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The role of FEV_6 in the detection of airway obstruction

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KEYWORDS
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Summary *Objectives:* There are recent reports regarding the use of forced expiratory volume in 6 s (FEV_6) in place of forced expiratory vital capacity (FVC) in the detection of airway obstruction. We aimed to investigate the role of FEV_6 in comparison with FVC in the evaluation of airway obstruction.

Methods: The pulmonary function tests (PFT) results of all 5114 patients, who had been tested in the pulmonary function laboratory between 1998 and 2003, were retrospectively analyzed to investigate the relationship between FEV_6 and FVC.

Results: We have found a mean difference of 95.35 ± 121.7 (min = 0, max = 1050) ml (3.37%) when FVC and FEV_6 values (FVC–FEV_6) of all cases were compared. This difference was found to be higher (180 ml, 7.3%) in patients with airway obstruction. When FEV_1/FVC is taken as the gold standard, FEV_1/FEV_6 had negative predictive value of 92.24% and a sensitivity of 86.09% in the detection of airway obstruction.

Conclusions: Although it is easier to use FEV_6 in place of FVC, relatively low sensitivity in that setting may result in the underestimation of airway obstruction. This drawback should be kept in mind when FEV_6 is utilized to detect airway obstruction.

Introduction

The acceptability criteria for forced vital capacity (FVC) maneuver during pulmonary function tests (PFT) have been previously described by American Thoracic Society (ATS): Duration of exhalation should be at least 6 s, during which a minimum 1 s plateau could be reached.[1] This total duration may be as long as 15–20 s in cases with airway obstruction. However patients frequently experience problems during expiration, finding it difficult to fulfill the end-of-test criteria for the FVC maneuver.[2] Because of this observation, utilization of forced expiratory volume in 6 s (FEV_6) in place of FVC has been proposed in order to make the spirometry a simpler and more widely used diagnostic modality in primary health care.[3] Hankinson et al.[4] have reported the reference values for FEV_6. Swanney et al.[5] have studied the feasibility of using FEV_6 instead of FVC in the determination of obstruction and restriction and reported promising results. However, since expiration could be prolonged during FVC maneuver in cases with obstruction, limiting measurement of expired volume to the first 6 s cannot only lead to underestimation of

Abbreviations: FEV_6, forced expiratory volume in 6 s; FVC, forced expiratory vital capacity; PFT, pulmonary function tests; BMI, body mass index

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the vital capacity but also to the underestimation of the degree of obstruction simply because FEV_1/FEV_6 values would be higher than the FEV_1/FVC values in that setting. In this study, we aimed to investigate the relationship between FEV_6 and FVC and to determine whether FEV_6 could be utilized in place of FVC in the detection of airway obstruction.

Materials and methods

The PFT results of all 5114 patients, who had been tested in the respiratory function laboratory of Istanbul University, Cerrahpasa Medical Faculty, Department of Pulmonary Diseases between 1998 and 2003, were retrospectively analyzed to investigate the relationship between FEV_6 and FVC. A SensorMedics Vmax22 spirometer was used during PFT, in which nasal shutters were utilized. FVC maneuver was performed in accordance with ATS criteria: 3 consecutive tests were performed and FVC and FEV_1 values in the best 2 tests were noted; the difference between the FVC and FEV_1 values of two tests had to be less than 200 ml.[1] The spirometer mentioned has the capability of measuring FEV_6 together with FVC so that both values could easily be detected during the same maneuver. Patients were divided into two groups depending on whether they had airway obstruction, indicated by FEV_1/FVC values $<70\%$.[6] The relationship between FVC and FEV_6 values were examined in both groups and any differences between the groups were investigated.

In the analysis of the data obtained, *SPSS (Statistical Package of Social Sciences)* 10.0 *for Windows* was used. The results were defined as mean value $\pm$ standard deviation. A $P<0.05$ was considered statistically significant. Paired-samples *t*-test was used for the comparisons of $FVC–FEV_6$ values of the cases with airway obstruction (group1) and cases without airway obstruction (group 2).

Results

The demographic characteristics of all of the 5114 patients are demonstrated in Table 1.

The mean PFT values of all cases are given in Table 2. The difference between FVC and FEV_6 ($FVC–FEV_6$) values was 95.35 ± 121.7 ml, with a rather wide range (0–1050 ml).

When $FVC–FEV_6$ values of the cases with airway obstruction (group1) and cases without airway obstruction (group 2) were compared, a statistically significant difference was observed (Table 3).

Table 1 Demographic characteristics.

Total number of cases (*n*)	5114
Sex (F/M) (M = Male, F = Female)	2742 F 2372 M
Age (years)	49.95 ± 15.48
BMI* (kg/m^2)	27.2 ± 5.0

*BMI = body mass index.

Table 2 Pulmonary function tests of all cases.

FVC (ml)	2821.7 ± 996.4
FVC (%)	85.2 ± 20.7
FEV_1 (ml)	2010.3 ± 890.4
FEV_1 (%)	72.9 ± 24.4
FEV_1/FVC (%)	70 ± 14
$FEF_{25–75}$ (l/s)	1.7 ± 1.16
$FEF_{25–75}$ (%)	47.8 ± 28.5
FEV_6 (ml)	2720.6 ± 998.2
$FVC–FEV_6$ (ml)	95.35 ± 121.7 (min:0–max:1050)
$FVC–FEV_6$/ FVC (%)	3.37 ± 4.67

The distribution of cases according to $FVC–FEV_6$ values is demonstrated in Table 4. There was no difference between these two values in 551 (10.77%) cases, whereas in 707 (13.82%) patients difference between FVC and FEV_6 values was more than 200 ml.

When the ratio of $FVC–FEV_6$ to FVC was investigated, it was found that in approximately 10% of the cases the difference was more than 10% of the FVC value (Table 5).

The value of $FVC–FEV_6$ was less than 100 ml in 87.3% of cases without airway obstruction whereas in only 34.4% of cases with airway obstruction $FVC–FEV_6$ was less than 100 ml (Table 6).

The ratio of $FVC–FEV_6$ to FVC was less than 5% in 97.4% of the cases without obstruction. On the other hand, ratio of $FVC–FEV_6$ to FVC was more than 10% in 25.8% of the cases with obstruction (Table 7).

When 70% was utilized as the criterion for airway obstruction according to GOLD, FEV_1/FVC parameter yielded obstruction in 1928 cases whereas according to FEV_1/FEV_6, obstruction was detected in 1660 cases (Table 8).[6] Since none of the cases had exhalation times less than 6 s, there are no cases in which airway obstruction is detected by using FEV_1/FEV_6, but not detected when FEV_1/FVC parameter is utilized.

Table 3 Distribution of cases according to the ratio of FVC–FEV_6 to FVC.

	$FEV_1/FVC < 70\%$ ($n = 3186$)	$FEV_1/FVC \geqslant 70\%$ ($n = 1928$)	P
FVC–FEV_6 (ml)	180.0 ± 155.0	44.0 ± 45.0	<0.0001
FVC–FEV_6/FVC (%)	7.3 ± 5.8	1.5 ± 1.4	<0.0001

Table 4 Distribution of cases according to FVC–FEV_6 difference.

FVC–FEV_6 (ml)	n	n (%)	Cumulative percent
0	551	10.77	10.77
0–99	2894	56.59	67.38
100–199	962	18.81	86.18
200–499	618	12.08	98.26
500–999	85	1.66	99.92
>1000	4	0.08	100

Table 5 Distribution of cases according to the ratio of FVC–FEV_6 to FVC.

FVC–FEV_6/FVC (%)	n	n (%)	Cumulative percent
0	551	10.77	10.77
0–4.99	3389	66.27	77.04
5–9.99	678	13.26	90.30
10–14.99	280	5.48	95.78
15–19.99	143	2.80	98.57
20–24.99	55	1.07	99.65
25–29.99	11	0.22	99.86
>30	7	0.14	100

Table 6 Distribution according to FVC–FEV_6 in cases with and without obstruction.

FVC–FEV_6 (ml)	$FEV_1 \geqslant 70\%$		$FEV_1 < 70\%$	
	n	n (%)	n	n (%)
0	478	15	73	3.8
0–99	2303	72.3	591	30.6
100–199	366	11.5	596	31
200–499	39	1.2	579	30
500–999	0	0	85	4.4
>1000	0	0	4	0.2

Table 7 Distribution in cases with and without obstruction according to the ratio of FVC–FEV_6 to FVC.

FVC–FEV_6/FVC (%)	$FEV_1 \geqslant 70\%$		$FEV_1 < 70\%$	
	n	n (%)	n	n (%)
0	478	15	73	3.8
0–4.99	2683	82.4	576	39.8
5–9.99	84	2.5	597	30.6
10–14.99	1	0.1	259	14.6
15–19.99	0	0	350	7.4
20–24.99	0	0	55	2.9
25–29.99	0	0	11	0.6
>30	0	0	7	0.3

Table 8 Comparison of FEV_1/FEV_6 with FEV_1/FVC in the evaluation of airway obstruction.

Sensitivity (%)	86.09
Specificity (%)	100
(+) Predictive value (%)	100
(−) Predictive value (%)	92.24

Discussion

For patients with airway obstruction or for older subjects, exhalation times longer than 6 s are frequently required to reach a plateau.[1] The FVC may be underestimated if not enough time is allowed for lung emptying at low lung volumes, where the emptying rate is determined by airflow limitation.[7] We have found a mean difference of 95.35 ± 121.7 ml (3.37%) when FVC and FEV_6 values (FVC–FEV_6) of all cases were compared. This difference was found to be higher (180 ml, 7.3%) in patients with airway obstruction. A substantial variation in the difference between FVC and FEV_6 among patients was detected. The FVC–FEV_6 value was more than 200 ml in 707 cases and greater than 1000 ml in 4 patients. FVC–FEV_6 was less than 100 ml in 2781 (87.3%) patients, and the ratio of FVC–FEV_6 to FVC was less than 5% in 3161 (97.4%) cases in the group without airway obstruction. On the other hand, in the group with airway obstruction, 668 (34.6%) patients had FVC–FEV_6 value more than 200 ml; and ratio of FVC–FEV_6 to FVC was higher than 10% in 682 (25.8%) patients in the same group. A difference of 200 ml is the upper limit of repeatability criterion of the FVC maneuver.[1] Widening of the gap between FVC and FEV_6 would eventually lead to the underestimation of airway

obstruction since the FEV_1 value would remain fixed. We have observed that obstruction was detected in 1928 cases using FEV_1/FVC; on the other hand utilization of FEV_6 in place of FVC resulted in detection of obstruction in only 1660 cases. When FEV_1/FVC is taken as the gold standard, FEV_1/FEV_6 had 100% specificity and positive predictive value and a sensitivity of 86.09% in the detection of airway obstruction. Since FEV_6 cannot be greater than FVC theoretically in a technically well-performed spirometry, one can anticipate the positive predictive value and specificity to be 100%. However, a sensitivity of 86.09% points out the fact that many patients with airway obstruction may be overlooked when FEV_6 is used in place of FVC. Swanney et al. have reported that obstruction was diagnosed by using FEV_1/FEV_6 but not by FEV_1/FVC; this is probably an indication of incorrect application of the FVC maneuver. In the same study, in which FEV_1/FEV_6 was presented as an acceptable method for the detection of airway obstruction, the authors have found the sensitivity to be 95%.[5] The difference between our finding 86.09% and this study may be due to the smaller number of patients Swanney et al. have included in their study and the difference between the obstruction criteria used. Although it is easier to use FEV_6 in place of FVC, relatively low sensitivity in that setting may result in the underestimation of airway obstruction. This drawback should be kept in mind when FEV_6 is utilized to detect airway obstruction.

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