# Difference Between The Slow Vital Capacity And Forced Vital Capacity: Predictor Of Hyperinflation In Patients With Airflow Obstruction

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**Citation**

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**Abstract**

Introduction: The aim of our study was to assess the relation between the difference in the vital capacity (dVC) measured by means of forced manoeuvres (forced vital capacity - FVC - ) and slow (expiratory vital capacity - EVC -) and the presence of air trapping. We also studied the predictive value of this difference as a marker of the degree of air trapping.

Methods: 162 consecutive individuals with suspected airflow obstruction comprised the study cohort. A simple spirometry and a determination of lung volumes by plethysmography were performed in all patients. The patients were classified in not obstructive, mild, moderate and severe obstructive. We randomly divided the 124 obstructive patients in two groups: regression group (n=94) and validation group (n=30). A multiple regression analysis was carried out, in which the hyperinflation (RV/TLC) composed the dependent variable and age, body mass index (BMI), forced expiratory volume in the first second (FEV1), and dVC composed the independent variables in the model. We subsequently verified the equation in the validation group.

Results: Thirty-eight patients were non-obstructive, 53 presented with mild obstruction, 39 moderate and 32 severe obstruction. The FVC was a 3,1% lower than the EVC in non-obstructive individuals, a 5,1% lower in those with mild obstruction, 10% lower in the moderate obstructive and a 16,8% lower in the severe obstructive groups. In the regression analysis FEV1 and dVC explained the 52% of the variability of the hyperinflation.

Conclusions: The FVC is lower than the EVC either in normal individuals or in obstructive patients. The difference between the FVC and the EVC increases with the degree of obstruction. Hyperinflation in patients with airway obstruction is determined by the degree of obstruction (FEV1) and by the difference in the vital capacity between forced and slow manoeuvres.

## INTRODUCTION

The European Respiratory Society ([1]) establishes three methods to measure the vital capacity (VC): inspiratory vital capacity (IVC), expiratory vital capacity (EVC) and forced vital capacity (FVC). The IVC begins with a slow manoeuvre from residual volume (RV) and ends at the total lung capacity (TLC). The EVC starts with a slow manoeuvre from TLC and concludes in RV. The FVC, contrary to the two previous, consists on a forced manoeuvre that begins in TLC and ends at the RV. In healthy young individuals the difference between the slow and forced vital capacity is practically null ([2]), while in those with airflow obstruction this could be important. For this reason the European Respiratory Society recommends the use of the slow manoeuvres to measure the vital capacity ([1]).

The RV is determined by the elastic properties of the thoracic wall ([3]) and by the expiratory air flow limitation ([4]). In healthy individuals, the RV is mainly determined by this property, but in those patients presenting with airflow limitation the decrease of the expiratory flow would lead to dynamic hyperinflation and RV increase.

Currently, volume and flow determinations are routinely based on forced spiromety. It is noted that the difference between the FVC and slow VC is related to the hyperinflation during the forced expiration ([2,4]), but there is little information in the literature in this regard ([5]).

The aim of our study was to assess the relation between the difference in the vital capacity (dVC) measured by means of slow versus forced manoeuvres and the presence of hyperinflation. We also studied the predictive value of this difference as a marker of the degree of hyperinflation determined by a slow manoeuvre.

## METHODS

We studied 162 consecutive individuals referred to one functional examination laboratory with suspected obstructive lung disease (asthma or chronic obstructive pulmonary disease –COPD-). In all patients, besides the spirometry, lung volumes were determined. All values above 80% and 70% of the predicted FEV1 and FEV1/FVC respectively, were considered normal. Patients with evidence of an spirometric obstructive pattern were classified into three groups: mild, moderate and severe according to the criteria of the Global Initiative for Chronic Obstructive Lung Disease ([6]).

Spirometric manoeuvres were performed according to the guidelines of the European Respiratory Society ([1]) by using an automatic system (Sensor Medics System 2100. SensorMedics Corporation. California 1984). TLC, EVC, RV, RV/TLC, functional residual capacity (FRC) and inspiratory capacity (IC) were recorded. These were obtained by use of a plethysmography camera (SensorMedics system 2800 transmural body box. SensorMedics Corporation. California 1984). Reference values proposed by the European Community for Coal and Steel ([1]) were defined.

Air trapping (AT) was defined as the difference between EVC and FVC, and was expressed as percentage of the EVC using the formula: AT%=(EVC-FVC)*100/EVC. It was also expressed as absolute value in litres, as follows: dVC=EVC-FVC.

The difference between Tiffeneau index (TI = FEV1/EVC) and the quotient FEV1/FVC in percentage, indicates the overestimation of the quotient FEV1/FVC. Difference Tiffenau index (DTI) was defined as follows: DTI%=((FEV1/FVC)-TI)*100/TI.

Statistical analysis was performed using SPSS (version 10,0) statistical software (SPSS Inc. Chicago, Illinois, USA). Results are expressed as mean and standard deviation (SD). Analysis of the variance and test of multiple comparisons T3 of Dunnett were used to assess differences between groups. P values minor than 0,05 were considered statistically significant. Pearson test was used for correlations between quantitative variables.

For the purpose of the study the obstructive patients cohort was divided into two random groups. Ninety-four patients with airway obstruction comprised the regression group and thirty comprised the validation group. A multivariate analysis was carried out in the first group in order to obtain a regression equation. Hyperinflation defined as the quotient RV/TLC in percentage, was taken as the dependent variable. FEV1, dVC, age and BMI constituted the independent variables. These variables were entered in a stepwise manner. Linearity, homocedaticity and normality were checked. The obtained model was tested on the 30 remaining patients (validation group) and the shrinkage (Sh) was calculated as follows: $Sh = R^2 – r^2$, where $R^2$ is the determination coefficient of the model in the first group and $r^2$ is the square power of the correlation coefficient between the RV/TLC% predicted by the regression equation and the value of the RV/TLC% in the second group.

## RESULTS

One hundred and sixty-two individuals were studied (142 men and 20 women), 38 (26 men and 12 women) presented a normal expiratory pattern and 124 (116 men and 8 women) demonstrated an obstructive pattern. Spirometric characteristics of this two groups are shown in table 1. Fifty-three presented mild, 39 moderate and 32 severe air flow obstruction.

### Figure 1

Table 1: Age, BMI and different respiratory functional parameters expressed as percentage of their theoretical values in a group with and without air way obstruction.

| | Normals (n=38) mean (SD) | Obstructives (n=124) mean (SD) |
|---|---|---|
| Age (years)* | 45(15) | 62,7(9,7) |
| BMI (Kg/m$^2$) | 28(8) | 22,8(9,5) |
| FVC(%)* | 110,7(14,2) | 82(18) |
| FEV1(%)* | 107,3(14,5) | 48,6(17,1) |
| EVC(%)* | 112(16,4) | 88,1(17,1) |
| TI%* | 78,4(6,7) | 42,2(13,1) |
| FEV1/FVC %* | 81(5) | 46,4(12) |
| TLC(%) | 106,9(10,3) | 110(18,5) |
| RV(%)* | 102,3(23,4) | 152,2(49) |
| RV/TLC %* | 30,6(7,5) | 51,1(10,5) |
| AT%* | 3,1(5,4) | 9,7(11,4) |
| dVC (litros)* | 0 ,152(0,2) | 0,321(0,3) |
| DTI %* | 3,6(5,9) | 12,6(15,2) |

* p<0,000 (T test).

BMI: Body mass index (Kg/m $^2$ ). (%): percentage of predicted. FVC: Forced vital capacity. FEV1: Forced expiratory volume in the first second. EVC: Expiratory vital capacity. TI%: Tiffeneau index (in percentage). TLC: Total lung capacity. dVC: Difference between EVC and FVC (in litres). RV: Residual volume. AT: air trapping in the forced manoeuvre (in percentage). DTI%: Difference between TI and FEV1/FVC % (in percentage).

FVC was 3,1% lower that EVC (95% confidence interval –CI-: 1,4 - 5) in normal individuals versus 9,7% (95%CI : 7,7 – 11,7) lower in those with obstructive pattern. FEV1/FVC was a 3,6% (95%CI: 1,6-5,6) higher than the TI in normal individuals versus a 12,6% (95%CI: 10,2-15,3) higher in obstructive patients. Table 2 and 3 show these results according different degrees of obstruction. Hyperinflation (RV/TLC) was correlated with age (r=0,25) and FEV1 (r=-0,64).

### Figure 2

Table 2: Hyperinflation indexes: forced versus slow manoeuvres and different degree of airflow obstruction.

| Degree of obstruction | AT% Mean (SD) | DTI% Mean (SD) |
|---|---|---|
| No obstruction (n=38)* | 3,19(5,4) | 3,6(5,9) |
| Mild obstruction (n=53)* | 5,1(11) | 7(12,8) |
| Moderate obstruction (n=39)* | 10(8,6) | 12(11,3) |
| Severe obstruction (n=32)* | 16,8(11,5) | 22,6(18,1) |

* P<0,05 between groups (analysis of the variance).

AT%: air trapping in the forced manoeuvre (in percentage). DTI%: Difference between Tiffeneau index and FEV1/FVC% (in percentage).

### Figure 3

Table 3: Hyperinflation indexes and different groups comparisons. Force versus slow manoeuvres and different degrees of obstruction: test T3 of Dunnet.

| Variable | Degree of airway obstruction | Degree of airway obstruction | p |
|---|---|---|---|
| AT% | normal | mild | 0,825 |
| | | moderate | 0,001 |
| | | severe | 0,000 |
| | mild | normal | 0,825 |
| | | moderate | 0,114 |
| | | severe | 0,000 |
| | moderate | normal | 0,001 |
| | | mild | 0,114 |
| | | severe | 0,045 |
| | severe | normal | 0,000 |
| | | mild | 0,000 |
| | | moderate | 0,045 |
| DTI% | normal | mild | 0,482 |
| | | moderate | 0,001 |
| | | severe | 0,000 |
| | mild | normal | 0,482 |
| | | moderate | 0,215 |
| | | severe | 0,000 |
| | moderate | normal | 0,001 |
| | | mild | 0,215 |
| | | severe | 0,037 |
| | severe | normal | 0,000 |
| | | mild | 0,000 |
| | | moderate | 0,037 |

p: statistical significance level. AT%: air trapping in the forced manoeuvre (in percentage). DTI%: difference between Tiffeneau index and FEV1/FVC% (in percentage).

A regression model was built with the data from the 94 patients with obstruction that comprised the regression group. FEV1 in litres, dVC, age, BMI were initially evaluated. FEV1 and dVC remained in the final model that explained the 52% of the deviation of hyperinflation. Results of the regression analysis are shown in Table 4.

### Figure 4

Table 4: Results of multiple regression analysis. RV/TLC% as a dependent variable. (n=98)

| Independents variables included in the model | coefficient beta | p | R | $R^2$ | EE |
|---|---|---|---|---|---|
| Constant | 70,179 | <0,000 | 0,72 | 0,52 | 7,10 |
| FEV1 | -11,789 | <0,000 | | | |
| FEV1*dVC | -7,526 | 0,0008 | | | |

P: significance level. R: Coefficient of multiple correlation. $R^2$ : Coefficient of determination. SE: Standard error. RV/TLC%: Hyperinflation (in percentage). FEV1: forced expiratory volume in the first second. dVC: Difference between EVC and FVC (in litres).

The best reduced final equation reads as follows: RV/TLC% = 70,179-7,526*FEV1*(1,566+dVC).

We calculate the shrinkage applying the regression equation in the validation group (n=30), obtaining the following results: $R^2$ = 0,52, $r^2$ = 0,53, Sh = 0,007.

## DISCUSSION

The results of our study show that, even in normal individuals, a slight difference takes place in the vital capacity where the forced manoeuvre is performed instead of the slow manoeuvre. This phenomenon is exaggerated in those patients with air flow obstruction, and this difference increases proportionaly with the degree of obstruction. In this way, the quotient FEV1/FVC underestimates the degree of obstruction with regard to the TI. Of note, in patients with severe obstruction the difference between FEV1/FVC and TI was up to a 22%. The different estimation of the VC with a forced manoeuvre versus a slow manoeuvre has been communicated previously ([1,7]). For the purposes of this study EVC was used, but differences between EVC and IVC have been reported in the literature ([8,9]). This is particularly evident in patients with moderate to severe obstruction in who EVC is reduced when compared to IVC ([2]).

RV in healthy young individuals is determined by the static balance between the force of the expiratory muscles together with a small contribution of lung elastic recoil and the elastic retraction of the thoracic wall ([10]). Individuals above 35-40 years of age, on the other hand, the RV is mainly related to a dynamic mechanism: in which when the maximum expiratory volume reaches the RV an interruption of the expiratory forced manoeuvre takes place with the subsequent increase of the RV ([11]). In patients with obstructive airflow disease the main determinant of the increment of the RV is the so described dynamic mechanism, since the calibre of the air way is of a great importance to determine the RV ([3]). In fact, the dynamic compression of the air way during a forced manoeuvre accentuates the closure of this way, with the rising increase of the RV and decrease of the vital capacity ([8]). The relation between the difference VC-FVC and the RV has been previously reported by Von Westernhagen et al ([5]), who observed an slight correlation between both variables (r=0,11) as well as an increase in the percentage of radiological features consistent with emphysema in those patients with a higher difference between the slow VC and FVC. Our results are in keeping with this findings.

All the variables that seemed to lead to hyperinflation were entered in the multivariate analysis, namely, age, air flow obstruction (measured as FEV1%) and degree of air way closure during the forced manoeuvre (indirectly measured by the variable dVC). All these variables, apart from the age, have been shown predictive of hyperinflation in the regression model. Further more, an interaction phenomenon seems to appear between the variable FEV1 and TG% that indicates a mutual strengthen of the effect that each one of them has on the hyperinflation.

## CONCLUSION

In conclusion, FVC is reduced when compared with EVC either in normal individuals or obstructive patients. A 3% different is observed in normal individuals whereas it reaches up to a 10% in affected patients. This difference between the FVC and the EVC increases with the degree of obstruction. The hyperinflation observed among the patients with obstructive pattern is determined by the degree of obstruction (FEV1) and by the difference between the slow and forced vital capacity (dVC). Therefore, we believe that the difference between the forced and slow vital capacity is related with the degree of hyperinflation and can predict its intensity. These manoeuvres should be incorporated to the routine spirometry, mainly in centres with limited access to static lung volumes examinations.

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