A New Biomarker in Diagnostic in Spirometry Exams with the Application of Wavelets

Rodrigo G.G. Piva, Rodrigo Prior Bechelli and Aldo Artur Belardi*

Centro Universitario´ da FEI – Electrical Engineering Dept. Av. Humberto de A. C. Branco, 3.972, 09850-901 Sao˜ Bernardo do Campo, Sao˜ Paulo, Brasil

Abstract: This article presents a new medical biomarker that can be use in spirometry tests. These biomarker was obtained through a set of tests, where Meyer wavelet was applied and allows through one statistical analysis of the data obtained in pulmonary exams, could be possible to obtain numerical indicators that assist the physician achieve diagnosis in patients pulmonary function as normal, obstructive or restrictive.

Keywords: Biomarker, Spirometry, Wavelets.

1. INTRODUCTION

Related studies about the classification of spirometry exams, which is the area of medicine that study lungs and airways, mostly was applied some kind of mathematical calculation, in order to correlate the patient results with others regional ethnography, and also, with the intention of raising the necessary parameters to create a reliable medical report. These values used as a parameter in order to classify the results, is called predict, and several studies presents methodologies the achieve a reliable prediction, resulting basically classify the patient into three different types: normal, obstructive and restrictive patterns [1, 2].

Several researchers apply a punctual analysis in some predicts values within a patient sample that is possible to collect the value for example Forced Vital Capacity (FVC), or Forced Expiratory Volume (FEV). In this way, this article present a methodology capable of classifying numerically and evaluate all points of the curve in order to be able assist a pulmonary function test performed previously.

This is an exam who receive interference from several variables, one of the most important in the execution of the expiratory manouver is the dependence of the patient's disposition that will perform this test, and the medical diagnosis, most of the time, is performed by visual method.

2. ESPIROMETRY TEST

The spirometry test is based obtaining the volume and airflow values of the patient's breathing, and their comparison with previously known results of the local population, since these previous values change according to the worldwide locality. This test is performed by a method that converts the air that circulates through the lungs into an electrical value that can be read by a computer, and through this value it is possible to calculate the basic parameters, *i.e*. the Flow (L=s) versus Volume (L), and Volume (L) versus Time (s) [3, 4].

Spirometry is a commonly performed Pulmonary Function Test (PFT) which is used to distinguish obstructive and restrictive lung diseases [5]. Presents the basic system requirements for an automatic pulmonary disease classification system based by signal using a know algorithm. The software of the system extracted features from the waveform values and classified the disorders with high accuracy. Classification was done using an Evolutionary Approach called Genetic Algorithm (GA) and without using any prediction equations as done by the conventional spirometry tests.

The respiratory system functioning is based on a ventilatory mechanism. The Lung quality depends by lung ventilation quality. The spirometry measure the pulmonary ventilation efficiency [6]. Presents a new model of spirometry that estimates the basis of spirometry measurements. These parameters allow us to obtain new information concerning breathing conditions. The parameters allow us to distinguish between healthy and diseased subjects. The experimental verification revealed the diagnostic usefulness of model parameters obtained on the basis of spirometry measurements.

Extraction of respiratory activity from physiological signals such as pulse oximeter's photoplethysmo-graphic (PPG) would be an alternative under clinical

*Address correspondence to this author at the Centro Universitario´ da FEI – Electrical Engineering Dept. Av. Humberto de A. C. Branco, 3.972, 09850-901 Sao˜ Bernardo do Campo, Sao˜ Paulo, Brasil; Tel: (11) 4353-2900;
E-mail: belardi@fei.edu.br

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settings to all the direct methods of recording respiratory signals such as spirometry [7]. Propose an effective method, based on multi scale independent component analysis (MS-ICA), for separation of artifact (MA) from PPG extraction of respiratory activity. The method was tested on PPG sets recorded from different subjects, including simultaneously respiratory signals.

In [8], who reports a prototype Electrical Impedance Imaging System, was able to detect the gravity-induced changes in the distributions of perfusion and ventilation in the lung between supine and lateral decubitus positions. Impedance signal was collected on healthy volunteer subjects and reconstruct 3D images produced in real-time, 20 frames per second on site, without averaging or a contrast agent. This data also can be reconstructed for further analysis.

Forced spirometry testing is gradually becoming a primary care. Been demonstrated in earlier work that commercially available spirometers are not fully able to guarantee individual spirometry quality. Thus, high-quality spirometry assessment beyond specialist pulmonary centres has arisen [9]. Propose a method to select and optimise a classifier using supervised learning techniques by learning from previously classified forced spirometry tests from a group of experts.

Had shown that smartphone spirometry can effectively measure lung function using the phone's built-in microphone and could be a critical role in making spirometry more usable. Traditional spirometry is performed with the guidance of a medical expert, smartphone spirometry do not guarantee the quality of a patient's spirometry efforts [10]. Introduce two approaches to analyze and estimate the quality of smartphone spirometry efforts.

The graphs of the spirometry exam express two characteristics: the inspiratory flow, through the inspiratory loop in the flow chart versus volume and expiratory flow in the same graph. In order to aid diagnosis, an auxiliary graph is generate that expresses the entire lung volume function versus time [11, 12].

Thus, the spirometry test should be accompanied, in addition to the diagnosis, by the parameters obtained with graphical numerics results obtained [13, 14].

In a superficial way, the curves for such diseases are present in Figure **1**.

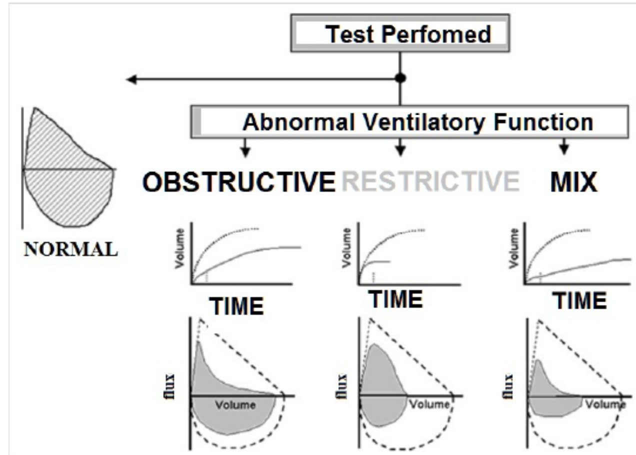

Figure 1: Spirometry Disease Forms.

3. METHODOLOGY

A database of 60 (sixty) exams were used, of which 20 (twenty) were tests of normal individuals, 20 (twenty) tests of obstructive individuals and 20 (twenty) tests of restrictive individuals. Each of the 20 (twenty) exam samples were divided into 10 (ten) male subjects and 10 (ten) female subjects.

The Figure **2** shows the differences in FVC and FEV1 values considering individuals with the same physical characteristics as males.

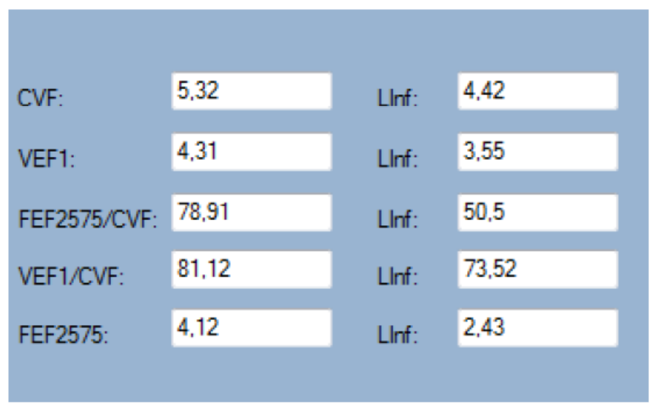

Figure 2: Predicted Example for male gender.

The changes observed in relation of the FVC and FEV1 values, according to the guidelines of the Brazilian society of pulmonology [4], are acceptable since it is less than 10% (ten percent) compared to exam performed, or like a 500ml difference in a single test.

This methodology uses data of both genders. Using the values of the exams provided by a spirometer, in the Figures **3** and **4** show the curves of the patients

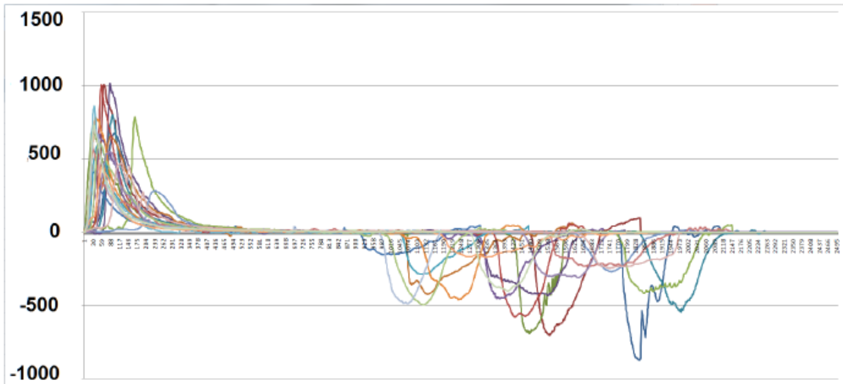

Figure 3: Curves of normal patients.

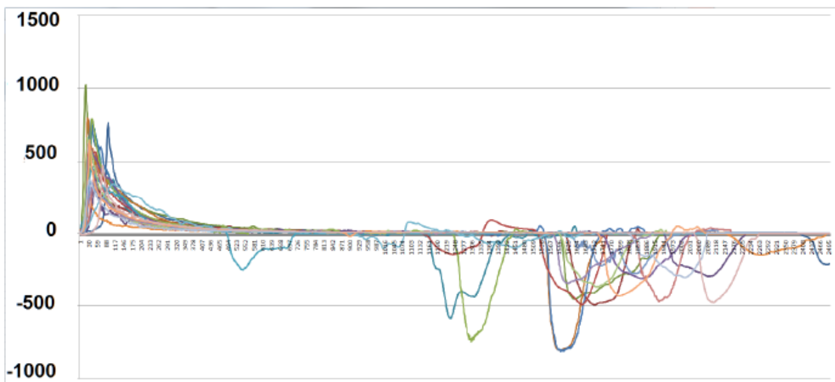

Figure 4: Obstructive and Restrictive patient curves.

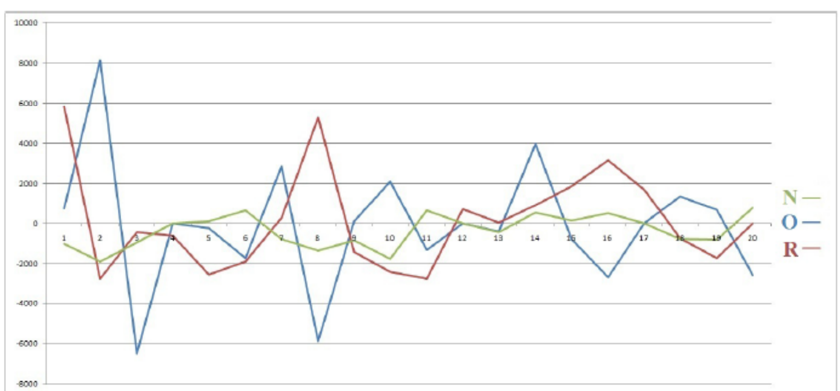

Figure 5: Covariance of patients before the application of wavelets.

exams respectively diagnosed as normal, obstructive and restrictive.

The Figure **5** presents the patients covariance before application of the proposed methodology that uses the details coefficients of the wavelets [15-17].

We can observe that is not possible to distinguish numerical values, since is not possible to caracterize patients with respiratory problems.

Table **6** shows values from 1–10 (one to ten) in forced expiration period, values from 800 to 820 (eight hundred to eight hundred and twenty) in context of the end of the forced expiration maneuver and values from 1540 to 1550 (one thousand five hundred and forty to one thousand five hundred and fifty) which, are the values during voluntary inspiration, of a sample of 2550 (two thousand five hundred and fifty) fast data points. The coefficients values were calculated in 8 (eight) male individuals with normal diagnosis, after the

		Indiv1	Indiv2	Indiv3	Indiv4	Indiv5	Indiv6	Indiv7	Indiv8
Forced expiration	1	335,15	510,88	3581,57	-410,85	-92,74	535,05	2118,96	1806,14
	2	285,36	-35,21	2191,34	209,54	150,41	46,58	984,10	-510,616
	3	371,84	340,05	3304,28	-105,24	73,99	516,59	1896,03	1372,12
	4	482,17	708,78	3600,53	-25,76	211,68	858,08	2153,78	2353,13
	5	238,47	-129,84	2371,11	29,17	22,60	-17,69	1122,24	-487,597
	6	361,91	299,47	3000,34	-3,68	115,87	424,94	1649,57	950,17
	7	483,62	704,64	3758,79	-73,39	189,76	901,85	2282,93	2551,28
	8	271,53	-9,29	2491,75	33,70	54,18	88,79	1224,54	-158,59
	9	317,22	142,32	2774,87	9,35	82,80	266,16	1460,58	433,07
	10	498,00	758,79	3805,35	-75,11	200,43	940,12	2321,41	2678,43
		...	...	...	...	...	...	...	...
Final expiration	800	-0,19	-3,12	-38,49	1,69	3,87	-0,45	-10,72	-3,09
	801	11,76	6,71	41,45	-3,72	-4,23	0,86	4,89	10,03
	802	-3,31	-11,12	-56,04	4,57	-2,97	-0,43	-8,66	-19,54
	803	7,24	22,04	19,08	2,91	8,09	1,81	8,74	20,36
	804	-5,17	-41,65	-4,31	-1,76	-10,21	-2,22	-4,40	-38,78
	805	15,45	86,76	-2,96	4,00	9,22	16,18	5,49	62,40
	806	-24,43	-145,09	15,43	-3,48	-14,87	-21,12	-2,31	-92,78
	807	1,60	9,78	8,39	-0,88	3,94	0,57	4,98	26,32
	808	-6,10	-21,83	-5,55	1,82	-7,27	1,71	-6,60	-23,19
	809	2,64	7,09	29,61	-7,04	-0,49	-1,28	5,51	19,06
	810	-8,48	-7,92	-12,19	9,32	4,40	1,44	-2,44	-14,18
	811	1,16	7,66	-1,54	-5,96	-7,36	-1,83	5,59	5,83
	812	5,69	-4,78	99,45	4,55	-2,07	4,56	12,76	-1,05
	813	-10,00	3,07	-98,65	-3,92	2,13	-4,36	-10,19	-1,43
	814	1,19	-3,10	59,71	4,54	6,80	2,21	6,02	2,53
	815	1,61	1,21	-18,74	-10,07	-7,40	-1,51	-5,04	2,92
	816	-2,81	3,50	-2,36	7,07	6,02	0,38	2,48	1,89
	817	3,21	16,46	-2,60	-4,04	2,81	-4,13	-3,08	0,20
	818	-5,41	13,42	-2,51	0,02	-0,01	0,77	1,24	16,74
	819	3,79	11,18	-9,10	-0,53	6,18	1,90	3,00	-6,47
	820	10,19	49,38	-1,71	-6,10	-9,30	-3,05	4,21	-26,29
		...	...	...	...	...	...	...	...
Voluntary inspiration	1540	1,18	0,53	-1,74	-0,083	-0,24	-0,26	-0,04	0,09
	1541	-0,38	-0,14	-0,14	0,78	0,36	0,02	-0,82	-0,00
	1542	0,06	0,22	-0,00	0,32	0,21	-0,25	0,74	-0,21
	1543	0,17	0,22	0,45	0,18	0,23	-0,37	-1,75	-0,13
	1544	-0,38	-0,14	-1,03	-0,35	-0,01	0,37	3,67	-0,43
	1545	-0,00	-0,29	-0,22	0,58	-0,53	-0,34	-7,77	-0,00
	1546	-0,32	-0,39	0,13	-0,06	0,13	-0,51	15,36	-0,00
	1547	-0,15	0,04	0,62	-0,46	-0,01	1,16	1,85	-0,04
	1548	-0,36	-0,03	-0,44	-0,35	0,04	0,00	-3,47	0,26
	1549	0,60	-0,21	-0,29	-0,07	-0,04	-0,25	-0,08	-0,03
	1550	-0,02	-0,28	0,49	0,40	0,19	-0,43	-0,37	0,44

Figure 6: Values obtained after application of Meyer's wavelets.

application of the Meyer wavelets. We emphasize that we tested other types of wavelets such as Haar, Mexican Hat, Morlet, Shannon, etc., but Meyer's was the most efficient in the classification of the results.

4. RESULTS

After the wavelets application, we observed that was a numerical difference between the patients considered normal, obstructive and restrictive.

In the Figures **7** and **8** we show the results obtained after the application of the Meyer wavelets in samples S25 and S42, which were chosen randomly, and correspond to a male subject being normal and restrictive respectively [18].

In the Figures **9** and **10** presents the results obtained with the application of the Meyer wavelets, for male and female respectively.

We can observe with the analysis covariance after the application of Meyer wavelets, there is a large significant numerical difference between the normal, obstructive and restrictive values for both genders.

The Table **1** shows the covariance values for males and females, and it is possible to classify the values in ranges (maximum and minimum) in exam.

Table 1: Statistical Values Obtained

	Males	Females
Normal	1079,38 – 1765,94	984,70 – 1228,11
Obstructive	1876,54 – 2739,91	1235,20 – 1402,54
Restrictive	Above 3062,28	Above 1392,23

To validate the proposed methodology, we randomly selected 12 (twelve) patients, 6 (six) males

Table 2: Validation of the Methodology and Estimated Differences

	Male	Female	Male	Female
Normal	1734	1167	1079,38 – 765,94	984,701 – 1228,11
Obstructive	2527	1346	1876,54 – 2739,91	1235,20 – 1402,54
Restrictive	5678	1873	Above 3062,28	Above 1392,23

and 6 (six) females, with a normal, obstructive and restrictive diagnosis. The results obtained are described in Table **2**.

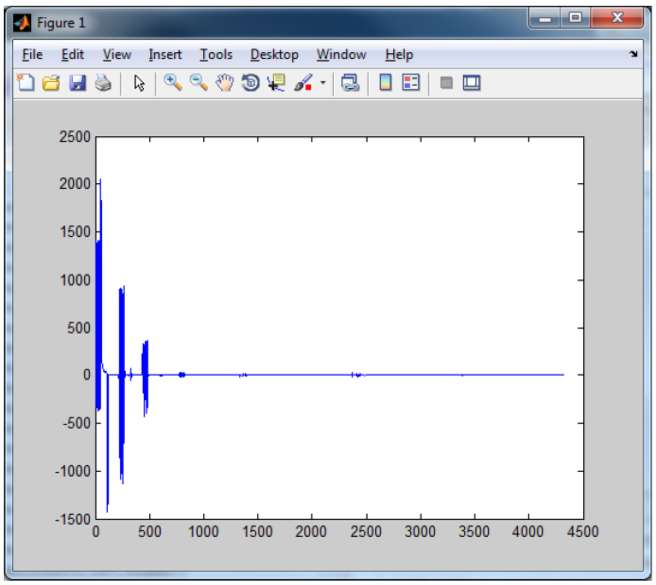

Figure 8: Coefficients of S42 data after the application of Meyer wavelet.

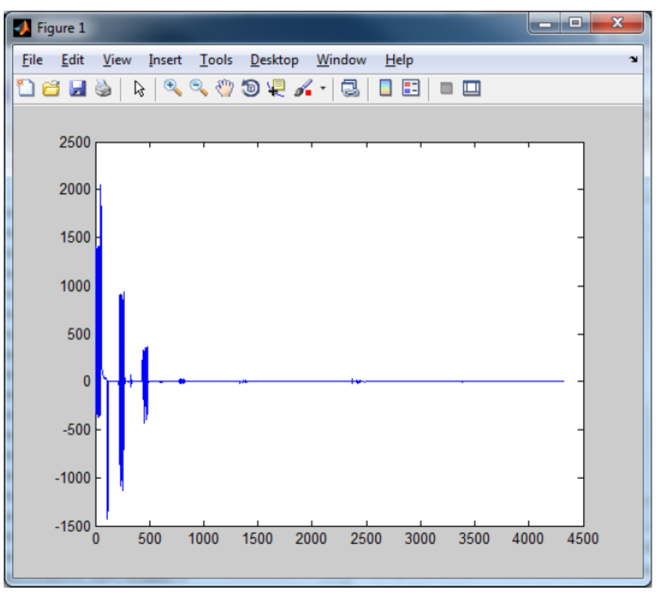

Figure 8: Coefficients of S42 data after the application of Meyer wavelet.

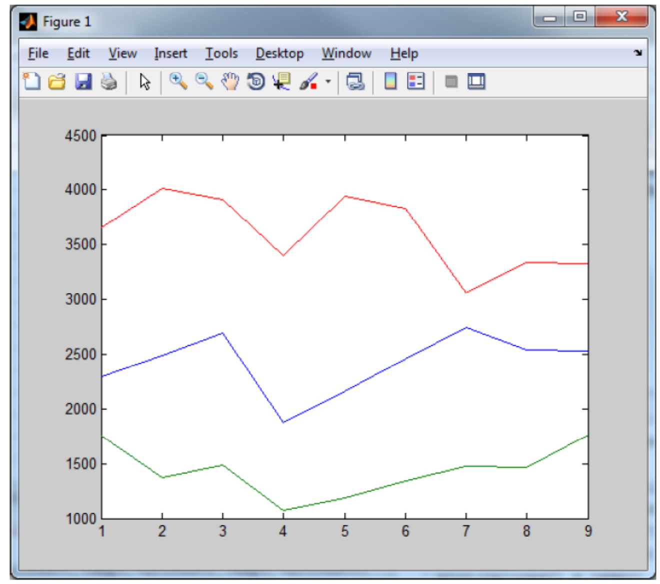

Figure 9: Data separation through covariance of database for the male subjects after the application of Meyer wavelet.

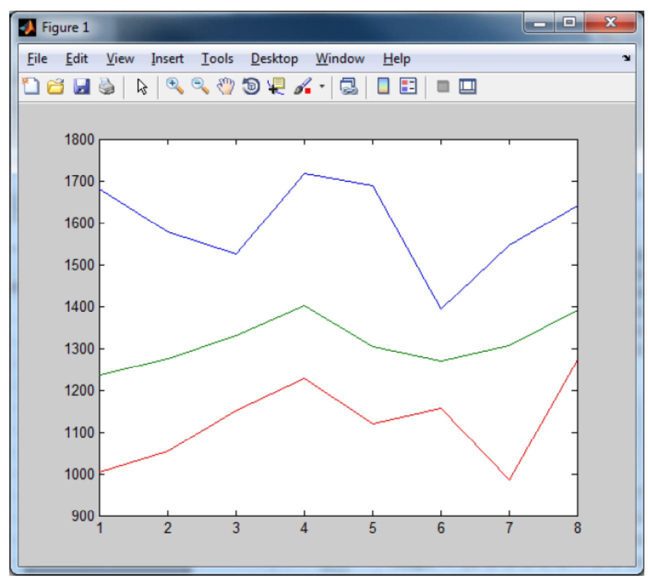

Figure 10: Data separation through covariance of database for the female subjects after the application of Meyer wavelet.

4.1. Results Obtained with Proposed Methodology

In some cases if the subject does not cooperate or does not understand the spirometric maneuver, the result can be misunderstood. In all the samples that are used in this article, at least four ventilators maneuvers were perform during the test, in an attempt to eliminate the possibility of a poorly performed examination.

An interesting case that were observed was the obtaining of the results of one of the samples that presented a significant difference, since it was a patient diagnosed as restrictive, but after the accomplishment of the proposed methodology, we obtained a different result of its diagnosis in normal pattern.

The test that was analyzed by our method is shown in Figure **11**.

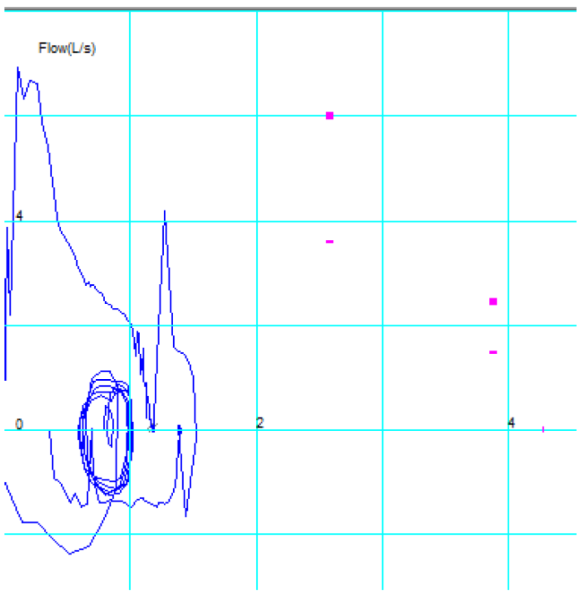

Figure 11: Forced Vital Capacity Exam Performed.

The Figure **12** presents part of the report of the examination where it is possible to verify the values finded out in exams, as well the relation with the preditc to associate and determine the diagnosis of the exam.

Therefore, this patient deserves a more detailed study, possibly for not collaboratin the exam execution or because the physician does not have subsidies or mathematical models to make a more precise report.

CONCLUSION

This paper shows the Meyer wavelets application in addition with a statistical analysis to obtain a new biomarker, which can be used in spirometry tests.

The analysis results indicate that this proposed method for exam characterization allows, successfully, an nearly exact characterization within the expected values. Four exams was used on this proposed method and was able to perform an spirometry curve analysis, and this numerical values achieved are validate, creating subsidies to the physician, performing a accurate diagnosis.

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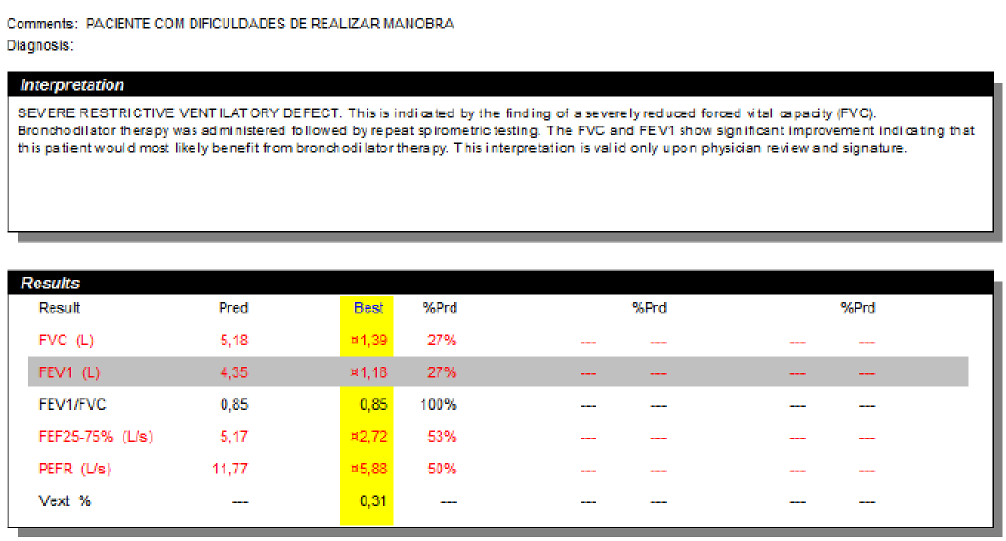

Comments: PACIENTE COM DIFICULDADES DE REALIZAR MANOBRA

Diagnosis:

Interpretation

SEVERE RESTRICTIVE VENTILATORY DEFECT. This is indicated by the finding of a severely reduced forced vital capacity (FVC). Bronchodilator therapy was administered followed by repeat spirometric testing. The FVC and FEV1 show significant improvement indicating that this patient would most likely benefit from bronchodilator therapy. This interpretation is valid only upon physician review and signature.

Results

Result	Pred	Best	%Prd		%Prd		%Prd
FVC (L)	5,18	¤1,39	27%	---	---	---	---
FEV1 (L)	4,35	¤1,18	27%	---	---	---	---
FEV1/FVC	0,85	0,85	100%	---	---	---	---
FEF25-75% (L/s)	5,17	¤2,72	53%	---	---	---	---
PEFR (L/s)	11,77	¤5,88	50%	---	---	---	---
Vext %	---	0,31	---	---	---	---	---

Figure 12: KOKO equipment report screen.

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