstruction and increase resistance to flow (bottom figure).

Schematic representation of an intrathoracic variable obstruction. The solid lines represent actual flow-volume curves, while the dashed line represents the normal expiratory pattern. During exhalation, the transthoracic positive pressure is transmitted to the intrathoracic narrowed segment, which results in an increased resistance to flow (top figure). Conversely, during inhalation, the negative intrathoracic pressure will distend the narrowed segment, resulting in little or no resistance to flow (bottom figure).