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DISCRIMINANT ANALYSIS OF VOLUME-TIME AND FLOW-VOLUME PARAMETERS BETWEEN HEALTHY ADULTS AND ASTHMATIC PATIENTS

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Abstract. Volume-time (V-T) and flow-volume (F-V) curves were measured in all the subjects of nonsmoking young males (mean value 26.3 yrs.), healthy and asthmatic. Eleven parameters of pulmonary function tests, which were composed of two V-T, six F-V, and three mean time constants (MTC) parameters, were calculated from the curves. These were used in the discriminant analysis through all possible selection procedures (APSP) to make clear the importance of the F-V recognition. In using only one parameter, $\dot{V}_{75}$, which was one of the F-V parameters, showed the lowest probability of misclassification, 18.78 %, and was the most useful parameter to discriminate the two groups. The probability of misclassification of the eleven parameters showed 15.46 %, and that of the six F-V ones showed 17.45 %. Though the probability of the six F-V ones was higher than that of the eleven ones, it was lower than that of the twoV-T or of the three MTC ones. Therefore the six F-V parameters including $\dot{V}_{75}$ was sufficient to discriminate the two groups of subjects. Thus it was made clear that the flow-volume recognition was important by the discriminant analysis.

Key words : discriminant analysis, volume-time and flow-volume curve, the all possible selection procedure (APSP), bronchial asthma, probability of misclassification.

It is generally said that the forced expiration curves of asthmatic patients in the asymptomatic stage are the same as those of healthy men. Takishima (1) reported that the flow volume curves (F-V curves) of asthmatic patients were characteristic compared with other chronic obstructive lung diseases (COLD), in that flow rates suddenly fell concavely at high lung volumes (70-80 % of FVC). At the asthmatic stage, the flow rate of the flow-volume curve fell concavely throughout the curve and the sudden flow-fall just below the peak flow rate (PF) was not remarkable in the asymptomatic stage (1).

We (2-4) reported discriminant analysis of healthy adults and asthmatic patients in the asymptomatic stage using eight volume-time and flow-volume parameters. The analysis was performed through the forward selection procedure (FSP) (5). The pulmonary function data of patients in the asymptomatic stage were different from those of healthy males. The order of the selected parameters,

the probabilities of misclassification, and the discriminant function equations were computed. However, in FSP, independent parameters are ordered step by step based on multiple correlation coefficients effective to the dependent parameters, so discrimination through all possible selection procedures (APSP) was not possible (5). In the previous report (4), parameters selected at any step through FSP were not always the best ones.

In this study, we performed discriminant analysis through APSP between the two groups. We wanted to investigate three points: derivation of the most useful of the eleven parameters by comparing the eleven probabilities of misclassification for any one parameter between healthy adults and asthmatic patients; evaluation of the discriminant ability of the F-V parameter group by comparing the final probabilities of the four parameter groups (V-T, F-V, MTC, and the total parameter group); and computation of selection of the best parameters and the probabilities at any step by using the total parameter group.

MATERIALS AND METHODS

The subjects were 32 nonsmoking healthy young males and 26 nonsmoking asthmatic young males (Table 1). Significant difference in age was found between the healthy adults

TABLE 1. ANTHROPOMETRIC DATA

	Healthy adults	Asthmatic patients	t-test
Number	32	26	
Age (Yrs.)	23.6± 1.5 (Range: 21-29)	29.2± 8.2 (Range: 18-44)	(+)
Height (cm)	169.1± 5.6	166.5± 5.1	(−)

(Mean± unbiased standard deviation)

and the asthmatic patients, but not in height. Though the age difference was significant, the flow-volume patterns for asthmatic patients were characteristic (1) and were almost the same for each decade age group.

The patients were chosen while they were under medical control at the Allergy Outpatient Clinic of the Department of Internal Medicine of Okayama University Medical School. All patients had been given bronchodilators under a doctor's control, but no patient had asthmatic attacks for at least the two days including the tested day. The severity of bronchial asthma was classified according to Oshima's classification (2), which depends on the intensity of asthmatic attacks as shown by dyspnea and effects on daily life and on the mean of the frequency of monthly attacks. Oshima's classification is commonly used in Japan at present. The observation period for determining the severity of bronchial asthma was more than six months. The healty males were medical students and young doctors, and had no respiratory symptoms, no past history of respiratory diseases, and no physical abnormalities.

A flow-volume curve recorder (OST-70D, Chest Co. Ltd.) was used for the forced expiratory procedure, which consisted of the forced expiratory V-T and the forced expiratory F-V procedures. The forced expiratory V-T and F-V curves were measured in the sitting position several times and the chart obtained at the first measure was not used for calculation. Instaed, one of the biggest F-V patterns with a sharp peak flow rate was selected out of those obtained at subsequent determinations. V-T parameters (% FVC and $FEV_{1.0\%}$), F-V

parameters (peak flow rate (PF), $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{25}$, $\dot{V}_{10}$, and $\dot{V}_{50}/\dot{V}_{25}$), and MTC parameters ($MTC_{75-50}$, MTC_{50-25}, and MTC_{25-RV}) were calculated from the curves.

In this study, eleven parameters were used for discriminant analysis. In the discriminant analysis between the nonsmoking healthy young males and the nonsmoking asthmatic young males, the all possible selection procedure (APSP) was performed by the electronic computer NEC ACOS 700-S in the Okayama University Computer Center. The procedure of the discriminant analysis is shown in Table 2.

TABLE 2. PROCEDURES OF THE DISCRIMINANT ANALYSIS THROUGH ALL POSSIBLE SELECTION PROCEDURE (APSP)

Parameter or parameter group	Parameters used
One parameter	% FVC, $FEV_{1.0\%}$, PF, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{25}$, $\dot{V}_{10}$, $\dot{V}_{50}/\dot{V}_{25}$, MTC_{75-50}, MTC_{50-25}, MTC_{25-RV}
V-T parameter group	% FVC and $FEV_{1.0\%}$
F-V parameter group	PF, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{25}$, $\dot{V}_{10}$, and $\dot{V}_{50}/\dot{V}_{25}$
MTC parameter group	MTC_{75-50}, MTC_{50-25}, and MTC_{25-RV}
Total parameter group	% FVC, $FEV_{1.0\%}$, PF, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{25}$, $\dot{V}_{10}$, $\dot{V}_{50}/\dot{V}_{25}$, MTC_{75-50}, MTC_{50-25} and MTC_{25-RV}

MTC_{x-y}(mean time constant x−y % level of FVC) is obtained from the next equation;

$$MTC_{x-y}=(\dot{V}_x-\dot{V}_y)/(1/4)\,FVC,$$

where x is a x % level of FVC, and y is a y % level of FVC. The mean time constants are recognized as parameters of the mechanics ef breathing. In the following equation;

$$MTC=d\dot{V}/dV=1/(R\times C)=1/T$$

MTC is the reciprocal of the time constant (T).

RESULTS

Pulmonary Function Data

The results of the pulmonary function tests are shown in Table 3. The mean values of F-V parameters, for example, $\dot{V}_{75}$, $\dot{V}_{50}$, and $\dot{V}_{25}$, and those of MTC ones, MTC_{50-25} and MTC_{25-RV}, obtained from asthmatic patients were lower than those from the healthy youths. Other parameters, for example, $FEV_{1.0\%}$, PF, $\dot{V}_{10}$, MTC_{75-50} and MTC_{25-RV} were also lower.

The t-tests for the differences between mean values. The differences in the mean values of the parameters except for % FVC and $\dot{V}_{50}/\dot{V}_{25}$ were statistically significant.

Discrimination with One Parameter

The probability order of the parameters. The order of the parameters from lower in the probability of misclassification to higher was as follows; $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{25}$, MTC_{50-25}, MTC_{25-RV}, $FEV_{1.0\%}$, PF, $\dot{V}_{10}$, MTC_{75-50}, % FVC and $\dot{V}_{50}/\dot{V}_{25}$.

TABLE 3. RESULTS OF PULMONARY FUNCTION TESTS IN EACH GROUP

Parameters	Healthy adults		Asthmatic patients		t-test (t-value)
	Mean value	and U.S.D	Mean value	and U.S.D.	
1. %FVC (%)	110.7	9.5	105.1	15.9	1.58 (−)
2. $FEV_{1.0\%}$ (%)	86.6	6.4	72.9	14.8	4.40 (***)
3. PF (L/sec)	10.7	1.4	8.4	2.4	4.33 (***)
4. $\dot{V}_{75}$ (L/sec)	9.3	1.5	5.6	2.6	6.44 (***)
5. $\dot{V}_{50}$ (L/sec)	5.9	1.4	3.2	1.9	6.22 (***)
6. $\dot{V}_{25}$ (L/sec)	2.5	0.8	1.3	0.8	5.68 (***)
7. $\dot{V}_{10}$ (L/sec)	1.0	0.6	0.5	0.4	3.79 (***)
8. $\dot{V}_{50}/\dot{V}_{25}$	2.5	0.4	2.7	0.6	1.46 (−)
9. MTC_{75-50} (1/sec)	2.85	0.89	2.19	0.80	2.94 (**)
10. MTC_{50-25} (1/sec)	2.99	0.90	1.72	0.94	5.23 (***)
11. MTC_{25-RV} (1/sec)	2.15	0.78	1.20	0.74	4.72 (***)

%FVC: Per cent of forced vital capacity, $FEV_{1.0\%}$: per cent of first one second volume in forced expiration curve, PF: peak flow rate in maximal expiratory flow-volume curve (MEFVC), $\dot{V}_{75}$: flow rate at 75% of FVC in MEFVC, $\dot{V}_{50}$: flow rate at 50% of FVC in MEFVC, $\dot{V}_{25}$: flow rate at 25% of FVC in MEFVC, $\dot{V}_{10}$: flow rate at 10% of FVC in MEFVC, $\dot{V}_{50}/\dot{V}_{25}$: ratio of V_{50} to $\dot{V}_{25}$, MTC_{75-50}: mean time constant (MTC) in the level of 75-50% of FVC, MTC_{50-25}: MTC in the level of 50-25% of FVC, MTC_{25-RV}: MTC in the level of 25-0% of FVC, U.S.D.: unbiased sample standard deviation, (**, ***): statistically significant at 1% or 0.1% rejection limit.

TABLE 4. THE PROBABILITIES OF MISCLASSIFICATION THROUGH THE ALL POSSIBLE SELECTION PROCEDURE

Parameter or parameter group	Probability of misclassification
%FVC	41.37 %
$FEV_{1.0\%}$	26.58
PF	27.66
$\dot{V}_{75}$	18.79
$\dot{V}_{50}$	20.01
$\dot{V}_{25}$	23.35
$\dot{V}_{10}$	31.81
$\dot{V}_{50}/\dot{V}_{25}$	43.03
MTC_{75-50}	35.04
MTC_{50-25}	24.59
MTC_{25-RV}	26.45
Volume-time parameter group	25.91
Flow-volume parameter group	17.45
Mean time constant parameter group	22.14
Total parameter group	15.46

The probability of misclassification. The results are shown in Table 4. $\dot{V}_{75}$ showed the lowest probability of misclassification, 18.78 %, $\dot{V}_{50}$ showed 20.02 %,

$\dot{V}_{25}$ 23.36 %, MTC_{50-25} 24.59 %, MTC_{25-RV} 26.45 %, $FEV_{1.0\%}$ 26.58 %, and PF 27.66 %. The results of the remaining parameters are shown in Table 4.

Discrimination with the Four Parameter Groups (the V-T, the F-V, the MTC, and the total parameter group)

The probability of misclassification with the parameter group is shown in Table 4.

The probability with the two V-T parameters. The probability was 25.91 %.

The probability with the six F-V parameters. The probability was 17.45 %.

The probability with the three MTC parameters. The probability was 22.14 %.

The probability with the total parameter group. The probability was 15.46 %.

Discrimination with the Total Parameter Groups

The results are shown in Table 5.

TABLE 5. DISCRIMINATION WITH THE ELEVEN PARAMETERS THROUGH ALL POSSIBLE SELECTION PROCEDURE

Step	Parameters of the selected group	Probability of misclassification
1	$\dot{V}_{75}$	18.78 %
2	$FEV_{1.0\%}$, $\dot{V}_{75}$	17.91
3	$FEV_{1.0\%}$, PF, $\dot{V}_{75}$	16.70
4	$FEV_{1.0\%}$, PF, $\dot{V}_{75}$, MTC_{75-50}	15.65
5	$FEV_{1.0\%}$, PF, $\dot{V}_{75}$, $\dot{V}_{50}/\dot{V}_{25}$, MTC_{75-50}	15.60
6	$FEV_{1.0\%}$, PF, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{50}/\dot{V}_{25}$, MTC_{75-50}	15.56
7	%FVC, $FEV_{1.0\%}$, PF, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{50}/\dot{V}_{25}$, MTC_{75-50}	15.49
8	%FVC, $FEV_{1.0\%}$, PF, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{50}/\dot{V}_{25}$, MTC_{75-50}, MTC_{25-RV}	15.47
9	%FVC, $FEV_{1.0\%}$, PF, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{10}$, $\dot{V}_{50}/\dot{V}_{25}$, MTC_{75-50}, MTC_{25-RV}	15.46
10	%FVC, $FEV_{1.0\%}$, PF, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{25}$, $\dot{V}_{10}$, $\dot{V}_{50}/\dot{V}_{25}$, MTC_{75-50}, MTC_{25-RV}	15.46
11	%FVC, $FEV_{1.0\%}$, PF, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{25}$, $\dot{V}_{10}$, $\dot{V}_{50}/\dot{V}_{25}$, MTC_{75-50}, MTC_{50-25}, MTC_{25-RV}	15.46

The probability of misclassification at each step. The probability at the first step was 18.78 %, the second 17.91 %, the third 16.65 %, and the fourth 15.65 %. The decrease in the probability was slight from the fourth step to the final. The final probability was 15.46 %.

The best selection parameter at each step. $\dot{V}_{75}$ was selected at the first step, and was selected at all the steps. $FEV_{1.0\%}$ was selected from the second on to the final. PF and MTC_{75-50} were selected from the third and fourth step, and both onward to the final. The later selection parameter groups are shown in Table 5.

DISCUSSION

In controlling asthmatic patients, it is useful to perform the maximal expiratory volume-time and flow-volume tests and estimate the ventilatory abnormality. In the field of public health, it is difficult to perform further pulmonary function tests and allergic examinations, such as a bronchial hypersensitivity reaction test,

or a skin reaction test or an I_gE measurement.

The flow-volume curve is useful both because it easily indicates the severity of bronchial asthma and because it estimates the extent of bronchoconstriction. The sudden flow-fall near $\dot{V}_{75}$ and the changes in the flow rate from $\dot{V}_{75}$ to $\dot{V}_{50}$ were specific for the recognition of bronchial asthma. It's disadvantage is the subjective nature of the decision.

Therefore we attempted discriminant analysis using six pulmonary function parameters (the two V-T, and the four F-V parameters) (2) and by using eight (addition of $\dot{V}_{75}$ and $\dot{V}_{10}$) (4). Using six parameters (2), $\dot{V}_{50}$ showed the lowest probability. As $\dot{V}_{75}$ was considered to be more effective than $\dot{V}_{50}$ in flow-volume recognition, $\dot{V}_{75}$ was added to make eight parameters (4). $\dot{V}_{75}$ showed the lowest probability of misclassification. The probability of the healthy was 15.8 % to total asthmatics at the fourth step. $\dot{V}_{75}$, $FEV_{1.0\%}$, PF, and $\dot{V}_{50}$, selected at the fourth step, were effective parameters for the discriminant analysis. The decrease in the probability was slight from the fifth step onward.

In this paper, three MTC parameters were added to the discriminant analysis because they are parameters of ventilatory mechanics and also because they are considered to be important and effective for discriminant analysis.

We attempted fifteen analyses through APSP (Table 2). We set the probabilities of the parameters and parameter groups against each other. Although the MTC parameters were considered to be effective, they were not selected at the higher steps using one parameter, but in using the eleven. The volume-time and the flow-volume parameters, $\dot{V}_{75}$, $\dot{V}_{50}$, and $\dot{V}_{25}$ were selected at the three consecutive higher steps.

In comparing the probabilities of misclassification between the eleven parameters and the V-T, the F-V, the MTC, and the total parameter group, the probability with the total one was lowest, but the probability with $\dot{V}_{75}$ and that with the F-V parameter group were much the same as that with the total one. Therefore the flow-volume parameters including $\dot{V}_{75}$ were considered to be sufficient for the discrimination even when $FEV_{1.0\%}$ was omitted. But the previous report (4) showed that $FEV_{1.0\%}$ was necessary for the discrimination between mild and moderate asthmatics.

Therefore discriminant analysis showed that flow-volume recognition is important and effective. The problem of decrease in the parameters will be discussed in the near future.

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