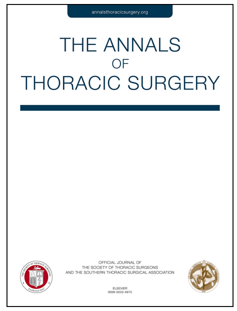

Flow-Volume Curve Analysis For Predicting Recurrence After Endoscopic Dilation Of Airway Stenosis

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Flow-Volume Curve Analysis For Predicting Recurrence After Endoscopic Dilation Of Airway Stenosis

Running title: Flow-volume curve to follow re-stenosis

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ABSTRACT

BACKGROUND: The flow-volume curve is a simple test for diagnosing upper airway obstruction. We evaluated its use to predict recurrence in patients undergoing endoscopic dilation for treatment of benign upper airway stenosis.

METHODS: The data of 89 consecutive patients undergoing endoscopic dilation of simple upper airway stenosis were retrospectively reviewed. Morphological distortion of flow-volume loop (visual analysis) and quantitative criteria including $MEF_{50\%}/MIF_{50\%}<0.3$ or > 1.0; $FEV_1/MEF>10$; and $FEV_1/FEV_{0.5}>1.5$ were considered as predictive of recurrence. In all cases, the recurrence was confirmed by radiological and/or bronchoscopic findings. The sensitivity, specificity, PPV, NPV, and accuracy of visual, quantitative and aggregate criteria for detecting recurrence were computed and compared.

RESULTS: Of89 patients treated, 27 (30%) had a recurrence. Visual analysis presented a sensitivity, specificity, PPV, NPV, and accuracy of 63%; 83.9%; 63%; and 83.9%, and 77.5% respectively. Among the quantitative criterion, the MEF50%/MIF50% was the most accurate having a sensitivity, specificity, PPV, NPV, and accuracy of 77.8%; 79%; 61.8%; and 89.1%, and 78.7% respectively. Aggregate criterion presented the best yield compared to other criteria in terms of sensitivity (81.5%), specificity (91.9%), PPV (81.5%), NPV (91.9%), and accuracy (88.8%).

CONCLUSIONS: The flow-volume curve is a simple and non-invasive method to follow patients undergoing endoscopic dilation of upper airway stenosis. Morphological changes in the flow-volume loop and in the MEF50%/MIF50% ratio are suggestive of recurrence and guide the physician to implement the follow-up with further diagnostic (non)invasive exams.

Endoscopy is a palliative treatment of upper airway obstruction (UAO) in patients unfit for surgery. Stenoses less than 1 cm in length, without cartilaginous involvement or tracheomalacia are defined as simple, and generally treated with radial cuts and mechanical dilation [1]. However, they can recur, and needs additional treatments. Since many of the patients who recur present symptoms at rest when narrowing is marked ($\leq$ 6 mm) [2], to early predict re-stenosis is desirable to avoid emergent treatment. Chest High Resolution Computed Tomography (HRCT) scan and bronchoscopy follow any progression of narrowing process, but they remain expensive and invasive methods. The flow-volume curve is a simple and non-invasive method that graphically records inspiration and expiration flows (on the y-axis) against volume (on the x-axis) obtained while patient performs maximal forced inspiratory and expiratory maneuvers. Miller et Hyatt [3] defined three distinct flattenings of curve depending on whether (i) the stenosis was fixed (plateau on inspiratory and expiratory phase of the curve), (ii) variable intrathoracic (plateau on expiratory phase of the curve), or (iii) variable extrathoracic (plateau on inspiratory phase of the curve). Despite flow-volume curve has been used for decades to assess UAO [4,5,6], its effectiveness for routine follow-up of patients with UAO undergoing endoscopic treatment remains unclear. Yet, in the years some authors [6,7,8,9] have questioned the low sensitivity of morphological distortion of curve to diagnosis stenosis.

Thus, in this study we aimed to evaluate the flow-volume curve as a surveillance tool in patients undergoing endoscopic treatment of UAO and to compare the accuracy of visual and quantitative criteria of the curve to detect recurrence.

MATERIAL AND METHODS

Study Design

It was a retrospective multi centers study including all consecutive patients undergoing endoscopic treatment of benign UAO between January 2013-January 2017. Data were extracted by prospective database of each participating centers. Patients (i) with benign UAO unfit for surgery and undergoing endoscopic dilation; (ii) able to undergo flow-volume curve measurement; and (iii) with complete follow-up for at least 12 months were included. Patients (i) treated with stent insertion as first approach; (ii) not performing flow-volume curve analysis before and after treatment; and (iii) with incomplete follow-up were excluded.

We supposed that flow-volume curve could be a valuable method to predict a re-stenosis after endoscopic dilation. To test it, we evaluated the alteration of visual, quantitative and aggregate criteria of curve in relation to recurrence (dependent variable) and then compared the accuracy of each criterion to identify the most accurate. The flow-volume curves were evaluated by two different physicians who were blinded to the results of follow-up. Discordant results were resolved by a consensus with a third reader. The study design was approved by Local Ethics Committees of University "Luigi Vanvitelli", Naples, Italy, (approval number: 684/18) the coordinator center of the study, and then by each participating center. All patients gave a written informed consent for the treatment of UAO and the follow-up exams.

Study population

Before treatment, all patients performed standard exams including flow-volume curve measurement, chest HRCT and bronchoscopy. The endoscopic treatment was performed in operating room with rigid bronchoscopy. Being simple stenosis, in all cases mucosal sparring technique was performed with radial incisions using scissors or laser, according to the center's preference, followed by dilation with balloon or rigid scope [1]. All patients were then followed with flow-volume measurements, chest CT, and bronchoscopy (if indicated) at 1, 3, 6, 9 and 12 months from the procedure. Patients who were free of symptoms for at least 12 months after the procedure were considered cured. In patients with suspicion of restenosis, follow-up was implement, and the measurements were performed every 4-6 weeks. In all cases, restenosis was documented by chest CT scan and confirmed by bronchoscopy.

Flow-Volume Curve Measurement

The flow-volume curve was measured by expert technicians of each participating center with a previously calibrated plethysmograph. All spirometries were performed in accordance with ATS standards [5], and included a standard forced maximal exhalation, followed by a forced maximal inhalation. The maximum flow-volume curves were plotted on x-y axes: the flow was measured at the mouth and the volume was obtained by integration of the flow. Three such maneuvers were performed and the best effort based on Forced Vital Capacity (FVC) and on Forced Expiratory Volume In The First 1 Second (FEV1) was selected by computer for the analysis.

Visual Criteria: The expiratory and inspiratory flow volume curves were reported from the best expiratory and inspiratory curves, respectively, which were those selected also for quantitative analysis. Visual alteration of loop were differentiated in three groups according to the classification of Miller et Hyatt [3]: (i) flattening on inspiratory and expiratory phase (fixed stenosis); (ii) flattening on the inspiratory phase (variable extra-thoracic stenosis); and (iii) flattening on the expiratory phase (variable intra-thoracic stenosis)

Quantitative criteria: based on previous experiences [3,7,8], the following quantitative criteria to predict the restenosis were evaluated:

- Maximal Expiratory Flow Rate At 50% Of The Vital Capacity/ Maximal Inspiratory Flow Rate At 50% Of The Vital Capacity (MEF50%/MIF50%): <0.30 or >1 (Miller et Hyatt index [3])

- Forced Expiratory Volume in the first 1 second/Maximal Expiratory flow (FEV1/MEF) > 10 ml/L/min (Empey index [7])
- Forced Expiratory Volume In The First 1 Second/ Forced Expiratory Volume In The First 0.5 second (FEV1/FEV0.5) > 1.5 (Rotman index [8]).

Aggregate Criterion: The quantitative criterion with the first-highest accuracy was associated to visual criterion to generate aggregate criterion. When both criteria were negative or positive, the aggregate criterion was considered as negative or positive, respectively; in cases of discordant results (one criterion negative and the other positive), to establish the correct response we also considered the quantitative criterion with the second-highest accuracy. Since all criteria were described such as dichotomous variables (1=positive, 0=negative), in all cases the aggregate criterion was obtained using a mathematical model based on Boolean algebra [9], defined by one of the authors (N.S.):

$$F = A \times B + C \times (A + B)$$

where: F=Aggregate criterion, A=Visual criteria, B=Quantitative criterion with the first-highest accuracy, and C=Quantitative criterion with the second-highest accuracy.

Statistical Analysis

Data were expressed as mean ± Standard Deviation (SD) for continuous variables; and as absolute number and percentage for categorical variables. Significant difference between two means was evaluated by the Student's t-test. Sensitivity, specificity, Positive Predictive Value (PPV), Negative

Predictive Value (NPV) and diagnostic accuracy of visual, quantitative, and aggregate criteria (independent variables) for predicting recurrence (dependent variable) were computed in a standard manner. To compare the diagnostic yield of each criterion, the multiple comparison with chi-square test followed by Z-test (post-hoc test) were performed. A value of $p<0.05$ was considered statistically significant. MedCalc statistical software (Version 12.3, Broekstraat 52;Mariakerke, Belgium) was used for this analysis.

RESULTS

In the study period, 285 patients with benign tracheal stenosis were endoscopically treated. Of these, 196 patients were excluded due to the stent insertion after dilation (n=101) or lack of available data on flow-volume curves (n=95). Thus, 89 patients were included in the analysis (Table 1). The mean age was 73±6.9 year-old. The main cause of stenosis was post-intubation (57%). Cardiac disease (44%), cerebral disease (31%), respiratory disease (22%) and drug abuse (3%) were the main comorbidities that contraindicated surgery. In all cases, the stenosis was simple with a length of 8±1.3mm, distance from vocal folds of 27±3.9mm, and diameter of 6±3.7mm that reduced ≥ 75% the tracheal lumen. After dilation, the airway diameter significantly increased (from 6±3.7 mm to 14±6.7 mm; p=0.0003) without any complications. In 27 (30%) patients the stenosis recurred 7±4.3 months later. Of these, 19/27 (70%) presented dyspnea at rest and stridor (airway diameter: 6.5±1.3mm), while 8/27 (30%) had dyspnea at mild-moderate effort (airway diameter: 8.9±2.7mm). They were re-treated with endoscopic dilation alone (n=15), dilation followed by stent insertion (n=10), and surgery (n=2).

Visual Analysis Of Flow-Volume Curve

Before dilation, the loop showed a flattening (i) on inspiratory and expiratory phase in 27 (30%) patients (fixed stenosis); (ii) on inspiratory phase in 35 (39%) (variable extrathoracic stenosis); and

(iii) on expiratory phase in 15 (17%) (variable intrathoracic stenosis). The remaining 12 (14%) patients presented aspecific changes as absence, truncate inspiratory loop or biphasic expiratory loop. Examples are reported in Figure 1.

Patients with recurrence (n=27): After dilation, visual analysis correctly identified the recurrence in 17 (63%) patients (true positive results), and in the most of cases (15 of 17; 88%) the flattening was suggestive of fixed stenosis. In all cases, a mild flattening was present 3 months after dilation, when clinical symptoms are not present. Then, the flattening become more evident at 4, 5, 6 months of follow-up in correlation with the reduction of tracheal diameter seen on HRCT scan and bronchoscopy. Finally, it was well marked concurrent with dyspnea at rest. An example is reported in Figure 2. In 10 (37%) patients, no alteration (n=8) or aspecific alterations of the loop (n=2) were observed (false negative results); of these, 8 presented dyspnea at mild-moderate effort.

Patients without recurrence (n=62): Among 62 patients without recurrence, in 52 (83.9%) cases an improvement of the loop was observed and maintained for the entire follow-up (true negative results). They were followed 1, 3, 6, 9, 12 months, and no increase of measurements was applied during the surveillance. Also in these cases, the improvement of curve was correlated with the increased diameter of trachea seen on HRCT and bronchoscopy. All patients were asymptomatic. An example is reported in Figure 3. The remaining 10 patients (16.1%) presented aspecific distortion of the loop (false positive results).

The sensitivity, specificity, PPV, NPV, and diagnostic accuracy of visual analysis were 63%; 83.9%; 63%; and 83.9%, and 77.5% respectively.

Quantitative Analysis of Flow-volume curve

The results are summarized in Table 2.

Among patients with recurrence (n=27), the MEF50%/MIF50%; FEV1/MEF, and FEV1/FEV0.5 index were positive in 21 (77.8%); in 10 (37%); and in 8 cases (29%), respectively.

Among patients without recurrence (n=62), the MEF50%/MIF50%; FEV1/MEF, and FEV1/FEV0.5 index were negative in 49 (79%); in 30 (48%); and in 23 cases (37%), respectively.

Aggregate Criterion Of Flow-Volume Curve

The aggregate criterion presented 17 positive results among 27 patients with recurrence and 49 negative results among 62 patients without recurrence where Visual criterion and MEF50%/MIF50% (quantitative criterion with first highest-accuracy) were concordant. In the remaining cases with discordant results (10 among patients with recurrence and 13 among patients without recurrence), the aggregate criterion identified 5 of 10 patients with recurrence and 8 of 13 patients without recurrence. The patients with or without recurrence were individuated according to above reported model:

Aggregate Criterion= (visual criterion x MEF50%/MIF50%) + (FEV1/MEF) x (visual criterion + MEF50%/MIF50%)

Considering all results, aggregate criterion was positive in 22 of 27 patients with recurrence (81.5%) and negative in 57 of 62 patients without recurrence (91.9%). The sensitivity, specificity, PPV, NPV, and accuracy were 81.5%; 91.9%; 81.5%; and 91.9%, and 88.8% respectively (Table 2).

Comparison among each individual criterion

Multi-comparison test showed for sensitivity, specificity, PPV, NPV, and diagnostic accuracy a significant difference among Visual Analysis, MEF50%/MIF50%, FEV1/MEF, FEV1/FEV0.5 and Aggregate Criterion ($p<0.0001$). Post hoc test showed that (i) for sensitivity, the Aggregate

Criterion presented the higher value than others (p=0.0257), while FEV1/FEV0.5 had the lower value (p=0.0081); (ii) for specificity, the Aggregate Criterion (p=0.0003) and Visual Analysis (p=0.017) presented the higher value while FEV1/MEF (p=0.003) and FEV1/FEV0.5 (p<0.0001) the lower values; (iii) for PPV, the Aggregate Criterion presented the higher value (p=0.0003), while FEV1/FEV0.5 the lower value (p=0.0014); (iv) for NPV, the Aggregate Criterion presented the higher value (p=0.0259) while FEV1/MEF (p=0.0234) and FEV1/FEV0.5 (p=0.0005) the lower values; and (v) for Accuracy, the Aggregate Criterion (p<0.0001), Visual Analysis (p=0.0261) and MEF50%/MIF50%(p=0.0153) presented the higher values, while FEV1/MEF (p=0.0004) and FEV1/FEV0.5 (p<0.0001) the lower values.

COMMENT

Visual distortion of flow-volume curve is the most simple and used parameter to diagnose UAO. However, its diagnostic accuracy could be affected by the quality of flow-volume and variability of interpretations by physicians, thus several authors proposed quantitative indexes to overcome these limits [6-8,10-11]. However, no papers, before the present, have compared the diagnostic yield of visual, quantitative and aggregate criteria to detect recurrence during the surveillance of patients endoscopically treated for UAO.

First, in agreement with previous papers [6,12-18], we found that visual analysis presented high specificity (84%), but low sensitivity (63%). Among patients with recurrence, it correctly detected the re-stenosis in 17 (63%) cases; after treatment, in the most of patients (88%) the loop was flattened on inspiratory and expiratory phase (fixed stenosis) while in 56% of these cases it presented a flattening on inspiratory or expiratory phases (variable stenosis) before treatment. The structural changes in stenotic scar as a result of dilation could explain these differences. Before dilation, the scar was less dense, and, thus, sensible to transmural forces that reduced the inspiratory flow rather than the expiratory flow in extrathoracic obstruction or vice versa in intrathoracic obstruction. After dilation, the formation of fixed scar produced a constant degree of airflow limitation, resulting in a similar flattening on inspiratory and expiratory phase of the loop. Interestingly, in all cases a mild flattening was present in the early follow up before symptoms but it become more evident in relation to the progression of airway narrowing. Similarly, previous studies evaluated the flow volume curves generated by normal subjects breathing through progressively smaller artificial orifices and found that flow-volume curve distortion were reflective oforifices caliber [2]. In 10 cases without recurrence, we observed aspecific alterations of loop. Sterner et al. [6] found that nearly 50% of 2.662 flow-volume curves presented similar aspecific inspiratory alterations, not associated with airway obstruction. These abnormalities could be due to different pre-existing disease as dysfunction of vocal folds, gastro-esophageal disease, Chronic Obstructive Pulmonary Disease (COPD), allergic rhinitis or flaccidity of anterior tracheal wall that reduced the inspiratory flow with consequent absence or truncation of inspiratory loop. In 10 of 27 (37%) patients with recurrence, no flattening of the loop was present. Similarly, a normal loop was reported by Gamsu et al. [12] in 4 of 21 patients with stenosis. In theory, the low degree of stenosis (80% of these patients did not present severe symptoms of UAO) could be insufficient to produce a marked limitation of flow rates.

Second, in line with previous studies [3,8,14-18], MEF50%/MIF50% ratio was the most sensitive quantitative parameter, and correctly identified 21 out of 27 (78%) patients with recurrence. In the most of fixed stenosis (16 of 21; 76%), the value of MEF50%/MIF50% ratio was between 1 and 1.5, since the fixed scar similarly reduced MIF50% and MEF50%. In the remaining 5 of 21 (24%) cases, MEF50%/MIF50% value was > 1.5; in theory, normal tracheal segments between the lesion and thoracic outlet to negative intraluminal pressures tended to close the airway during inspiration [12], with consequent reduction of MIF50% rather than MEF50%. Das et al. [14] found higher sensitivity of MEF50%/MIF50% (85%) for detecting injury due to laryngotracheitis while Miller et al. [19] lower value of the same index (31%) for diagnosing UAO due to a goiter. However, the different etiologies of extrathoracic airflow obstruction between our and other series make difficult any comparison. FEV1/MEF ratio presented the second-highest accuracy; it correctly identified the recurrence in 10 of 27 (37%) cases while Empey et al. [7] found higher value. In theory, our low sensitivity could be due to the coexisting presence of COPD and emphysema that reduced FEV1 more than MEF [20]. Similarly, Gelb et al. [21] found that the improvement of loop after airway re-canalization was significantly masked by the obstruction of smaller airway in COPD and emphysematous patients. In theory, the FEV1/FEV1 0.5 index could be used to differentiate the flow-volume curve abnormalities due to smaller airway obstruction from those due to UAO [22], but in our series it was unable to obtain this effect due to its low sensitivity and specificity.

Third, in line with other papers [15,23,24] no significant difference was found between visual and quantitative criteria while aggregate criterion presented the best accuracy.Among 10 patients with restenosis but without visual alteration of curve, 5 had positive aggregate criterion with consequent improvement of sensibility to 81.5%. Conversely, among 10 patients without restenosis but with visual alteration of curve, 5 had negative aggregate criterion with consequent improvement of specificity to 91.9%. In theory, the quantitative criteria used for generating aggregate criterion balanced the subjective variability of visual criterion. Similarly, Modrykamien et al. [18] found that the aggregate criterion increased the sensitivity to 69.4% for predicting UAO compared to that of quantitative and visual criteria alone. However, in Modrykamien's study [18] visual and quantitative criteria presented lower sensitivity than that observed in our study. These differences could be explained by the high number of COPD patients who masked UAO on the flow-volume loop and/or by potential under diagnosis of UAO since not all patients performed endoscopy and/or imaging check [18].

Since flow-volume curve presented a good correlation with radiological and endoscopic findings, it could be an alternative option to CT scan and/or bronchoscopy in the surveillance of patients treated for UAO. Patients with normal follow-up loop could delay to perform CT and/or bronchoscopy; this strategy may be very useful in the settings where these procedures are least available i.e. rural settings, far distance for CT scan centers and specialists. Yet, the reduction of CT scan done reduced the cancer risk related to radiation exposure and health care cost considering that the cost of flow-volume curve is three folds lower than that of CT (40 Euros versus 150 Euros). In line with this tendency, Brenner and Hall [25] analyzed the current trend to increased use of CT scan imaging and reported that one third of CT scan could be avoided or replaced with a different diagnostic tool. Conversely, in patients with early modification of follow-up flow volume curve, the measurements during the surveillance should be implemented (i.e. every 4-6 weeks). Despite patients do not come to endoscopic intervention until they have symptoms, however the early diagnosis of re-stenosis before symptoms could avoid an emergent and challenging treatment considering that exertional dyspnea occurs when the airway diameter is reduced to about 8 mm while resting dyspnea and stridor at a diameter of 5 mm [26].

Obviously, our results should be evaluated with cautious due to the retrospective nature of the study, the lack of a standardized protocol, and the measurements of curve performed and analyzed by different technicians and physicians being a multicenter study. In conclusion, Flow-volume curve is a simple and non-invasive method to follow-up patients treated for UAO and its routine use could reduce the number of follow-up CT scan, and bronchoscopy done in patients with normal loops. However, prospective and larger studies are needed to confirm our impressions.

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Table 1. Study population (n=89)

Variables	**Number (%)**
Age	73±6.9
Sex (M/F)	55 (62%)/34(38%)
Etiology of stenosis • *Idiopathic* • *Post-intubation* • *Post-tracheostomy*	 3 (4%) 51 (57%) 35 (39%)
Comorbidities contraindicating surgery • *Cardiac* • *Cerebral* • *Respiratory* • *Drug Abuse*	 39 (44%) 28 (31%) 20 (22%) 2 (3%)
Characteristics of the stenosis • *Distance from vocal folds (mm)* • *Diameter (mm)* • *Length (mm)*	 27±3.9 6±3.7 8±1.3
Diameter after dilation	14±6.7
Recurrence of stenosis	27 (30%)
Treatment of recurrence • *Dilation alone* • *Stent insertion* • *Surgery*	 15 (55%) 10 (37%) 2 (8%)

Table 2. Diagnostic yield of flow-volume curve criteria

Variable	**Sensitivity**	**Specificity**	**PPV**	**NPV**	**Diagnostic accuracy**
Visual Analysis	63.0% (42.3-80.3)	83.9% (72.3-91.9)	63.0% (44.9-75.9)	83.9% (76-89.7)	77.5% (67.2-85.5)
MEF50%/MIF50% Miller et Hyatt index [3]	77.8% (57.7-91.3)	79.0% (66.8-88.3)	61.8% (48.4-72.8)	89.1% (80.2-94.4)	78.7% (68.5-86.5)
FEV1/MEF Empey index [7]	37.0% (19.4-57.6)	48.4% (35.4-61.4)	23.8% (15-34.7)	63.8% (54.9-72.5)	44.9% (34.5-55.8)
FEV1/FEV0.5 Rotman index [8]	29.6% (13.7-25.1)	37.1% (25.1-50.3)	17.0% (9.8-27.1)	54.8% (45-64.8)	34.8% (25.2-45.6)
Aggregate Criterion	81.5% (61.9-93.7)	91.9% (82.1-97.3)	81.5% (64.7-91)	91.9% (83.9-96.2)	88.8% (79.9-94.5)

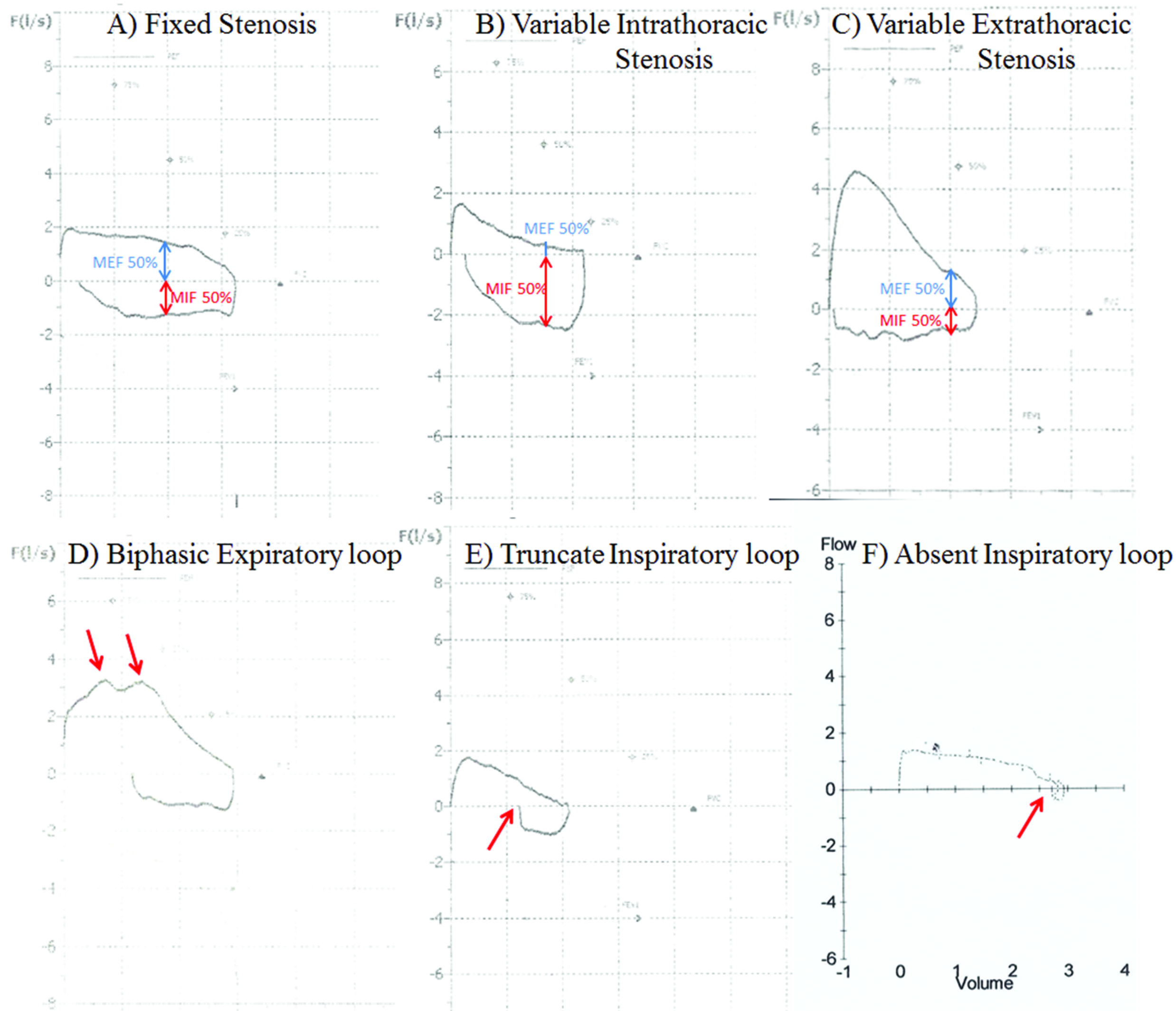
Abbreviations: MEF50%/MIF50%=Maximal Expiratory Flow Rate At 50% Of The Vital Capacity/ Maximal Inspiratory Flow Rate At 50% Of The Vital Capacity; FEV1/MEF=Forced Expiratory Volume in the first 1 second/Maximal Expiratory flow; FEV1/FEV0.5=Forced Expiratory Volume In The First 1 Second/ Forced Expiratory Volume In The First 0.5 second

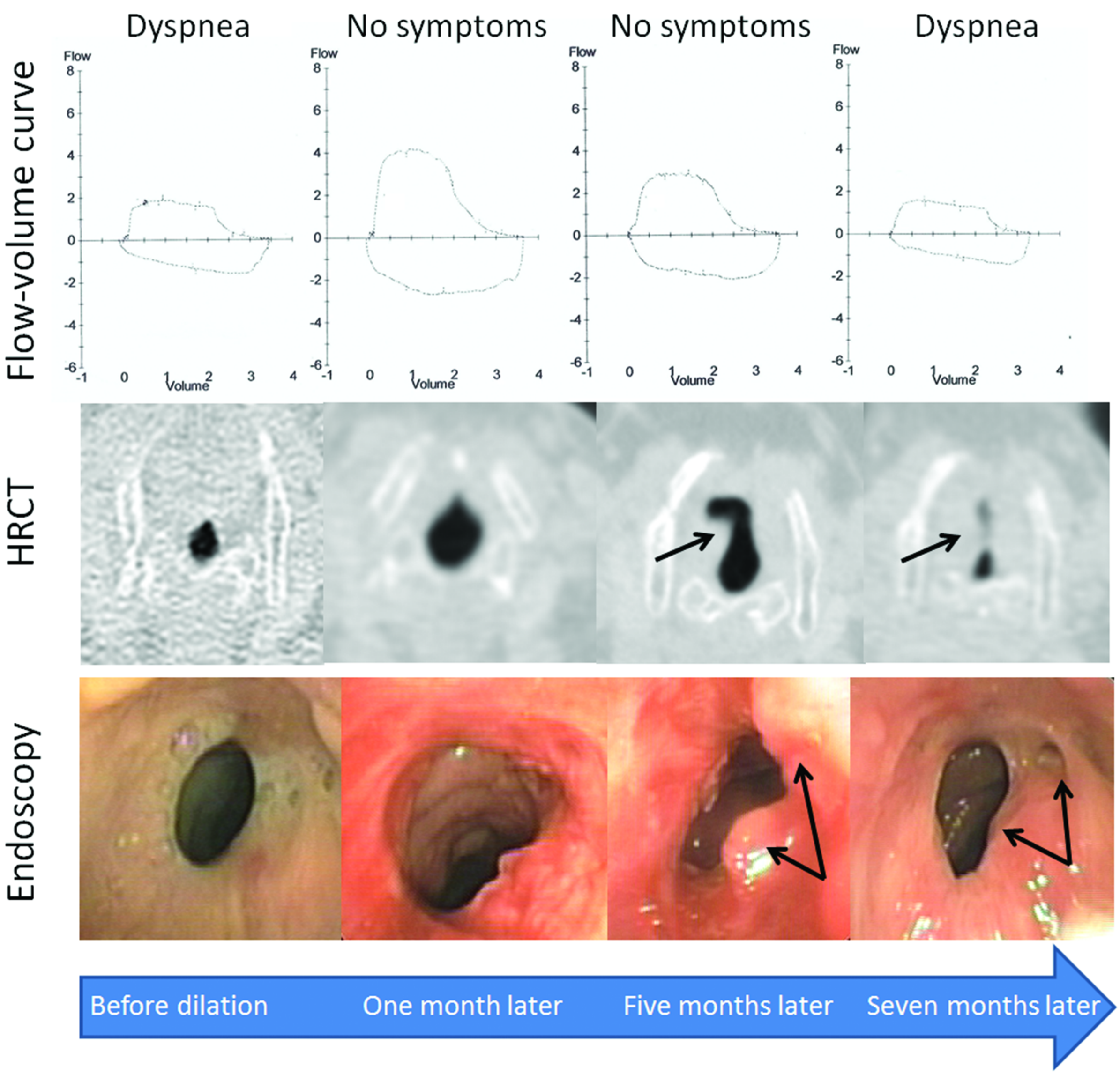
FIGURE LEGENDS

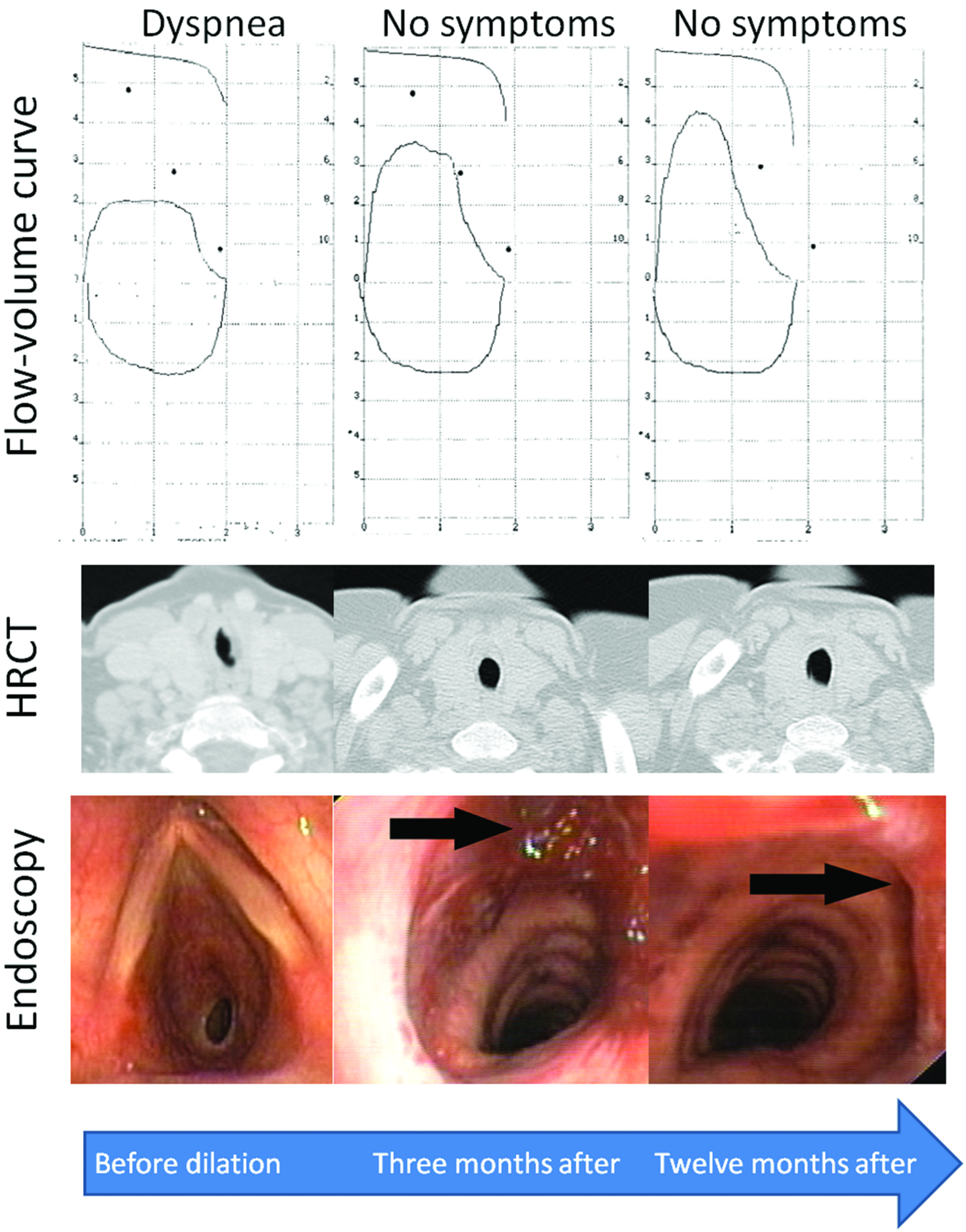
Figure 1. Different shape of flow-volume loops before dilation. (A) Flattening on inspiratory and expiratory phases of the loop (fixed stenosis); B) Flattening on expiratory phase of the loop (variable intrathoracic stenosis); C) Flattening on inspiratory phase of the loop (variable extrathoracic stenosis); Aspecific flow-volume loops: D) Biphasic expiratory loop; E) Truncate inspiratory loop; F) Absence of inspiratory loop.

Figure 2. Before endoscopic dilation, it was well evident a flattening on the inspiratory and expiratory phase of the loop (fixed stenosis). One month after dilation, the flow-volume curve showed a marked improvement in the first month. A flattening was then present 5 months later and become more marked 7 months later, concurrent with the reduction of airway diameter seen on High Resolution Computed Tomography (HRCT) and endoscopy and with the onset of symptoms. Black arrows showed the progression of the scar during the follow-up that caused the re-stenosis.

Figure 3. Before endoscopic dilation, it was evident a flattening on the expiratory phase of the loop (variable intrathoracic stenosis). After dilation, the expiratory loop improved, concurrent with the increase of airway diameter seen on HRCT and endoscopy and with the lack of symptoms; these results were maintained during the entire follow-up. Black arrows showed the cicatrization of the scar, preserving normal airway patency.


A) Fixed Stenosis
F(l/s)
MEF 50%
MIF 50%
B) Variable Intrathoracic Stenosis
F(l/s)
MEF 50%
MIF 50%
C) Variable Extrathoracic Stenosis
F(l/s)
MEF 50%
MIF 50%
D) Biphasic Expiratory loop
F(l/s)
E) Truncate Inspiratory loop
F(l/s)
F) Absent Inspiratory loop
Flow
Volume


Dyspnea
No symptoms
No symptoms
Dyspnea
Flow-volume curve
Flow
Volume
HRCT
Endoscopy
Before dilation
One month later
Five months later
Seven months later



Dyspnea
No symptoms
No symptoms
Flow-volume curve
HRCT
Endoscopy
Before dilation
Three months after
Twelve months after