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Discriminant analysis of bronchial asthma by linear discriminant function with parameters of flow-volumes: discriminant analysis of bronchial asthma in young male non-smokers

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Abstract

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KEYWORDS: discriminant analysis, bronchial asthma, flow-volume, curve, young male non-smokers

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DISCRIMINANT ANALYSIS OF BRONCHIAL ASTHMA BY LINEAR DISCRIMINANT FUNCTION WITH PARAMETERS OF FLOW-VOLUMES: DISCRIMINANT ANALYSIS OF BRONCHIAL ASTHMA IN YOUNG MALE NON-SMOKERS

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Abstract. With the parameters of a flow-volume and a volume-time curve, the discriminant analysis of bronchial asthma is described. The subjects were classified into three groups (healthy adults, mild asthmatic patients and moderate ones). The difference of the mean vectors of the parameters of the three groups was made clear by the selection methods of the discriminant analysis between any two of the groups both with 6 parameters (%FVC, $FEV_{1.0\%}$, peak flow rate (PF), flow rate at 50% of FVC ($\dot{V}_{50}$), flow rate at 25% of FVC ($\dot{V}_{25}$), and $\dot{V}_{50}/\dot{V}_{25}$) and with 8 (6 parameters mentioned above and $\dot{V}_{75}$, $\dot{V}_{10}$). Forced expiratory volume in 1 second percent ($FEV_{1.0\%}$) or $\dot{V}_{50}$ was selected at the first step with 6 parameters, and $\dot{V}_{75}$ was selected at the first step with 8 parameters. Probabilities of misclassification with 8 parameters were lower than those with 6 ones and the probability of misclassification at the discriminant analysis between healthy adults and mild asthmatic patients with 8 parameters was 15.75% at the final step.

Key words: discriminant analysis, bronchial asthma, flow-volume curve, young male non-smokers

It is generally said that the forced expiration curves of asthmatic patients at the asymptomatic stage are the same as those of healthy men. Recently, however, Takijima (1) reported that flow-volume curves ($\dot{V}$-V curves) (2, 3) of asthmatic patients were characteristic compared with other chronic obstructive lung diseases (COLD), that is, flow rates suddenly fell concavely at the high lung volume (70–80% of FVC), and that at the asthmatic stage, the flow rate of flow-volume curve fell concavely all over the curve and the sudden fall of the peak flow rate was not remarkable (1).

Although many pulmonary function parameters were calculated from the forced expiration curves and flow-volume curves recently, no report has been presented about the over-all evaluation by multivariate analysis on bronchial asthma. In a previous report, the discriminant analysis of bronchial asthma was

reported between healthy adults and asthmatic patients with 5 and 6 parameters in pulmonary functions tests (4).

In this study, we wanted to investigate four aspects of the discriminant analysis of bronchial asthma between any two of the three groups (healthy adults, mild asthmatic patients, and moderate ones) of our subjects: first, to make clear the difference between healthy adults and asthmatic patients: second, to make clear the order of the selected parameters: third, to ascertain the probability of misclassification in the discriminant analysis: and fourth, to determine the discriminant function between any two of the groups. Pulmonary function tests (volume-time and flow-volume curves) were performed for healthy non-smoking young adults and non-smoking young adult asthmatic patients at the asymptomatic stage. Eight parameters (%FVC, $FEV_{1.0\%}$, PF, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{25}$, $\dot{V}_{10}$, and $\dot{V}_{50}/\dot{V}_{25}$) were calculated from those curves. In order to make clear the difference between healthy adults and asthmatic patients, the subjects were classified into three groups (mentioned above). The difference of the groups was made clear by the discriminant analysis (5, 6, 7) between any two groups both with 6 parameters (%FVC, $FEV_{1.0\%}$, PF, $\dot{V}_{50}$, $\dot{V}_{25}$, and $\dot{V}_{50}/\dot{V}_{25}$) and with 8 (6 parameters mentioned above, $\dot{V}_{75}$, and $\dot{V}_{10}$) by using an electronic computer 2200/500 (5). In this analysis, the parameters which discriminate between any two of the groups were selected by the forward selection and backward elimination procedure, *i.e.* multiple regression analysis (8). The backward elimination procedure begins with the largest regression, using all variables and subsequently reduces the number of variables in the equation until a decision is reached on the equation to use. The forward selection procedure is an attempt to achieve a similar conclusion by inserting variables in turn until the regression equation is satisfactory. The order of insertion is determined by using the partial correlation coefficients as a measure of the importance of variables not yet in the equation.

MATERIALS AND METHODS

We studied 32 healthy non-smoking young male adults and 26 patients with bronchial asthma, who were non-smoking young male adults. Sex, age, height, and smoking habits are correspondingly shown in Table 1. The patients were

TABLE 1. ANTHROPOMETRIC DATA*

Group	Number	Age (Yr)	Height (cm)
Healthy adults	32	23.6	169.1±5.6
Mild asthmatics	15	28.6	166.1±4.5
Moderate asthmatics	11	31.3	167.1±5.9

* Considering the effects of aging on the flow-volume curve, the subjects were almost all under 40 yr.

selected at the Allergy Out-patient Clinic of the Department of Internal Medicine of Okayama University Medical School when they were asymptomatic. The severity of bronchial asthma was classified according to Ōshima's classification of asthmatic severity (9), which depends on the intensity of asthmatic attack shown in dyspnea and effect on daily life and on the frequency of mean monthly attacks. Ōshima's classification is commonly used in Japan at present. The observation period for determining the severity of bronchial asthma was more than 6 months. Healthy adults were composed of medical students and young doctors, and they had no respiratory symptoms, no past history of respiratory symptoms nor any physical abnormalities.

A flow-volume curve recorder (OST-70D, Chest Co. Ltd.) was used for the forced expiratory procedure, that is, the forced expiratory volume-time procedure and the forced expiratory one. The forced expiratory procedure was measured in the sitting position several times and the chart obtained at the first measure was not used for calculation. Instead, one of the biggest flow-volume patterns with a sharp peak flow rate was selected out of the rest obtained at the subsequent determinations.

In this study, 6 parameters (%FVC, $FEV_{1.0\%}$, PF, $\dot{V}_{50}$, $\dot{V}_{25}$, and $\dot{V}_{50}/\dot{V}_{25}$) and 8 (6 parameters mentioned above and $\dot{V}_{75}$ and $\dot{V}_{10}$) were used for the discriminant analysis. In the discriminant analysis between healthy non-smoking young adults and asthmatic patients, the forward selection and backward elimination procedure were used with 6 and 8 parameters using an electronic computer (NEAC 2200/500).

RESULTS

The volume-time and the flow-volume curve

The results of the volume-time curve and the flow-volume curve with healthy adults and asthmatic patients are shown in Table 2. The flow rates at 75% of FVC ($\dot{V}_{75}$) of asthmatic patients were markedly lower than those of healthy adults, especially $\dot{V}_{75}$ with moderate asthmatics. Other parameters, for example, PF, $\dot{V}_{50}$, and $\dot{V}_{25}$ were also lower.

The order of selected parameters and the probabilities of misclassification

The discriminant analysis between healthy adults and asthmatic patients

With 6 parameters. The results were shown in Table 3. The flow rate at 50% of FVC($\dot{V}_{50}$) was selected at the first step, and the probability of misclassification was 20.02%. Forced expiratory volume in 1 second percent ($FEV_{1.0\%}$) and percent of forced vital capacity (%FVC) were selected at the second step and at the third step, the probability was 19.69%. Similar results were obtained between healthy adults and mild asthmatic patients.

With 8 parameters. The results were shown also in Table 3. The flow rate at 75% of FVC ($\dot{V}_{75}$) was selected at the first step, and the probability of misclassification was 18.78%. The order of the parameters selected was as follows, $FEV_{1.0\%}$, PF, $\dot{V}_{50}$, %FVC, $\dot{V}_{50}/\dot{V}_{25}$, $\dot{V}_{10}$, and $\dot{V}_{25}$. The probability of misclas-

sification was lowered to the 6th parameter. At the 6th step, the probability was 15.79%, but at the 7th and 8th steps, the probability was not lowered at all. At the final step the probability was 15.79%.

TABLE 2. RESULTS OF PULMONARY FUNCTION TESTS IN EACH GROUP

Parameters	Healthy adults	Bronchial asthma			
		Mild asthma		Moderate asthma	
	Mean	U.S.D.[a]	Mean	U.S.D.[a]	Mean	U.S.D.[a]
1. %FVC (%)	110.7	9.5	108.0	15.7	101.4	16.0
2. $FEV_{1.0\%}$ (%)	86.6	6.4	78.0	11.4	65.8	16.4
3. PF (1/s)	10.7	1.4	9.2	2.3	7.4	2.3
4. $\dot{V}_{75}$ (1/s)	9.3	1.5	6.5	2.5	4.3	2.3
5. $\dot{V}_{50}$ (1/s)	5.9	1.4	3.8	1.8	2.4	1.7
6. $\dot{V}_{25}$ (1/s)	2.5	0.8	1.5	0.7	1.1	1.0
7. $\dot{V}_{10}$ (1/s)	1.0	0.6	0.5	0.3	0.4	0.5
8. $\dot{V}_{50}/\dot{V}_{25}$ (1/s)	2.5	0.4	2.6	0.5	2.8	0.9

%FVC: Percent of forced vital capacity, $FEV_{1.0\%}$: percent of first one second volume in forced cxpiration curve, PF: peak flow rate in maximal expiratory flow volum (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, *a* Unbiased sample standard deviation.

TABLE 3. DISCRIMINATION BETWEEN HEALTHY ADULTS AND ASTHMATIC PATIENTS WITH 6 AND 8 PARAMETERS BY THE FORWARD SELECTION AND BACKWARD ELIMINATION PROCEDURFS

Procedure	Number of parameters	Step	Healthy adults vs. All asthmatics		Healthy adults vs. Mild asthmatics		Mild asthmatics vs. Moderate ones	
			Parameter	P (%)	Parameter	P (%)	Parameter	P (%)
Foward selection procedure	6 parameters	1	$\dot{V}_{50}$	20.0	$\dot{V}_{50}$	24.3	$FEV_{1.0\%}$	32.8
		2	$EEV_{1.0\%}$	19.8	%FVC	23.8	$\dot{V}_{25}$	30.1
		3	%FVC	19.8	$\dot{V}_{25}$	23.4	$\dot{V}_{50}$	27.1
		4	PF	19.7	PF	23.4	$\dot{V}_{50}/\dot{V}_{25}$	20.5
		5	$\dot{V}_{25}$	19.7	$\dot{V}_{50}/\dot{V}_{25}$	23.1	PF	20.3
		6	$\dot{V}_{50}/\dot{V}_{25}$	19.6	$FEV_{1.0\%}$	23.0	%FVC	20.0
and		1	$\dot{V}_{75}$	18.8	$\dot{V}_{75}$	23.4	$\dot{V}_{75}$	29.1
		2	$FEV_{1.0\%}$	17.9	PF	22.7	$\dot{V}_{25}$	25.2
		3	PF	16.7	$FEV_{1.0\%}$	22.1	$\dot{V}_{50}/\dot{V}_{25}$	22.4
Backward elimination procedure	8 parameters	4	$\dot{V}_{50}$	15.9	$\dot{V}_{50}$	21.0	$\dot{V}_{50}$	21.7
		5	%FVC	15.8	$\dot{V}_{25}$	20.6	$\dot{V}_{10}$	20.9
		6	$\dot{V}_{50}/\dot{V}_{25}$	15.8	%FVC	20.4	PF	20.4
		7	$\dot{V}_{10}$	15.8	$\dot{V}_{50}/\dot{V}_{25}$	20.3	$FEV_{1.0\%}$	19.6
		8	$\dot{V}_{25}$	15.8	$\dot{V}_{10}$	20.3	%FVC	19.4

P, Probability of misclassification

Discriminant analysis between mild asthmatic patients and moderate ones

With 6 parameters. The results were shown in Table 3. Forced expiratory volume in 1 second percent ($FEV_{1.0\%}$) was selected at the first step, and the probability of misclassification was 32.78%. The flow rate at 25% of FVC ($\dot{V}_{25}$) was selected at the second step and $\dot{V}_{50}$ at the third step. The probability was lowered gradually, and at the final step, the probability was 19.99%.

With 8 parameters. The results were shown in Table 3. The flow rate at 75% of FVC ($\dot{V}_{75}$) was selected at the first step, and the probability of misclassification was 29.12%. The flow rate at 25% of FVC ($\dot{V}_{25}$) was selected at the second step and $\dot{V}_{50}/\dot{V}_{25}$ at the third step. The order of the following parameter was $\dot{V}_{50}$, $\dot{V}_{10}$, PF, $FEV_{1.0\%}$, and %FVC. The probability of misclassification was lowered gradually. At the 6th step the probability was 20.41%, but at the 7th and at the 8th step, the probability was 19.44%.

TABLE 4. DISCRIMINANT COEFFICIENTS AND DISCRIMINANT POINTS BETWEEN ANY TWO GROUPS

Number of parameters	Group	Discriminant coefficients								D. P.
		b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	
6 Parameters	Healthy adults vs. All asthmatics	+0.018	−0.030	−0.090	——	+1.058	+0.532	——	+0.359	+5.415
	Healthy adults vs. Mild asthmatics	+0.042	−0.016	−0.244	——	+0.502	+1.613	——	+0.623	+8.125
	Mild asthmatics vs. Moderate asthmatics	−0.027	+0.152	+0.442	——	+2.659	−8.996	——	−3.475	−0.818
8 Parameters	Healthy adults vs. All asthmatics	+0.017	−0.138	−0.705	+1.516	+0.610	+0.144	+0.163	+0.295	−0.796
	Healthy adults vs. Mild asthmatics	+0.025	−0.124	−0.684	+1.071	+0.015	+1.979	+0.105	+0.131	+1.168
	Mild asthmatics vs. Moderate asthmatics	−0.020	+0.074	+0.638	+1.003	+1.944	−11.424	+6.025	−2.854	+0.613

b_1: Discriminant coefficient (D. C.) for %FVC, b_2: D. C. for $FEV_{1.0\%}$, b_3: D. C. for PF, b_4: D. C. for $\dot{V}_{75}$, b_5: D. C. for $\dot{V}_{50}$, b_6: D. C. for $\dot{V}_{25}$, b_7: D. C. for $\dot{V}_{10}$, b_8: D. C. for $\dot{V}_{50}/\dot{V}_{25}$, D. P.: Discriminant point.

The discriminant coefficients, the discriminant points and the probabilities of misclassification

In the Table 4, the individual pulmonary function parameters were used in the following discriminant function equation.

$$Z = b_1 \times (\%FVC) + b_2 \times (FEV_{1.0}\%) + b_3 \times (PF) + b_4 \times (\dot{V}_{50}) + b_5 \times (\dot{V}_{25}) + b_6 \times (\dot{V}_{50}/\dot{V}_{25}).$$

The discriminant score is obtained when the individual 6 pulmonary function parameters are substituted for the above equation.

For example, while the pulmonary function parameters are as follows, $\%FVC = 102.3\%$, $FEV_{1.0} = 89.3\%$, $PF = 9.8$ l/s, $\dot{V}_{50} = 5.7$ l/s, $\dot{V}_{25} = 2.9$ l/s, $\dot{V}_{50}/\dot{V}_{25} = 1.97$, the discriminant score calculated are 6.561.

This score was compared with the discriminat point, and was found to be greater than that point, therefore, this subject was discriminated as being healthy.

DISCUSSION

In promoting the decrease of ventilatory abnormalities of the population in the field of the public health, it is important for us to recognize the flow-volume pattern diagnostically, or to perform the discriminant analysis between healthy adults and asthmatic patients with many pulmonary function parameters. Especially, we may detect the early ventilatory abnormalities of bronchial asthma and classify the severity of bronchial asthma by the discriminant analysis with the volume-time and flow-volume parameters.

Discriminant analysis has the following advantages. Firstly, the use of all the variables or only the most effective ones shows whether there is any probability of misclassification between any two of the populations to be totally discriminated. Secondly, the application of pulmonary function parameters to the discriminant function shows which population the subject belongs to. Namely, the individual parameters are substituted for the discriminant function equation and then the discriminant score obtained is compared with the discriminant point. If the score is greater, the subject is discriminated as healthy, and if smaller, he is discriminated as asthmatic.

When we perform the discriminant analysis, factors influencing the flow-volume pattern, *i.e.*, sex, age, and smoking habits, are very important. In this paper, male sex, younger age, and non-smoking groups were chosen as the important factor for classifying and then the discriminant analysis was performed.

The flow rate at 75% of FVC ($\dot{V}_{75}$) has not been used up to 1975 as a routine parameter of the flow-volume curve, but recently, researchers of respiratory physiology urged the necessity of this value, therefore we added $\dot{V}_{75}$ and $\dot{V}_{10}$ for examining whether the probability of misclassification is lower or not.

The orders of the selected parameters were different in using the discrimi-

nant analysis. With 6 parameters, the flow rate at 50% of FVC ($\dot{V}_{50}$) was selected at the first step, $FEV_{1.0\%}$ at the second step, and %FVC at the third step, but with 8 parameters, $\dot{V}_{75}$ was selected at the first step, $FEV_{1.0\%}$ at the second step and peak flow rate (PF) at the third step. In the discriminant analysis, the flow rates in higher lung volumes were considered to be important parameters, especially $\dot{V}_{75}$ was the most important parameter. In the flow-volume pattern, the difference near the 75% of FVC was shown to be remarkable. The probabilies of misclassification were lowered to the 6th step, but with further steps, the probabilities were not lowered. Our data indicates that the upper 6 parameters were sufficient for the discriminant analysis of bronchial asthma.

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