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Spirometry in clinical practice. Functional manifestations of bronchoobstructive diseases (clinical examples)

Key words: *spirometry, COPD, bronchial asthma.*

Spirometry is widely used in clinical practice, however, in some cases, to it's conduction it is nessessary to approach with caution. During forced maneuvers we seek maximum efforts in order to get valid results, and the maximum physical exertion may, under certain circumstances, to provoke unwanted negative effects. Therefore, before the procedure, is necessary to interrogate the test in terms of its holdings of possible contraindications for this study [4]:

- hemoptysis (the previous month).
- Pneumothorax,
- unstable cardiovascular system,
- recent (within 3 months) myocardial infarction or stroke,
- uncontrolled hypertension,
- pulmonary embolism,
- aneurysm (any),
- failure of the venous valves of the lower limbs with varicose veins,
- trophic disorders and a tendency to increased blood clotting,
- recent eye surgery, chest or abdominal cavity – within the previous 3 months,
- retinal detachment,
- nausea, vomiting,
- impairment of consciousness, dementia,
- respiratory infection, tuberculosis

There are reasonable difficulties for this investigation in patients with the inflammatory diseases of the oral cavity (pain or discomfort when the mouthpiece in the mouth), neuralgia of the facial nerve paresis (the same reason, plus the inability to tightly cover the mouthpiece lips). In the majority of cases spirometry is well tolerated, side effects are rare, but the most deep breathing can lead to dizziness, headache, facial flushing, fainting, and maximum effort – to a transient incontinence.

Spirometry should be performed as in a sitting position, as standing, however, subsequent studies should adhere to the same position. Preferred position – sitting, to avoid potentially an unconscious situation. If the research is done standing, the patient must stand close to the seat or chair, in case he became dizzy during respiratory maneuvers, so that he could sit down and avoid falling [1, 2, 5 , 6, 8].

Standing position can be used for patients with obesity, it will allow them to make a more deep-breathing exercises. For patients with normal weight position is not significant.

On spirometry results may influence some factors, which have been checked prior the study:

Patient have been:

abstained from smoking for at least one hour before the procedure,

- do not drink alcohol for at least 4 hours prior to the study,
- avoid significant physical activity for at least the last 30 minutes,
- came in loose clothing, which do not impede chest and abdomen during full breath,
- do not have square meal 2 hours before the study (assuming a light breakfast);
- if patient is taking bronchodilators - withdraw bronchodilators for appropriate washout periods prior to the study (Table 1).

Table 1
Recommended time washout bronchodilators before spirometry [2].

Broncholytic medicine	Wash-out period (hours)
SABA, SAMA, their combination	4-6
LABA (salmeterol, formoterol)	12
Ultra LABA (indacaterol)	36
LAMA	36

Spirogram validity criteria are well known [2 , 3 , 5, 6 , 7, 8]. Curves of flow – forced expiratory volume should be acceptable:

1) on the forced expiratory curve should not be artifacts:
- cough during the first second forced expiratory volume,
- closing of the vocal cords,
- premature termination of the respiratory maneuver or it's interruption,
- breathing maneuver is carried out not at the maximum level,
- air leakage,
- block mouthpiece (tongue, chewing gum, dentures or their fragments),
- additional respiratory maneuvers;

2) rapid onset of exhalation (no back extrapolation);

3) the duration of forced expiratory volume at least 6 seconds or reaching a plateau on the exhale part of the curve.

FVC and FEV_1 data must be reproducible: upon receipt of at least 3 acceptable curves is necessary to assess:
- 2 largest values of FVC differ by no more than 150 ml,
- two largest FEV_1 differ by no more than 150 ml, in theat FVC < 1.0 L – 100 ml).

If these two criteria are met, the test can not continue.

If not, continue:
- until both criteria are met, or
- up to 8 attempts, or
- the patient is unable or unwilling to continue the study.

In this paper we present examples of how to assess spirogram. It is important to remember that the results of functional techniques should be interpreted only in conjunction with the clinical evaluation.

Consider the examples spirograms executed after receiving a bronchodilator.

Figure 1 shows the spirogram of patient N.

1) Evaluating the eligibility criteria of spirogram: there are no artifacts on spirometry, no back extrapolation, there is a sharp peak expiratory, expiratory duration of more than 6 seconds and reached a plateau phase [2, 3, 5, 6, 7, 8]. Spirogram acceptable.

Achieved at least 3 attempts acceptable? Yes.

2) Now it is nessessary to evaluate the reproducibility of attempts. The difference between the highest FEV_1 (FEV_1) – in this example is 3.10 liter and most closest (2.99 L) is less 150 ml? Yes, 110 ml. By FVC (FVC) – 4,87 l and 4,79 l – less 150 ml? Yes 80 ml. Reproducibility is achieved.

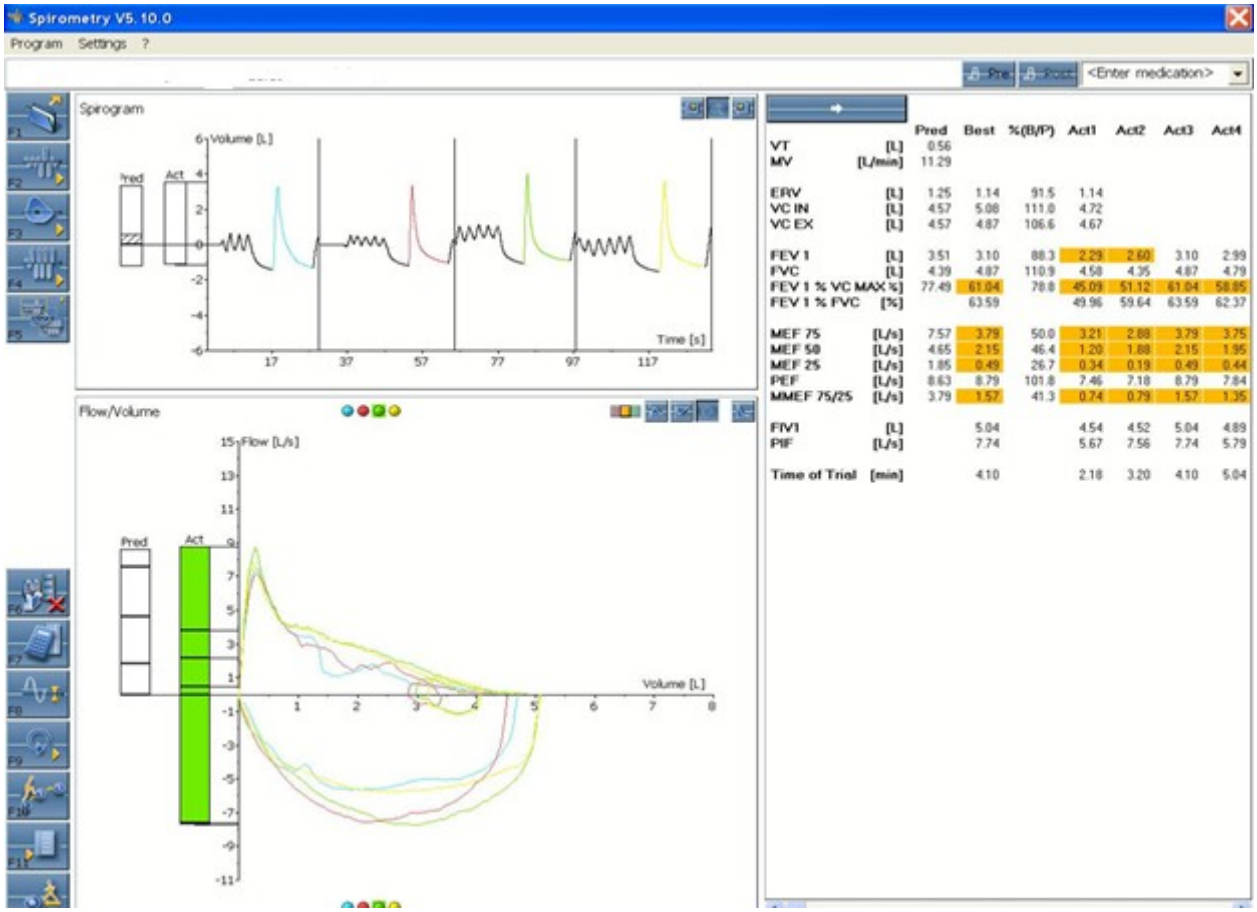


Figure 1. **Example of mild bronchial obstruction, GOLD 1**

Spirogram suitable for evaluation.

FEV_1 (FEV_1) – 3,10 l, 88, 3 % due – in the normal range (see Table 1), forced vital capacity (FVC) – 4,87 (110 %) – the norm, but their ratio of 3.10 / 4 87 = 0,636 – less than 0.7 (70 %) – in the presence of clinical symptoms we can think about COPD, mild bronchial obstruction (GOLD 1).

The presence of a minor, but fixed bronchial obstruction, in this example may be suspected and appearance expiratory curve, it is quite noticeable concave rather than straight.

The example of moderate bronchial obstruction (the study was carried out after receiving 400 mcg salbutamol) we can see on Fig. 2. The left graph has 3 acceptable curves (all except the third), 1.2 and 4th attempts highly reproducible, highest FEV_1 – 2.44 liters (66.7 % predicted), FVC 4.68 l. On the presence of persistent bronchial obstruction indicates decrease FEV_1/FVC below 0.7 – in this case – 0.52 – corresponds to spirometric classification GOLD 2, a moderate degree of bronchial obstruction.

The right graph – all curves are acceptable and reproducible FEV_1 – 2.18 (67.7 %), FVC – 3.45, FEV1/FVC – 0.616, also a fair fixed bronchial obstruction.

Example of severe bronchial obstruction and its dynamics over time are shown in Figures 3 and 4. The first study was conducted in 2007, the second – two years later.

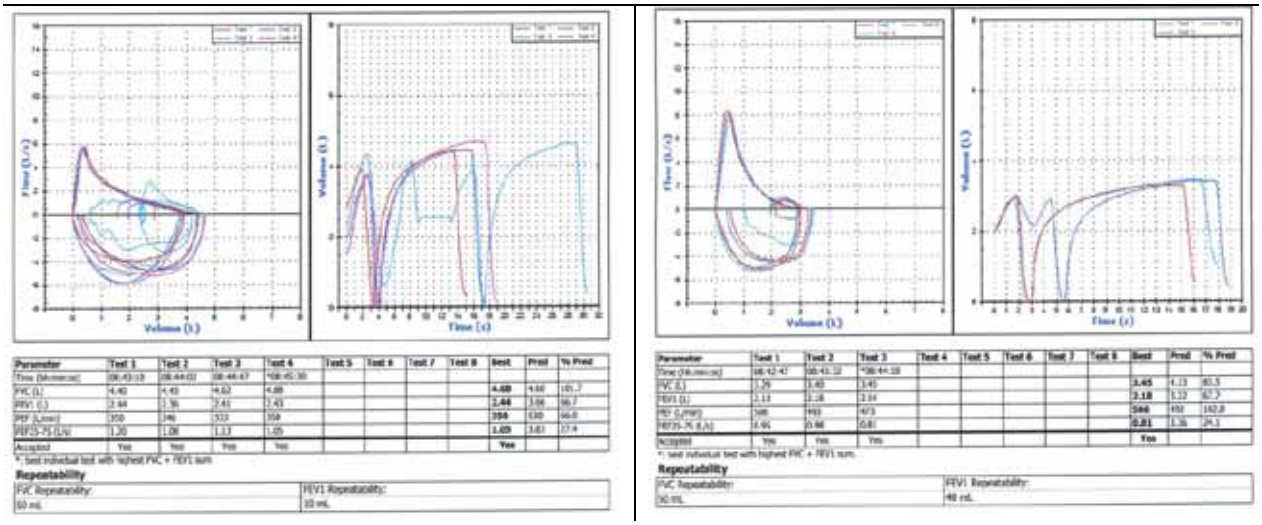
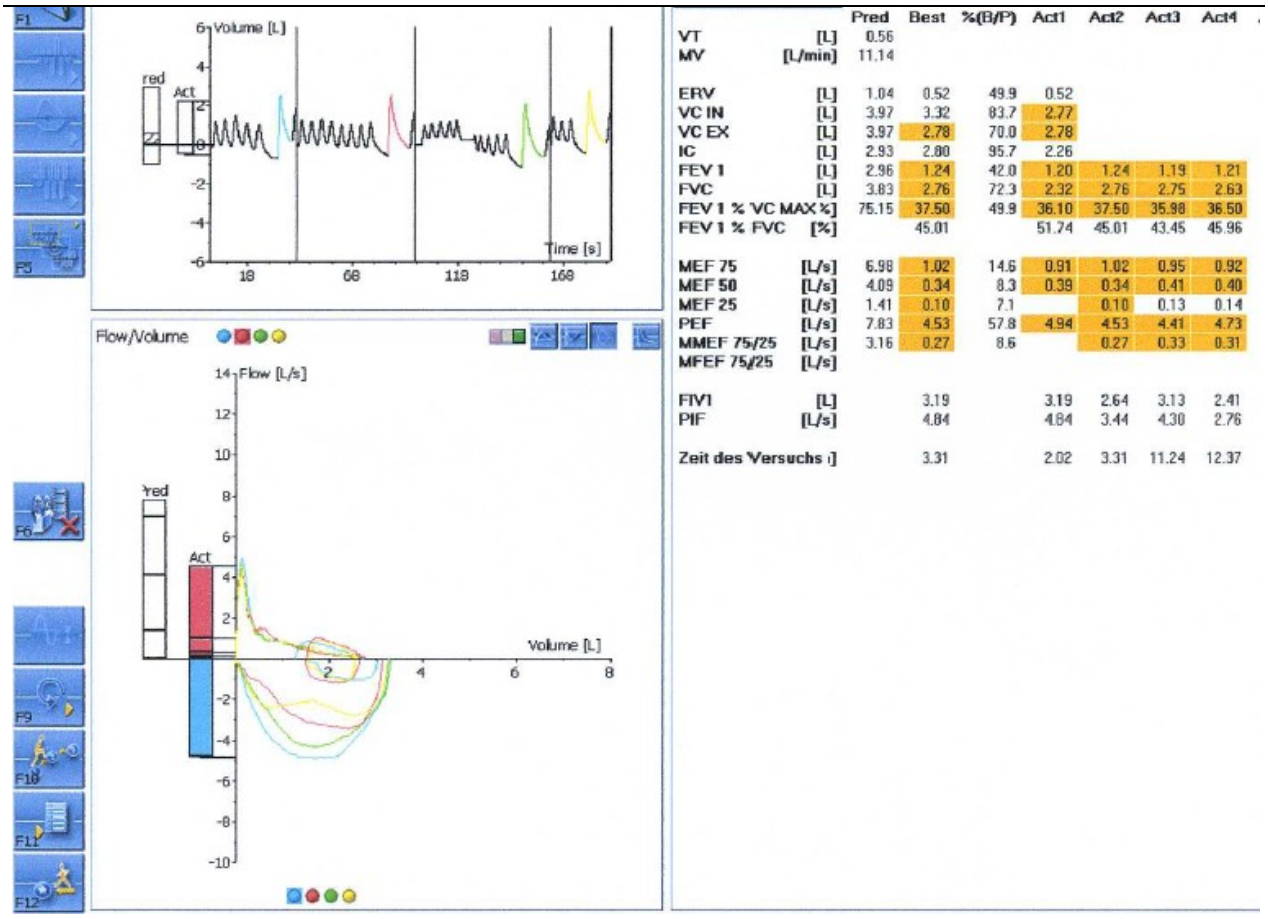


Figure 2. **Moderate bronchial obstruction, GOLD 2**



		Pred	Best	%(B/P)	Act1	Act2	Act3	Act4
VT	[L]	0.56						
MV	[L/min]	11.14						
ERV	[L]	1.04	0.52	49.9	0.52			
VC IN	[L]	3.97	3.32	83.7	2.77			
VC EX	[L]	3.97	2.78	70.0	2.78			
IC	[L]	2.93	2.80	95.7	2.26			
FEV 1	[L]	2.96	1.24	42.0	1.20	1.24	1.19	1.21
FVC	[L]	3.83	2.76	72.3	2.32	2.76	2.75	2.63
FEV 1 % VC MAX	[%]	75.15	37.50	49.9	36.10	37.50	35.98	36.50
FEV 1 % FVC	[%]		45.01		51.74	45.01	43.45	45.96
MEF 75	[L/s]	6.98	1.02	14.6	0.91	1.02	0.95	0.92
MEF 50	[L/s]	4.09	0.34	8.3	0.39	0.34	0.41	0.40
MEF 25	[L/s]	1.41	0.10	7.1		0.10	0.13	0.14
PEF	[L/s]	7.83	4.53	57.8	4.94	4.53	4.41	4.73
MMEF 75/25	[L/s]	3.16	0.27	8.6		0.27	0.33	0.31
MFEF 75/25	[L/s]							
FIV1	[L]		3.19		3.19	2.64	3.13	2.41
PIF	[L/s]		4.84		4.84	3.44	4.30	2.76
Zeit des Versuchs	[]		3.31		2.02	3.31	11.24	12.37

Figure 3. **Patient K. Severe bronchial obstruction, 2007**

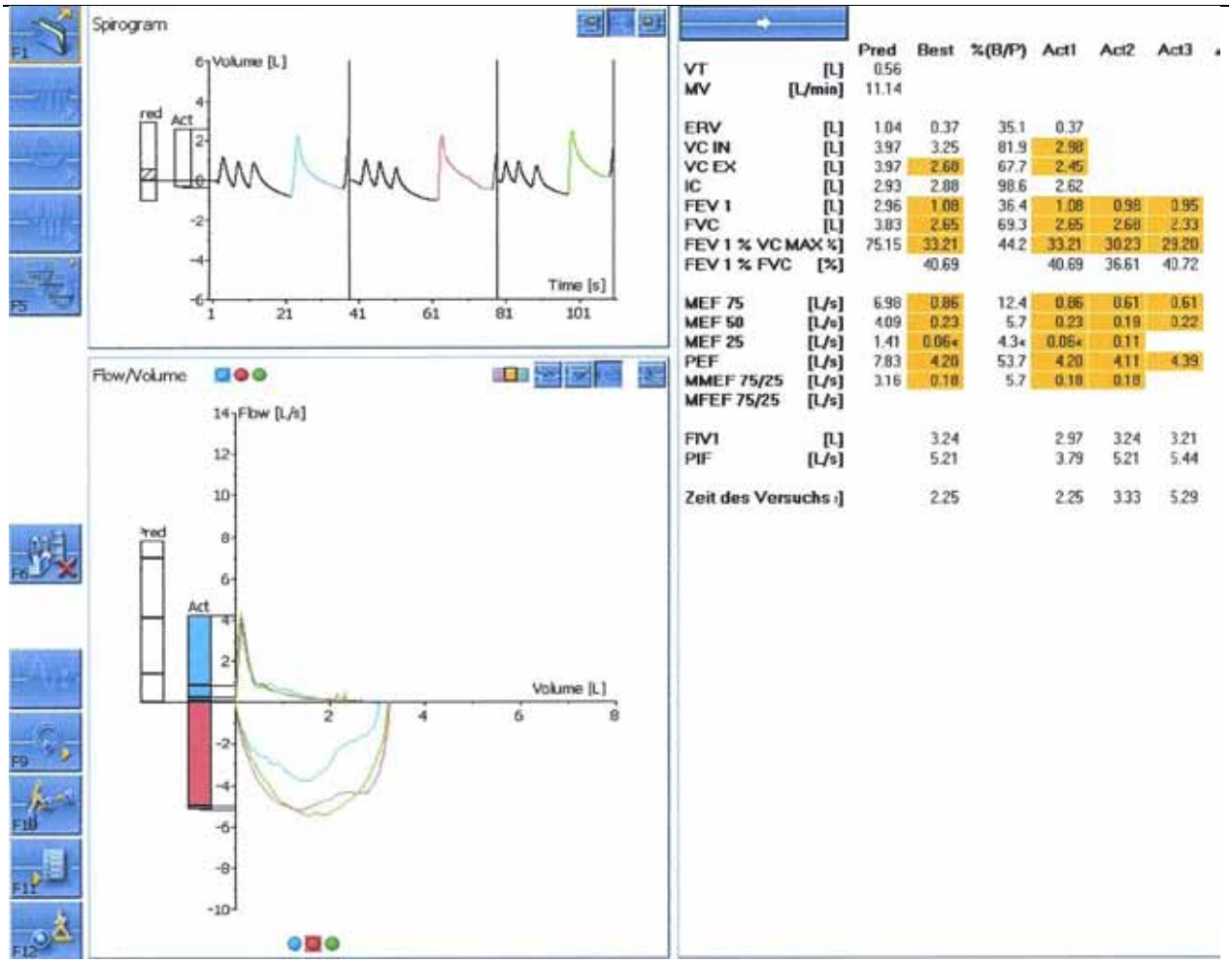


Figure 4. **Patient K, 2 years later, 2009**

Let's check criteria for acceptability curves.

FEV_1 is low, the maximal value of 1.08 liters, the minimal 0.95. In the case when FEV_1 is less than 1 liter of criteria to assess the reproducibility of more narrow – the difference between the highest and the nearest value of FEV_1 and FVC should be up to 100 ml. In this case, high reproducibility (for FEV_1 (FEV_1) – 1,24–1,21 = 30 ml, FVC (FVC) – 3,76-3,75 = 10 ml, FEV_1 – 42 % due, FEV_1/FVC 0,45 (45 %). study was performed correctly, the result corresponds to the severe obstruction by GOLD (III).

Example demonstrates the decline in FEV_1 over time in patients with severe COPD. Over 2 years FEV_1 decreased from 1,24 L to 1.08 L, despite the basic therapy with the use of a triple combination – inhaled corticosteroid + long-acting bronchodilators (b_2-agonist and anticholinergic).

Forced expiratory curves of such a configuration is often observed in patients with verified CT emphysema. .

Figure 5 shows an example bronchoobstructive violations, patient ID, and heavy, FEV_1 – 47,8 %, but the character of the curve is somewhat different than in Figure 2. FVC is also reduced, and more pronounced than in the previous example (63.4 % predicted). However, the patient – the owner of overweight (BMI 30.4), significant stomach, high standing and flattening of the diaphragm exacerbate its ventilation violations and explain the low rates of FVC. This patient ventilatory disorders can be characterized as mixed, but you need to keep in mind that reducing the capacity of the lungs due to the physiological characteristics of the patient.

Example of a very severe bronchial obstruction fixed (corresponding GOLD IV) presented in Figure 6.

At the patient's FEV_1 below 1 liter. In this example, we can note an important caveat: the maximum value of 0.88 was obtained in the second attempt, but the computer is automatically chosen as the best shot in this case the other, although it does not FEV_1 highest – 0.73 l. We agree with the choice of the computer, because the attempt with the highest FEV_1 was not done at maximum effort (you can see a wider peak expiratory curve). FEV_1 – 0.73 (25.5 % predicted) indicates very severe bronchial obstruction, respectively GOLD IV. FVC this patient is also reduced, but not to the extent of catastrophic (to 63.4 % predicted).

In severe bronchial obstruction is often reduced FVC between VC (performed during quiet maneuver) and FVC (forced expiratory made) there is a significant difference (normally they usually are, there are physiological fluctuations in the average of 100–200 ml). Slowly and quietly as possible to inhale and exhale level VC patient with severe obstruction may, but with significant exertion small bronchi subsides formed air "traps" to maximize exhale, you need to make greater efforts. It is a vicious circle. In severe and very

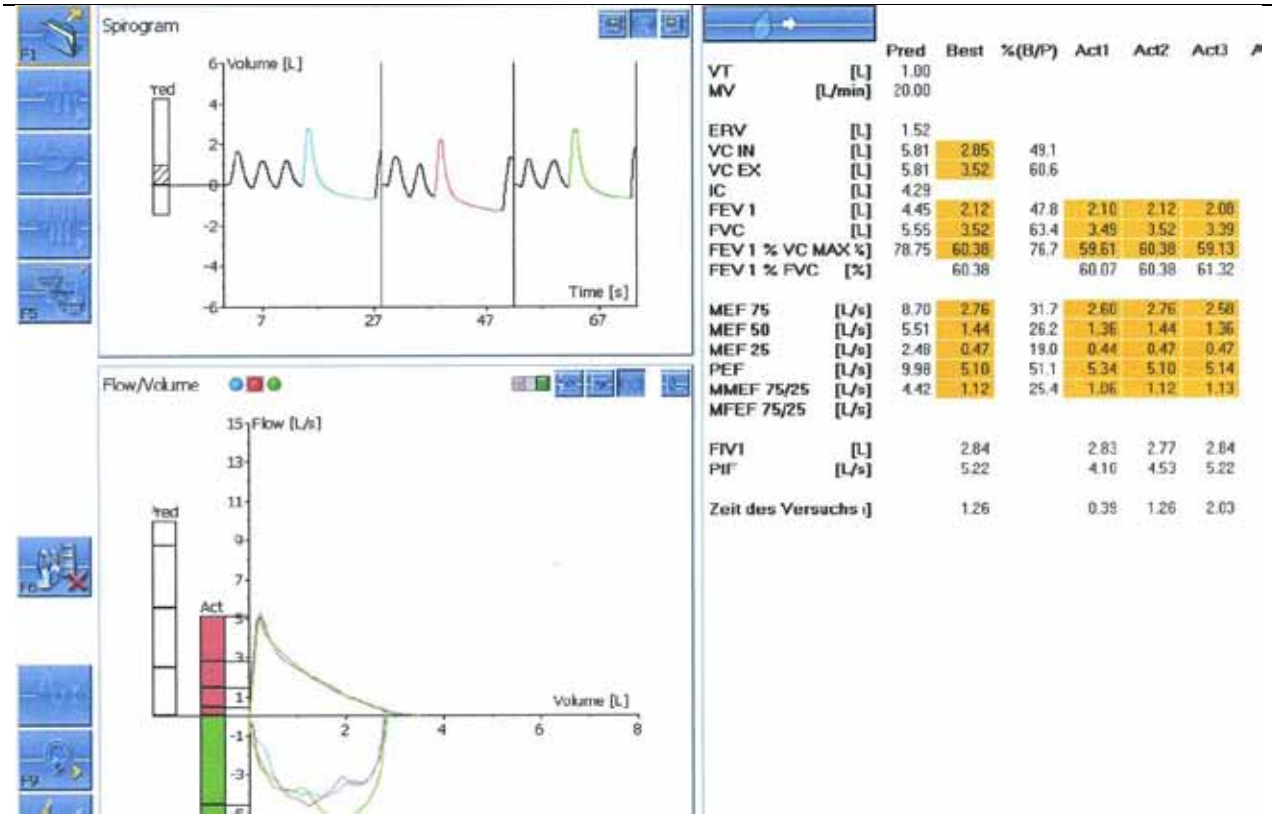


Figure 5. **Severe bronchial obstruction**

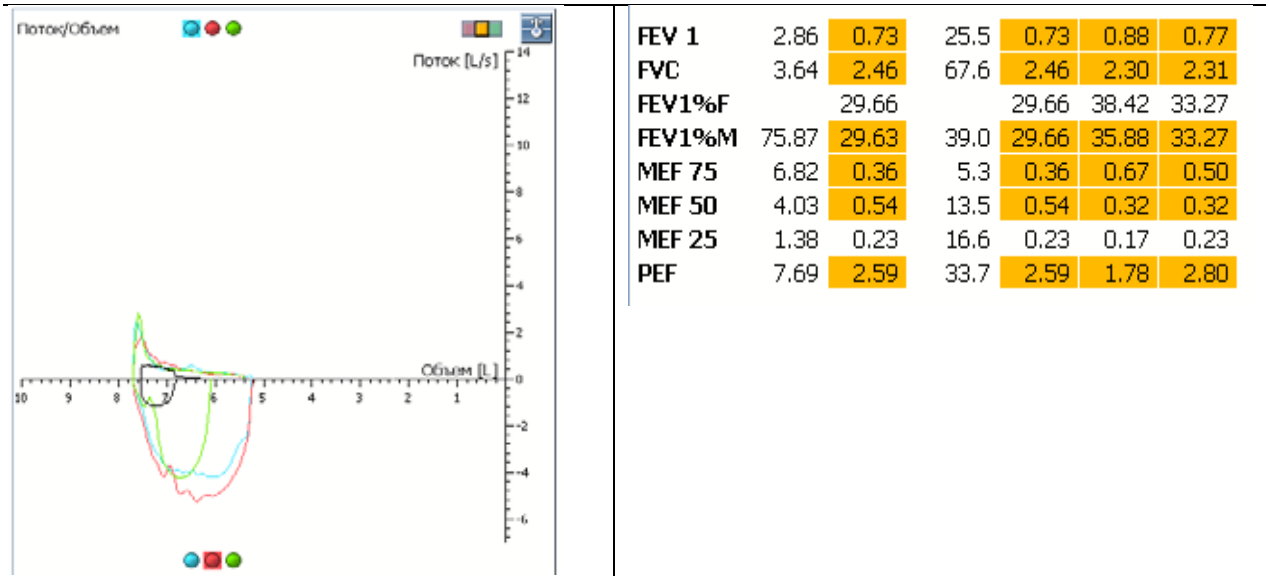


Figure 6. **Very severe bronchial obstruction**

severe obstruction exhalation significantly lengthened. If a healthy person breathes FVC for a few seconds and exhale problem for him as much as 6 seconds, a patient with severe bronchial obstruction exhales for 12, 15, 20 seconds or more, and the stage of the plateau and is not achieved. Therefore not recommended for severe obstruction to exhale more than 15 seconds, even if at that time the plateau is reached.

Today itself reversibility of bronchial obstruction in COPD is neither diagnostic nor differential diagnostic criterion, and its role in asthma remains the same. Functional diagnostic criterion is the increase in asthma in the sample FEV_1 bronchodilator ≥ 12 % and 200 ml, more growth – the more likely the diagnosis of asthma. Figure 7 shows spirogram asthma patient before and after administration of 400 micrograms of salbutamol.

Initially the patient's FEV_1 was reduced to 1.87 L (with the proper value 3.18) – 59 % of predicted. After receiving bronchodilator FEV_1 increased to 2.57 liters (an increase of 700 ml, and (2,57-1,87) / 1.87 * 100 = 37.4 %. Very high reversibility in response to salbutamol, the argument "for" bronchial asthma.

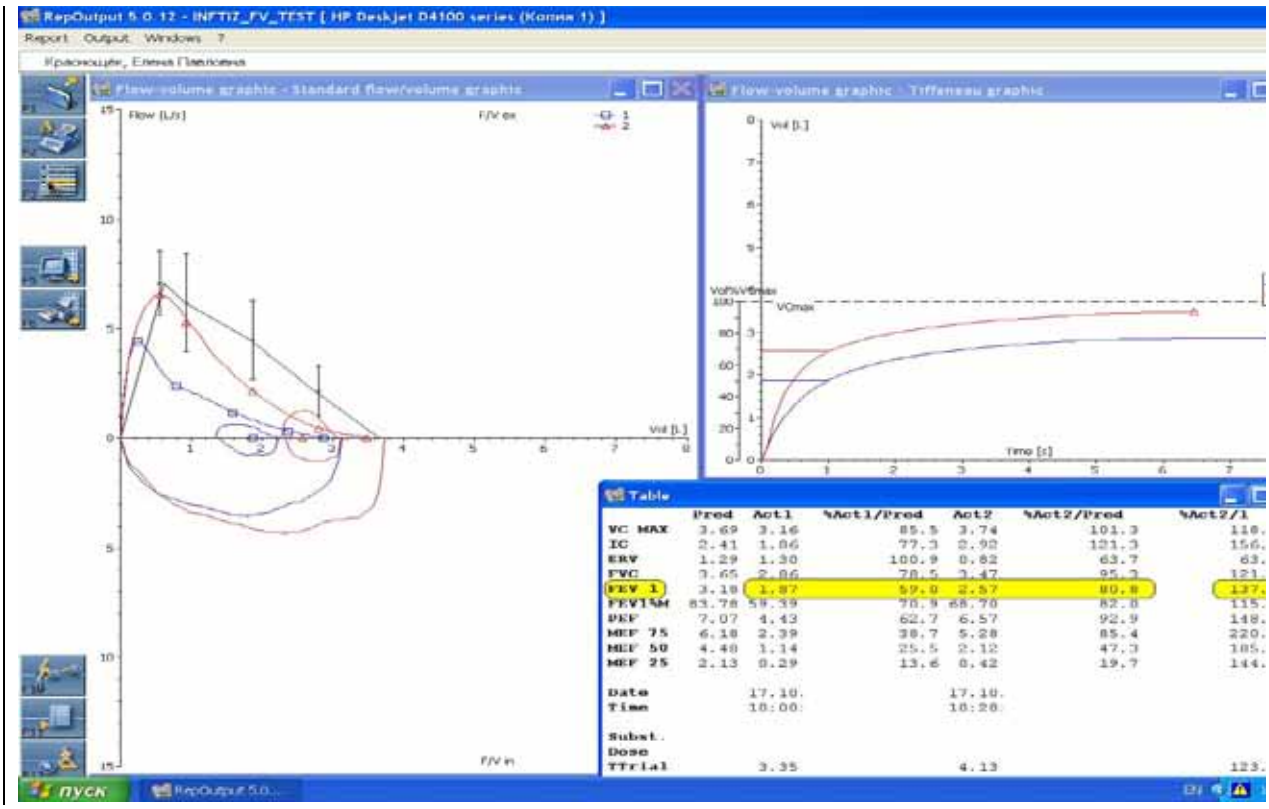
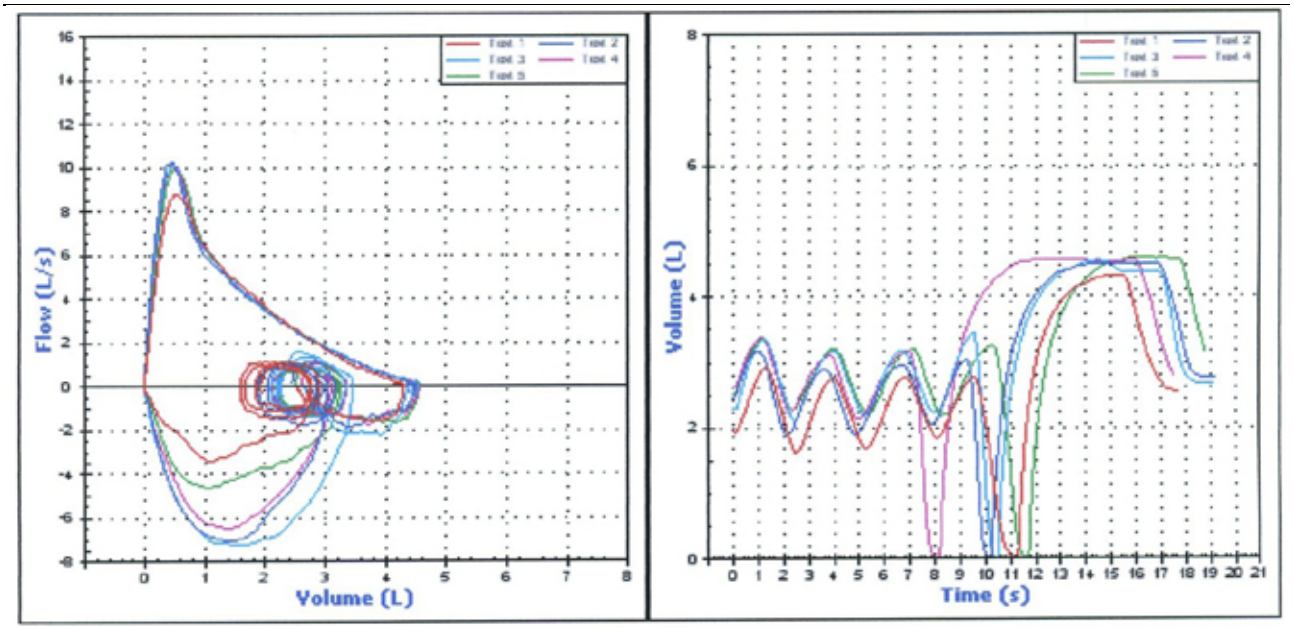


Figure 7. **Positive trial with bronchodilatator**



Parameter	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Best	Pred	% Pred
Time (hh:mm:ss)	08:15:46	08:16:39	08:17:25	08:17:58	*08:18:31						
FVC (L)	4.31	4.50	4.55	4.56	4.59				**4.59**	4.61	99.6
FEV1 (L)	3.38	3.39	3.42	3.42	3.42				**3.42**	3.92	87.2
PEF (L/min)	529	617	612	611	602				**617**	556	111.0
FEF25-75 (L/s)	2.90	2.64	2.67	2.64	2.60				**2.60**	4.76	54.6
Accepted	Yes	Yes	No	Yes	Yes				Yes		

*: best individual test with highest FVC + FEV1 sum.

Repeatability

FVC Repeatability:	FEV1 Repeatability:
30 mL	0 mL

Figure 8. **Spirogram of partly controlled asthma patient**

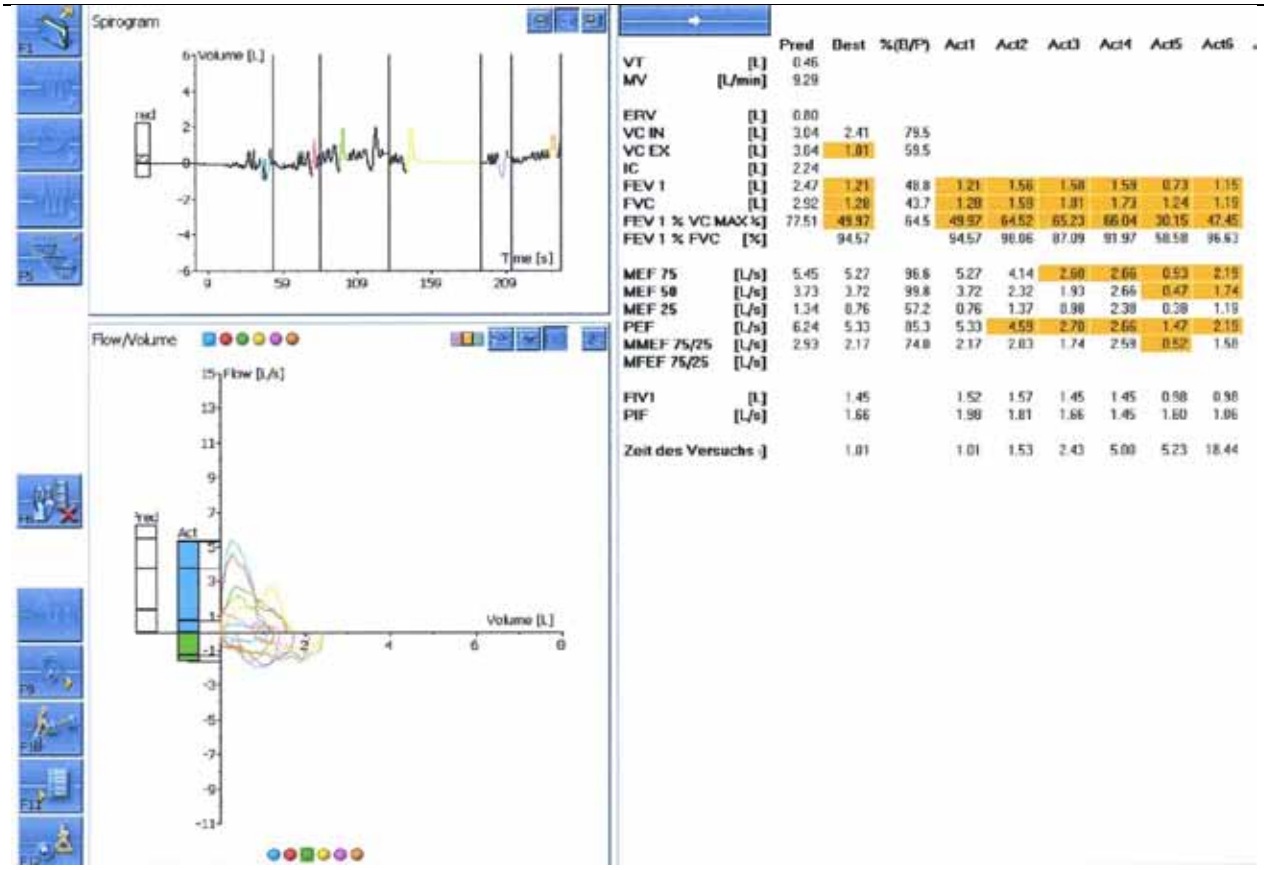
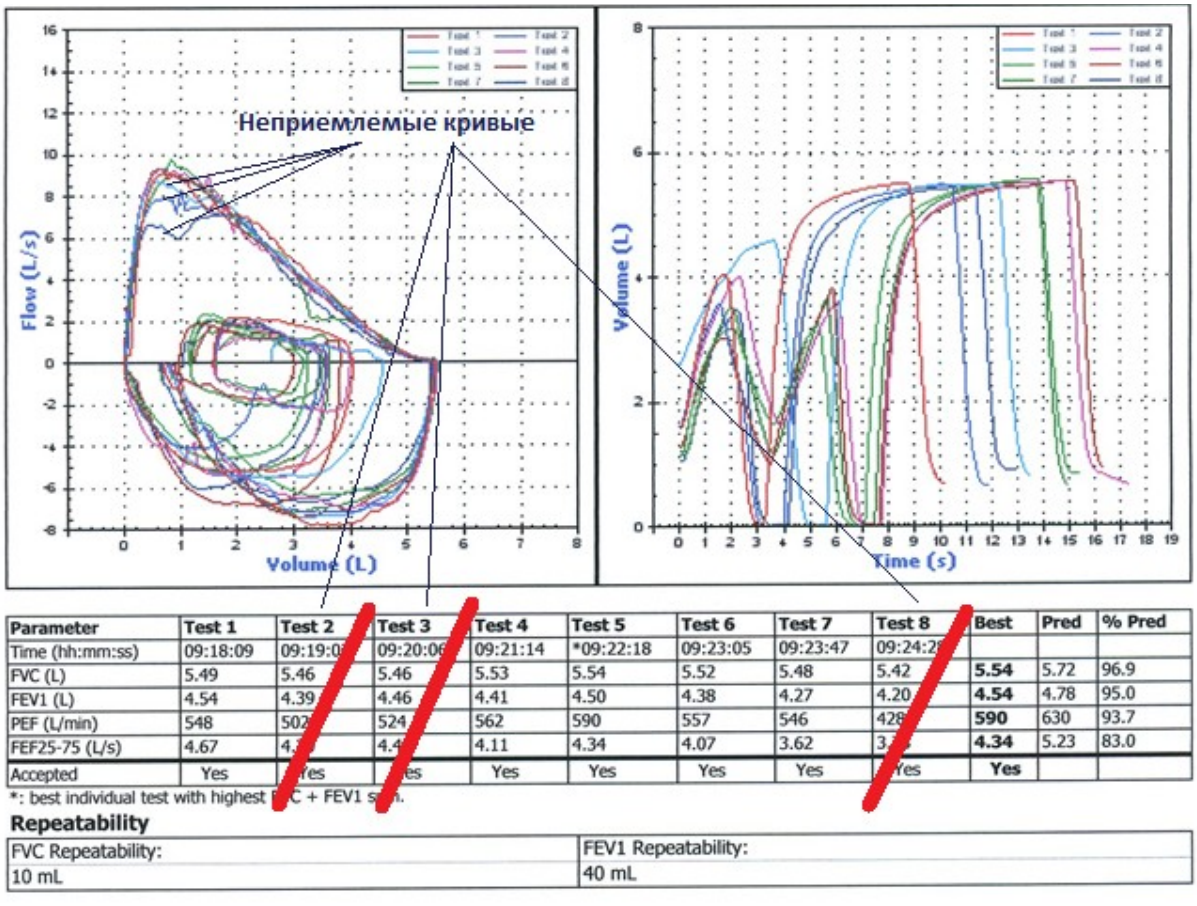


Figure 9. **Poor compliance in performing spirimetry**



Parameter	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Best	Pred	% Pred
Time (hh:mm:ss)	09:18:09	09:19:0	09:20:0	09:21:14	*09:22:18	09:23:05	09:23:47	09:24:2			
FVC (L)	5.49	5.46	5.46	5.53	5.54	5.52	5.48	5.42	**5.54**	5.72	96.9
FEV1 (L)	4.54	4.39	4.46	4.41	4.50	4.38	4.27	4.20	**4.54**	4.78	95.0
PEF (L/min)	548	502	524	562	590	557	546	428	**590**	630	93.7
FEF25-75 (L/s)	4.67	4.	4.4	4.11	4.34	4.07	3.62	3.	**4.34**	5.23	83.0
Accepted	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**Yes**		

*: best individual test with highest FVC + FEV1 s[illegible].

Repeatability

FVC Repeatability:	FEV1 Repeatability:
10 mL	40 mL

Figure 10. **In reaching of acceptability it is necessary to perform up to 8 attempts**

Spirogram of asthma patient. Figure 8 – spirogram of patient with persistent, partially controlled asthma. 1-2 times a week disturb daytime symptoms, sometimes wakes up at night due to asthma symptoms (2-4 times a month), a few times a week uses salbutamol to relieve symptoms, auscultation – forced expiratory listened dry wheezing in small quantities.

Analysis of spirogram: acceptable are all 5 attempts, reproducible – 4. FEV_1 – 87.2 % of predicted, 3.42 L, FVC – 4.59 liters, FEV_1/FVC ratio – 0.745: no signs of persistent bronchial obstruction, FEV_1 within normal limits. But if you look closely at the curve of exhalation, at its descending part, and as in the first example, noticeable concave curve, which suggests the presence of a small bronchial obstruction in this patient, what is confirmed in this case, the collection of history (see above).

Not all patients can be successfully perform spirometry, despite the explanation and demonstration of respiratory maneuvers. Example of the lack of doctor-patient interactions – in Figure 9.

It was performed 6 attempts. Assessment of each one in details: the first (blue) – there is a sharp peak on the exhale, no cough, but the maneuver is finished prematurely plateau phase is reached, the expiration lasted considerably less than 6 seconds, the second – red – the peak is there, but in the middle descending part of the curve the patient made a small breath, and again reached the plateau phase, exhale lasted considerably less than 6 seconds, the maneuver is finished prematurely, and the third attempt, the green curve – exhale weak, not the maximum, ended prematurely, the fourth curve, yellow – start forced expiratory weak, in the middle of an additional breath, not achieving plateau phase; attempting to try – raspberry – very faint exhalation, the sixth attempt – orange – no peak exhalation weak. Patient refused to continue the study, for any acceptable curve analysis is not received, nothing to evaluate.

We want to remind – spirogram can be assessed if received at least 3 acceptable curves, and among them there are reproducible. To achieve acceptability and reproducibility makes sense to do up to 8 attempts, then – no, the patient is likely to be tired, and up to a level approaching the maximum values do not exhale.

Figure 10 shows an example of attempts to achieve acceptable and reproducible curves. Criteria to assess study (curves acceptable FEV_1 and FVC repeatable) were achieved only when the 8 attempts were done.

Evaluating the results of spirometry it is important to see not only the digital result, but also a graphic representation of curves. If the study is judged only by the digital results, it is not clear why it was nessessary to do so many attempts. Reproducibility of FVC (FVC) is high – the greatest result of 5.54 l, closest to it – 5.53 L, then 5.52 L, 5.49 L, 5.48 L, the lowest value of 5.42 liters – the maximum difference between the largest and smallest value – 120 ml, FEV_1 (FEV1) – 4,54 l (the highest value), followed by 4.50 l, 4.46 l , 4.41 l , 4.39 l, 4.38 l etc. FEV_1 is highly reproducible (a difference of less than 150 mL) in 4 attempts.

But, if you look at the graphic image – you can see that the three curves (attempts (tests) 2, 3, 8) are not acceptable – on the curve forced expiratory additional respiratory maneuvers. And if we see only the data curves without graphics, only figures (Table 2):

Table 2

Indicators of FEV1 and FVC from technically unacceptable attempts

	Test 2	Test 3	Test 8
FVC	5,46	5,46	5,42
FEV_1	4,39	4,46	4,20

One would think that the study was carried out well, the results are reproducible. However, these three curves are not suitable for evaluation and interpretation! Only fully represented result, when we can see all curves, and the digital data can be the basis for interpretation.

References

1. *Полянская, М. А.* Спирометрия в вопросах и ответах [Текст] / Полянская М. А. // Медична газета «Здоров'я України». – 2009. – № 2/1. – С. 38–39.
2. *Фещенко, Ю. И.* Основы спирометрии и ее особенности при ХОЗЛ [Текст] / Ю. И. Фещенко, Л. А. Яшина, М. А. Полянская // Астма та алергія. – 2012. – № 2. – С. 22–27.
3. *Coates, A.* Spirometry in primary care [Text] / Coates A., Craham B., McFadden R. et al. //Can. Respir. J. – 2010. – Vol. 20, № 1. – P. 13–21.
4. *Cooper, B. G.* An update on contraindications for lung function testing. 2010 [Электронный ресурс] / B. G. Cooper. – Режим доступа: http://www.ncbi.nlm.nih.gov/pubmed/20671309.
5. *Levya, M.* Diagnostic Spirometry in Primary Care: Proposed standards for general practice compliant with American Thoracic Society and European Respiratory Society recommendations Primary Care [Text] / M. Levya, P. Quanjerb, R. Bookerc // Respiratory J. – 2009. – Vol. 18, № 3. – P. 130–147.
6. *Miller, M. R.* Standardisation of spirometry. ATS / ERS task force: standardisationoflungfunctiontesting [Text] / Miller M. R. et al. // Eur. Respir. J. – 2005. – Vol. 26. – P. 319–338.
7. *Quanjer, P.* Become an Expert in Spirometry. 2012 [Электронный ресурс] / P. Quanjer. – Режим доступа: http://www.spirxpert.com/indices7.htm.
8. *Queensland* Health Spirometry Training Program [Электронный ресурс]. – Режим доступа: https://ilearn.health.qld.gov.au/login/index.php 17.

ПРОВЕДЕННЯ СПІРОМЕТРІЇ В КЛІНІЧНІЙ ПРАКТИЦІ. ФУНКЦІОНАЛЬНІ ПРОЯВИ БРОНХООБСТРУКТИВНИХ ЗАХВОРЮВАНЬ (КЛІНІЧНІ ПРИКЛАДИ)

М. О. Полянська

Резюме

Спірометрія – поширене інформативне дослідження, яке широко використовується в клінічній практиці. Проте оскільки основні дихальні маневри при цьому дослідженні потребують максимальних зусиль, в ряді випадків проведення спірометрії – небажане чи взагалі протипоказане. Докладання максимальних зусиль (за відсутності протипоказань) може спричинити небажані прояви, це також треба мати на увазі. Протипоказання та небажані

прояви щодо спірометрії наведено у статті. Значну увагу приділено процесу аналізу спірограми, детально на клінічних прикладах висвітлено етапи оцінки, відбір тестів, придатних або непридатних для подальшого аналізу.

Ключові слова: *спірометрія, хронічне обструктивне захворювання легень, бронхіальна астма*

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IMPLEMENTATION OF SPIROMETRY IN CLINICAL PRACTICE. FUNCTIONAL EXPRESSION OF BRONCHOOBSTRUCTIVE DISEASES (CLINICAL EXAMPLES)

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Summary

Spirometry is a widespread, informative study, which is widely used in clinical practice. But since the main respiratory maneuvers in this study require maximum effort, in some cases, conducting spirometry undesirable or even contraindicated. Application of maximum effort (in the absence of contraindications) may cause undesirable manifestations, it must be borne in mind. Contra-indications and adverse manifestations on spirometry are given in the article. Much attention is paid to the analysis process of spirogram. The stages of evaluation and selection of tests, suitable or not suitable for further analysis is described in details on clinical examples.

Key words: *spirometry, chronic obstructive pulmonary disease, bronchial asthma.*

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