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EXPERIENCES WITH A NEW OSCILLATION METHOD FOR MEASURING OSCILLATORY AIRWAY RESISTANCE

H. G. KRIEGER[1], H.-J. WOITOWITZ[1],
U. JEREMIE[2] and E. FLÜGEL[2]

Institute of Occupational and Social Medicine, University of Giessen, Giessen[1] and Siemens AG, Department of Medical Techniques, Erlangen[2], F.R. Germany

ABSTRACT

In the work area the effects of dusts, gases and vapours often present a considerable health risk. Therefore an early diagnosis of obstructive or restrictive respiratory diseases is of practical importance in medical surveillance.

So far obstructive airway diseases could only be demonstrated with the aid of the methods which either require an active cooperation of the patient or are based on rather complicated techniques. Recently a new method for the determination of airway resistance which is based on the principle of oscillation has become available. This method is simple and rapid and does not require an active collaboration of the patient.

The accuracy, specificity and sensitivity of the new method have been ascertained in 146 patients with occupational diseases on the basis of anamnestic and clinical data as well as analytical results of lung function tests, especially body plethysmography. In about 80 per cent of the patients the results coincided with those of body plethysmography. In approximately 10 per cent of the patients false positive and in about 10 per cent false negative results were found. In some patients with "false positive" findings there are indications that the oscillation method yields more sensitive results of bronchial resistance than body plethysmography. The false negative results of the oscillation method are in a range which is to be considered as a slight obstructive lung disease as determined by body plethysmography.

According to the present experience the reliability, practicability and applicability of the oscillation method is such that it can be expected to contribute considerably to the diagnostic possibilities in occupational medicine.

Inhalation noxas especially dusts, gases and vapours present a considerable health risk at numerous workplaces. Therefore an early diagnosis of an obstructive respiratory disease is of essential practical importance in medical surveillance.

Up to now the diagnosis of an obstructive respiratory disease has been connected with procedures which, like forced expiratory volume, presumed either an active collaboration of the patient[7] or, like body plethysmography[19], required rather sophisticated techniques.

Recently an apparatus has become available for measuring airway resistance which has a certain advantage for routine application (Siregnost FD 5, Fa. Siemens AG, Erlangen, F.R. Germany). It is based on the principle of oscillation and makes it possible to ascertain bronchial obstruction in a rapid and simple manner. Continuous measurements over longer periods are possible. The examination does not demand an active cooperation of the subject. So far this principle of measuring has not come to routine application in Europe on account of methodological problems[1,3,4,5,6,10,11,14,17]. In the meanwhile the first experimental results obtained with the apparatus have been published[2,9,12,15,16].

In further text the validity of the new method for measuring oscillatory airway resistance will be discussed.

SUBJECTS AND METHODS

The principle of measurement will be presented here only briefly because it has been described in detail elsewhere[8,15,16].

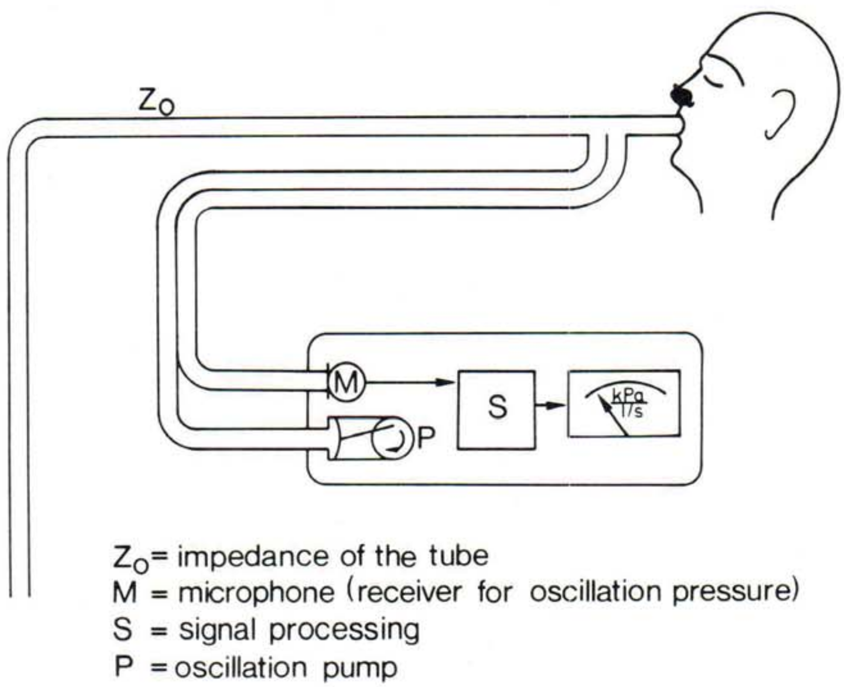

FIG. 1 – Schematic diagram of the oscillation method for determining respiratory resistance.

The subject breathes through a tube Z_0 of defined dimensions which serves as reference resistance (Fig. 1). At the mouthpiece an oscillatory flow with a frequency of 10 c/s and a volume amplitude of ± 0.7 cm^3 is impressed. The resulting oscillation pressure is measured in the apparatus. The flow resistance of the airways and (to a different extent) the resistance of the chest wall enter into the result of the measurement. The measured value therefore cannot be termed pure airway resistance. The nomenclature oscillatory airway resistance or oscillatory resistance (R_{os}) has been proposed[13]. The value can be read off directly as an instantaneous value or it can be continuously registered by an x/t--recorder. An advantage of the recording lies in the greater accuracy of reading.

We used the apparatus during occupational medical examinations. The oscillatory resistance (R_{os}) as well as the airway resistance (R_t) were registered in 146 patients by the method of body plethysmography. We also measured the endexpiratory thoracic gas volume (TGV_e) and the specific airway conductance (G_{aw}) by Siregnost FD 40 and FD 91, Fa. Siemens AG, Erlangen F.R.G. The vital capacity (VC) and the forced expiratory volume (FEV_1) were measured by Vitalograph, Fa. Wedge Bellows, and Magnatest, 710, Fa. Meditron, Hamburg, F.R.G. In addition to this we determined the residual volume (RV) by the helium method in 125 patients (86%). The R_{os} and the R_t recordings were repeated in 12 patients by workplace related inhalation tests[20].

RESULTS

Sensitivity and specificity

To evaluate the sensitivity and the specificity of the oscillation method we correlated the resistance values determined by oscillatory measurements and those of body plethysmography (Figure 2). With the oscillation method

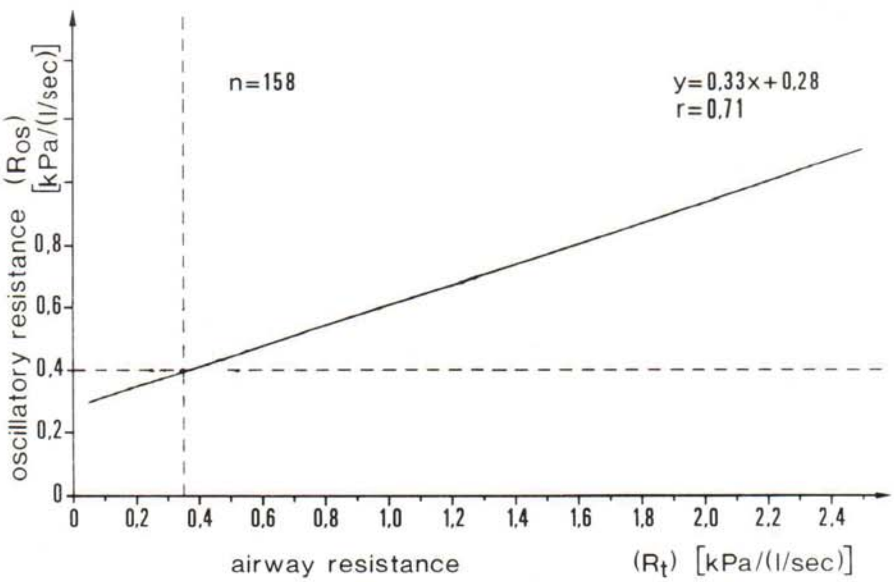

FIG. 2 – Correlation and regression line between oscillatory (R_{os}) and airway resistance (R_t). Inserted lines mark the border between normal and increased values.

resistance values to about 1.0 kPa*/(l/s) can be measured, on account of a different principle of measurement. The upper normal limit for body plethysmographic resistance is 0.35 kPa/(l/s)[18] and for oscillatory resistance 0.4 kPa/(l/s)[13].

The correlation diagram shows only a small increase of oscillatory resistance at higher airway resistances. For the linear regression R_{os} to R_t a correlation coefficient is $r = 0.71$.

Considering the upper normal limits for oscillatory resistance there are 13 (about 8%) false positive and 21 (about 13%) false negative results. In about 79 per cent of the subjects the resistance values were determined with both methods as normal (81 = 52%) or increased (43 = 27%). The false negative findings are mainly (14 : 21) in an area which can be described also by body plethysmography only as slight bronchial obstruction $R_t \leq 0.45$ kPa/(l/s). Three additional values of

TABLE 1

Examples of occupational obstructive lung diseases of allergic (n = 8) and toxic (n = 1) origin without contact with the noxas. The airway resistance measured by body plethysmography (R_t) < 0.35 kPa/(l/s) is normal, the oscillatory resistance (R_{os}) > 0.40 kPa/(l/s) is borderline or raised.

Patient		Occupational noxas	R_t	R_{os}	FEV_1
sex	age				
m	35	flour	0.35	0.58	72
f	22	animal hairs	0.23	0.57	78
m	20	flour	0.24	0.43	66
m	22	wood	0.35	0.51	61
m	37	isocyanate	0.27	0.44	74
m	22	flour	0.25	0.40	77
m	34	flour	0.30	0.50	70
m	42	flour	0.20	0.47	80
m	52	animal hairs	0.35	0.52	68
$\overline{X}$	31.8		0.28	0.50	72
S. D.	11.1		0.06	0.06	6.2

R_t = airway resistance; R_{os} = oscillatory resistance; FEV_1 = forced expiratory volume.

$R_{os} = 0.40$ kPa/(l/s) are borderline cases. Among the 13 false positive oscillatory findings eight refer to obstructive lung disease like bronchial asthma caused by occupational allergens and one is of toxic origin. The findings of these nine patients without contact with the causing agent are described in Table 1. The oscillatory airway resistance values range distinctly above the body plethysmographic findings. The mean value of oscillatory resistance is $\overline{X}_{R_{os}} = 0.50$ kPa/(l/s) and of body plethysmographic resistance $\overline{X}_{R_t} = 0.28$ kPa/(l/s).

*1 kPa = 10.198 cm H_2O; 1 cm H_2O = 0.0981 kPa

Phase shift measurements

The registration of the phase shift between pressure signal and volume flow is an additional information obtained by the oscillation method. When the phase angle is positive there are more so-called inductive components. When the angle is negative there are more so-called capacitive parts of the total resistance. Diseases change the capacitive and the inductive resistances of the bronchopulmonary system. Therefore we determined the correlation coefficients of the phase angle to the parameters shown in Table 2.

The phase angle correlates comparatively closely with oscillatory resistance ($r = -0.76$). Less close are correlations between bronchial obstruction and specific conductance ($r = 0.54$), between lung hyperinflation and residual volume in per cent of the total capacity ($r = -0.52$) and between the restrictive type of lung disorder and vital capacity in per cent of the lower normal limit ($r = 0.44$). The correlation with the thoracic gas volume is lowest, with $r = -0.34$.

TABLE 2

Correlation coefficient r between body plethysmographic and spirometric values to the phase angle φ.

φ	R_{os}	G_{aw}	RV % TLC	VC % norm	TGV_e
r	−0.76	+0.54	−0.52	+0.44	−0.34
n	158	154	125	144	158

φ [°] = phase shift between pressure and flow, R_{os} = oscillatory resistance, RV % TLC = residual volume in % of total lung capacity, VC % norm = vital capacity in % of the lower normal limit, G_{aw} = specific airway conductance, TGV_e = endexpiratory thoracic gas volume.

Resistance-volume diagram

Another possibility of application yields the recording of the resistance--volume diagram. For this an open spirographic system with an x/y-recorder is necessary. When a healthy person is tested the resistance increases steeply only at the end of the maximal expiration (Figure 3).

Deviations from the normal slope are obvious with different diseases of the bronchopulmonary system.

For example the resistance-volume diagram of a 40-year old patient with coal workers' pneumoconiosis shows a considerably higher increase in resistance while the lung volume decreases (Figure 4).

DISCUSSION

The new method for measuring oscillatory resistance can be expected to contribute considerably to the diagnostic possibilities in occupational medicine. It can be applied in a very simple way. With a specificity of 0.86 and a sensitivity of 0.67, it is more convenient for mass screening than body plethysmography. The new method seems to be suitable for practice in occupational medicine and

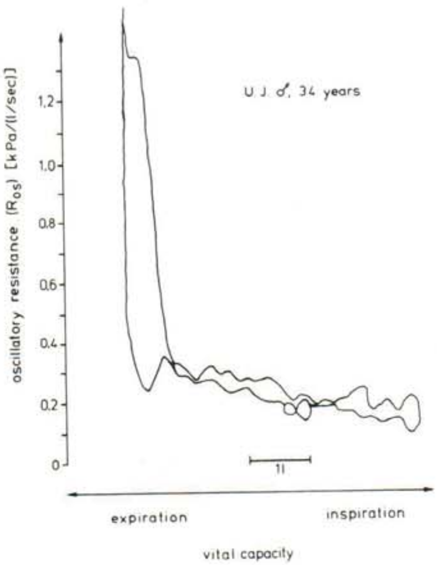

FIG. 3 – Oscillatory resistance-volume diagram of a healthy subject.

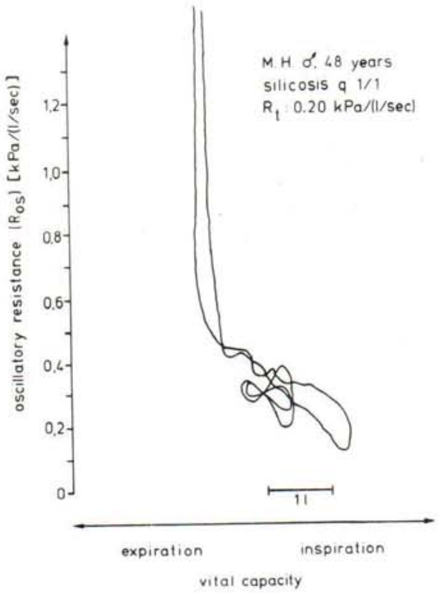

FIG. 4 – Oscillatory resistance-volume diagram of a subject with a restrictive lung disease (coal workers' pneumoconiosis) without bronchial obstruction. Lung function parameters, predicted values in parentheses: VC (vital capacity) = 2.60 (3.46) l; FEV_1 (forced expiratory volume) = 2.00 l = 76.9 % TLC; RV (residual volume) = 1.00 (1.14) l; PO_2 = 68.5 (85 ± 10) torr.

for the measurements conducted directly at the workplace. New diagnostic advantages are also evident. This for instance seems to be valid for restrictive lung diseases such as silicosis or emphysema. Furthermore very often the method makes possible a more sensitive i.e. earlier diagnosis of an allergen-induced obstructive lung disease.

According to our experience conventional methods such as spirography will be considerably supplemented by the direct oscillatory airway resistance measurement especially when an early diagnosis is required.

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