E.V. Kiryanova, I.A. Pochekutova, V.I. Korenbaum

INTERRELATION OF FORCED EXPIRATORY ACOUSTIC AND SPIROGRAPHIC PARAMETERS UNDER JOINT AND SEPARATE RECORDING

V.I. Il'ichev Pacific Oceanological Institute, Far Eastern Branch, Russian Academy of Sciences
43 Baltiyskaya Str., Vladivostok, 690041, Russia.
Ph.: (4232) 375-698; Fax: (4232) 312-573.
E-mail: bel-ev@poi.dvo.ru

Forced exhalation (FE) as a kind of provocative maneuvers is widely used for revealing infringements of human respiratory function. Temporal parameters of forced expiratory tracheal noises are considered as acoustic signs applicable for bronchial obstruction detecting (Korenbaum and Pochekutova, 2006). The objective of the paper consists in the experimental definition of interrelations between acoustic and spirographic FE parameters under their joint and separate recording. Examinations were carried out on 19 volunteers. Forced expiratory tracheal noises were recorded by acoustic sensor, connected to sound card of personal computer with help of "PPhT-99" program. Flow-volume data were recorded by means of spirograph Spiro-USB (MicroMedical Ltd.). Under joint recording of noises and spirographic indexes mathematic model is developed that links volumetric flow to ratio of acoustic and spirographic times from the beginning of FE maneuver. It has been shown that under joint recording noise duration is 65.6 ± 17.2% (M ± SD) from spirographic duration (n=57). Under separate recording noise and flow noise duration is 69.7%; 65%; 86.5 % (Me; LQ; UQ) from noise duration recorded with spirograph (n=57). Results obtained are interpreted from acoustics-biomechanical point of view.

Forced exhalation (FE) as a kind of provocative maneuvers is widely used for revealing infringements of human respiratory function. As acoustic parameter of forced expiratory tracheal noises (FETN), suitable for definition of bronchial obstruction, duration of the noise process in a frequency band of 200-2000 Hz is offered [1] .

For standardization of FE maneuver its combination with spirography is expedient. However the armature used for flow measuring renders the considerable influence on spectral characteristics of FETN [2]. Similar but preliminary arguments with reference to spectral - time FETN performance contains in [1].

The objective of the paper consists in the experimental definition of interrelations between acoustic and spirographic FE parameters under their joint and separate recording.

Examinations were carried out on 19 volunteers. FETN (exhalation through unclosed mouth) were recorded by the acoustic sensor connected to a sound card of the personal computer with the help of the program "PPhT-99". The acoustic sensor (electret microphone with a stethoscopic head) was placed on a frontal-lateral wall of a larynx and retained by hand. Flow-volume data were recorded by means of spirograph Spiro-USB (MicroMedical Ltd.). Each subject performed 3 FE attempts. Recorded sound files were processed in program SpectraLab. The signal was filtrated by the built - in filter (Band Pass; center - 1100 Hz; width - 1800 Hz; steep - slowest), it was scaled on amplitude in a window of the time chart so that to drag it on all screen. In the filtered signals FETN duration was measured in a frequency band of 200-2000 Hz by envelope drop to the background: T_{ak} - FETN duration in maneuver without spirograph, T_{aks} - in maneuver with spirograph.

Recording FE by spirograph a curve «Volume - Time» and reference indexes «Flow - Volume» curve have been evaluated: FVC - forced vital capacity; MEF_{25}, MEF_{50}, MEF_{75} - maximal flows at levels of an exhalation of 25 %, 50 %, 75 % of FVC, T_{ss} - FE spirographic duration.

Under simultaneous recording of spirography and FETN in three attempts of each subject (n=57) the correlation coefficient between acoustic (T_{aks}) and spirographic (T_{ss}) durations has made r = 0.58 ($p < 0.001$). Ratio T_{aks}/T_{ss} in group (n=57) has made 65.6±17.2 % (M±SD).

Under simultaneous FE recording the separate acoustic phenomena can be obviously linked to parameters of flow in time. In particular, we compared spirographic times of achievement of standard volumetric rates MEF_{25}, MEF_{50}, MEF_{75} to acoustic duration (T_{aks}). For this purpose FETN attempts with peak duration T_{aks} and relevant to them flow-volume curve are picked. Then the curve «Volume - Time» is processed in program Adobe Photoshop, with use of a regimen of rulers for each axis (scaling of a fragment of 200 %). Assignment of FVC value to a maximum of a curve «Volume - Time» is yielded, further the diagram is broken into levels of volume of 25 %, 50 % and 75 % of FVC. On crosses of these volume levels from a curve «Volume - Time» times of achievement of the relevant volumes (with keeping axes scale) are determined. Ratios of times of achievement of 25 %, 50 % and 75 % of FVC to FETN acoustic duration T_{aks} (n=19) - T_{25}/T_{aks}, T_{50}/T_{aks}, T_{75}/T_{aks} are calculated. Distribution of received variables appeared distinct from normal one, therefore they are characterized by values of median, lower and upper quartiles (Me; LQ; UQ). They are: (0.126; 0.087; 0.175), (0.223, 0.181, 0.277), (0.408, 0.380, 0.491) respectively. Variables MEF_{25}, MEF_{50}, MEF_{75} have normal distribution and consequently are characterized by average and standard deviation (M ± SD). They are: 6.68 ± 1.36 (l/s), 4.33 ± 1.32 (l/s), 1,76 ± 0.64 (l/s), respectively.

On the data obtained on the chart with coordinate axes T_{ss}/T_{aks}, and volumetric flow rate of exhaled air ($\dot{U}$, l/s) 3 points with average values for variable MEF and medians for ratio T_{ss}/T_{aks} are constructed. the 4-th poin is added, that is relevant to ending conditions of maneuver (T_{ss}/T_{aks} = 1; MEF_{100} = 0). With the help of program Origin by these four points interpolating exponential dependence is constructed (by least quadrate method) which links volumetric flow rate $\dot{U}$ and spirographic/acoustic durations ratio T_{ss}/T_{aks} (fig. 1). It is analytically expressed as:

$$\dot{U} = 11.97 * \exp((-T_{ss}/T_{aks})/0.225) - 0.153, \quad (R^2 = 0.999), \tag{1}$$

where R^2 – determination coefficient, describing approximation quality.

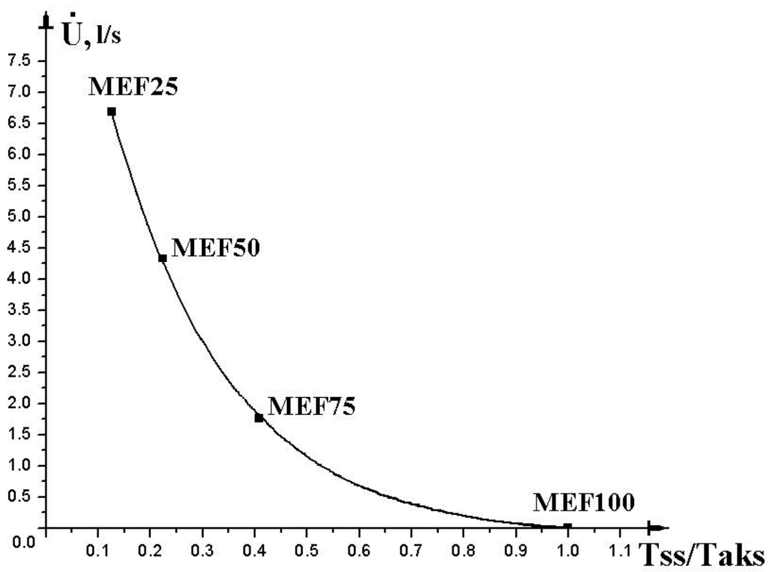

Fig.1. Dependence of volumetric flow on ratio T_{ss}/T_{aks}:
points – experimental meanings, solid line – fitting curve.

Dependence (1) can be used for prediction of volumetric rate of an exhaled flow of air at the arbitrary moment of time of FE maneuver in interests of comparison of biomechanical FE performances with acoustic ones, for example wheezes [3], and detailing FE noise production mechanisms.

Under recording FETN separately from spirography at the same subjects (n=19) FETN duration (peak of 3 attempts) T_{ak} was determined and compared to the FETN duration measured together with spirography T_{aks} (also peak of 3 attempts). These durations statistically reliably differ (p=0.000001, the t-test for the matched samples), and duration without spirograph makes (Me; LQ; UQ - 69.7; 65 %; 86.5 %) from the duration with spirograph.

Acoustic duration of FE without спирографа (T_{ak}) does not correlate significantly with spirographically determined duration of FE maneuver (T_{ss}). The estimate of ratio acoustic duration without spirograph to spirographic duration T_{ak}/T_{ss} (attempts with the peak acoustic duration) has made 49.7 ± 13.5 % (M ± SD).

The FETN duration measured together with spirograph (T_{aks}), makes 65.6 ± 17.2 % from спиspirographic FE duration T_{ss}. Hence there is prevalence of laminar flow (at which noise production is small enough [4]) in terminating part of FE maneuver.

The FETN duration measured without spirograph makes (Me; LQ; UQ - 69.7; 65 %; 86.5 %) from the FETN duration measured together with spirograph. This phenomenon obviously testifies the influence of spirograph measuring armature on acoustic parameters (duration) of FETN which can be presumably bound to entering additional hydrodynamic resistance into exhaled air flow [5]. This resistance frames redundant positive pressure inside of bronchial tree lumen, that, probably, interferes to squeeze pressure accompanying FE with functional expiratory stenosis (closing of fine bronchi) and thus provides appreciable augmentation of volume of air expired from lungs during FE.

Thus, in the complete consensus with deductions [2] concerning FETN spectral characteristics, we can conclude, that undisturbed parameters of FETN duration can be measured, basically, only without spirographic equipment.

The fact, that spirographic FE duration does not correlate with FETN time and essentially differs with the FETN duration determined without spirograph, except for pointed physical aspects, testifies to self-maintained value of both these parameters with reference to problems of estimation of respiratory function state and diagnostics of respiratory diseases.

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