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Application of impulse oscillometry in respiratory system evaluation in elderly patients

Wykorzystanie oscylometrii impulsowej IOS w badaniu stanu układu oddechowego u osób w wieku podeszłym

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Abstract

Introduction: Spirometry, which is a basic diagnostic tool of the respiratory system, may cause problems to patients of advanced age because of required cooperation and specific respiratory manoeuvres. Impulse oscillometry (IOS) may be an interesting alternative for spirometry as the examination is made during quiet breathing and gives information about resistive properties of the respiratory system.
Material and methods: This work presents the results of oscillometric measurements made in 277 patients aged 65–96 years, in whom spirometry was also performed.
Results: Resistances measured with IOS (R5, R5-R20) and the resonant frequency Fn correlated significantly with FEV_1 (r = –0.503; –0.570 and –0.673, respectively). A comparison of the results from patients with airway obstruction confirmed in spirometry with those of the non-obstructed group showed highly significant differences in mean values of oscillometric parameters ($p < 0.001$).
Conclusions: As R5-R20 is regarded as a measure of peripheral airways resistance, IOS may serve as an interesting complementary or alternative method for spirometry in elderly subjects for evaluation of the state of respiratory system.

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Key words: impulse oscillometry, lung function testing, spirometry

Streszczenie

Wstęp: Spirometria będąca podstawowym badaniem diagnostycznym układu oddechowego, z uwagi na wymagania dotyczące współpracy oraz konieczność wykonywania niefizjologicznych manewrów oddechowych może sprawiać problemy osobom w wieku podeszłym. Oscylometria impulsowa (IOS) może być alternatywą dla spirometrii, ponieważ badanie wykonuje się podczas spokojnego oddychania i przynosi ono informację o własnościach oporowych układu oddechowego.
Materiał i metody: W niniejszej pracy prezentujemy wyniki pomiarów IOS w grupie 277 badanych w wieku 65–96 lat, u których wykonano także spirometrię.
Wyniki: Opory mierzone w badaniu oscylometrycznym (R5; R20-R5) oraz częstotliwość rezonansowa Fn istotnie korelowały z wartością FEV_1 (r = –0,503; –0,570 oraz –0,673). Porównanie wyników badań u osób, u których stwierdzono obturację w badaniu spirometrycznym, z badanymi bez cech obturacji wykazało wysoce istotne statystycznie różnice w średnich wartościach parametrów oscylometrycznych ($p < 0,001$).

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Wnioski: Ponieważ R5-R20 uznawane jest za miarę oporu obwodowych dróg oddechowych, IOS może stanowić interesujące uzupełnienie lub alternatywę dla badania spirometrycznego u osób w podeszłym wieku dla oceny stanu układu oddechowego.

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Słowa kluczowe: oscylometria impulsowa, badanie czynności płuc, spirometria

Introduction

Impulse oscillometry (IOS) is the technique introduced to diagnostics in the early 1990s [1]. It is a modification of the forced oscillations technique (FOT). FOT enables assessment of respiratory mechanics (resistive and elastic properties) through the analysis of respiratory system response to known external pressure forcing [2, 3]. Commonly it is a pressure sinusoidal wave or a complex one being the sum of several component waves, which makes it possible to assess the measurement in several frequencies at the same time. Impulse oscillometry uses a triangular pressure pulse instead of sinusoidal (or pseudorandom) forcing from which, using a mathematical method, one can extract the mechanical properties of the respiratory system in frequencies interesting from the point of view of diagnostics.

Oscillatory techniques, due to the lesser requirements concerning cooperation (the examination is performed during quiet, natural breathing), are commonly used in children, especially younger ones. Potentially, they can also be used in adults, particularly in patients who have problems performing spirometry. This is the case in patients in a severe state, with advanced pathological changes in the respiratory system, and also in aged persons in whom neurodegenerative diseases may cause problems with cooperation and understanding. In a recently published report [4] concerning the quality of spirometry in elderly patients (age > 65 years) examined in the Physiopathology Department of the Regional Centre for COPD and Respiratory Failure in Bydgoszcz, it was shown that only a little more than 30% of patients were able to perform spirometry that fulfilled all of the quality criteria as defined by ERS/ATS and Polish Respiratory Society standards [5–7]. The data presented by Pezzoli et al. [8] showed that the proportion of qualitatively good spirometries in patients from a geriatric unit was even lower — 16.5%. In a Polish study in a relatively small group of 80-year-old patients this proportion reached 11% [9].

The aim of the present work was to evaluate the use of impulse oscillometry in the assessment of respiratory system state in elderly people.

Material and methods

The study was designed as a retrospective analysis. The material consisted of the results of diagnostic tests performed in patients from the Outpatient Department in the Regional Centre for COPD and Respiratory Failure in Bydgoszcz. They routinely underwent spirometric evaluation (flow-volume curve) and, after obtaining their consent, an impulse oscillometry test was performed. Among the patients enrolled in the study there were persons with diagnosis of obstructive diseases (COPD — 191, asthma 30), restrictive disease (fibrosis — 8, kyphoscoliosis — 3, lung tumours — 4 and patients after thoracosurgical interventions — 2) and other pulmonary diseases (pulmonary hypertension — 3, abnormalities in X-ray picture — 3, bronchiectasis, pulmonary oedema, Wegener's syndrome, tubercoulous changes and diffuse changes). There were also 28 patients who were diagnosed according to indications other than pulmonary diseases.

Both diagnostic tests were performed using MasterLab (Jaeger, Care Fusion). IOS was performed according to the users' manual. After placement of a nose clip the patients were asked to sit upright and breathe through the pneumotachograph. A pressure signal in the form of triangular pulses was applied via a loudspeaker through the pneumotachograph to the respiratory system. The examination lasted for 60 seconds, during which several respiratory cycles were registered. The software analysed recorded pressure and flow signals in frequency domain with the methods of signal analysis and calculated parameters of respiratory mechanics.

Although the report from IOS measurements contains several parameters calculated for frequencies up to 35 Hz, in practice only a few have any diagnostic importance and are chosen for analysis and interpretation (Table 1).

Spirometric measurements were made according to the above-cited standards [5–7] after oscillometric measurements, because potentially forced respiratory manoeuvres may cause bronchoconstriction, which could influence the results of IOS examination.

The analysis was performed on the results of the tests obtained in elder patients, i.e.

Table 1. Most frequently used parameters in oscillometric examination

Parameter	Description	Interpretation
R5	Respiratory system resistance at 5 Hz	R5 represents total resistance of respiratory system (extrathoracic, central and peripheral airways resistance)
R20	Respiratory system resistance at 20 Hz	R20 represents resistance of proximal part (extrathoracic and central airways resistance)
R5-R20	Difference of resistances between 5 and 20 Hz	R5-R20 reflects the resistance of peripheral airways
Fn	Resonant frequency	The frequency at which respiratory system reactance equals 0

Table 2. Characteristics of the examined group

	Range	Median (interquartile range)	Mean ± SD
Age (yrs)	65–96	72.4 (8.7)	–
Height	136–186	163 (13)	162.8 ± 8.8
Weight	37–128	74 (23)	–
FEV_1/FVC	19.2–98.3	48.47 (31.71)	–
FEV_1 (L)	0.42–3.88	1.11 (0.9)	–
FVC (L)	0.88–5.47	2.56 (1.31)	–
R5 (hPa/L/s)	0.18–1.63	0.6 (0.32)	–
R20 (hPa/L/s)	0.15–0.73	0.33 (0.13)	–
R5-R20 (hPa/L/s)	0.01–1.27	0.28 (0.25)	–
Fn (Hz)	10.1–44.4	27.2 (10.05)	26.8 ± 7.16

those who were older than 65 years in the day of tests. We analysed results gathered during a six-month period in 2010/2011. During that time, IOS and spirometry were obtained in 277 persons. The characteristics of the group are shown in Table 2.

Spirometric results were compared to reference values from the Global Lung Initiative Project (GLI2012), which allowed calculation of predicted values up 95 years of age [10]. Impulse oscillometry results were analysed using the predicted values equations of Schulz et al. [11].

Statistical analyses were made using R software [12]. This consisted of correlation analysis between spirometric and oscillometric indices and receiver-operator characteristics (ROC) oriented on diagnosing obstruction in the respiratory system; taking as a standard the decrease of FEV_1/ /FVC below the lower limit of normal. Data having Gaussian distribution (derived with Shapiro-Wilk test) are presented as mean ± SD, and for the remaining — median and interquartile range (IQR). The Wilcoxon rank test was used for comparisons, and a paired t-test was used for data with normal distribution. In calculations p = 0.05 was taken as the significance level.

Results

In the analysed group, obstruction (the decrease of FEV_1/FVC ratio below LLN) was seen in 197 patients (71.1%). Mean values of R5, R20, R5-R20 and Fn for obstructed (n = 197) and non-obstructed patients (n = 80) are presented in Table 3. Respiratory system resistance at 5 Hz, which is assumed to reflect total respiratory system resistance, and the difference between R5 and R20 reflecting peripheral airways resistance were significantly greater in subjects with obstruction compared to those without bronchial obstruction (Table 3).

Correlation coefficients between R5, R20, R5-R20, Fn and FEV_1 were –0.503 ($p < 0.001$); –0.166 ($p < 0.01$); –0.570 ($p < 0.001$); and –0.673 ($p < 0.001$), respectively. Very similar results were obtained when calculating correlation coefficients between oscillometric parameters and $1/FEV_1$ (r = –0.505, $p < 0.001$; –0.147, $p < 0.05$; –0.582, $p < 0.001$; and –0.618, $p < 0.001$). Figure 1 presents scatterplots of the relationship between R5, R5-R20 and FEV_1.

Receiver-operator characteristics analysis was also performed to calculate specificity and

Table 3. Values of oscillometric parameters in subjects with and without obstruction

Parameter	Obstruction		No obstruction		p
	Range	Median (interquartile range) Mean ± SD	Range	Median (interquartile range) Mean ± SD	
FEV_1	0.42–2.81	0.94 (0.45)	0.70–3.88	1.87(1.06)	< 0.01
FEV_1% nal.	17.06–109.61	40.32 (25.13)	34.40–132.88	81.30 (30.39)	< 0.001
FEV_1/FVC	19.15–65.53	39.90 (21.35)	56.72–98.31	91.31 (28.53)	< 0.001
FEV_1/FVC% nal.	25.44–83.04	51.41 (27.69)	77.47–124.73	92.50 (12.23)	< 0.001
FVC	0.88–5.05	2.53 (1.26)	0.93–5.47	2.67 (1.47)	< 0.05
FVC% nal.	34.77–133.33	82.23 (28.54) 82.12 ± 19.0	36.65–136.09	91.31 (28.53) 91.04 ± 20.40	< 0.01
R5	0.18–1.63	0.65 (0.30)	0.23–1.26	0.46 (0.26)	< 0.001
R5% nal.	60.26–633.30	214.9 (96.9)	56.01–531.28	140.48 (62.41)	< 0.001
R20	0.15–0.73	0.33 (0.13)	0.18–0.71	0.32 (0.12)	0.75
R20% nal.	66.15–301.94	147.34 (48.37)	60.56–372.26	136.61 (40.22)	< 0.05
R5-R20	0.01–1.07	0.32 (0.22)	0.01–0.72	0.13 (0.015)	< 0.001
Fn	10.19–44.36	29.38 (7.61) 29.2 ± 6.2	10.09–37.50	20.34 (7.22) 21.1 ± 6.0	< 0.001
Fn% nal.	71.54–518.62	193.41 (81.59)	76.15–310.63	125.74 (47.75)	< 0.001

FEV_1, FVC: l; R5, R20, R5-R20: kPa/l/s; Fn: Hz

Table 4. Specificity and sensitivity of IOS parameters

	Sensitivity	Specificity	AUC
R5	0.7	0.66	0.72
R5-R20	0.71	0.82	0.8
Fn	0.83	0.74	0.83

R5, R5-R20: kPa/l/s; Fn: Hz; AUC — area under curve

sensitivity of IOS indices in assessing airway obstruction using as a threshold spirometric criterion for obstruction. The results are presented in Table 4.

Discussion

Impulse oscillometry, because of its advantages concerning fewer requirements in cooperation, short time of measurements and relatively good reproducibility of the results, is used mainly in younger children who have problems performing spirometry properly. Potentially, IOS might also be used in elderly patients because in that group of patients the performance of spirometry -fulfilling quality criteria may be problematic. Analysis of the spirometry quality in a large group of patients aged > 65 years yielded (4) only 33.4% of tests that met all the quality criteria defined in the standard. In the group of 277 patients being analysed in the present study this percentage was 39.4%. In the remaining cases, the software signalled mainly a 'lack of plateau at the end of expiration' (the error coded by 100), which in fact means interpretation is still possible. On the contrary, IOS measurements did not cause any problems. Results obtained in our study are similar to theses reported by other researchers. In the work of Wiliamson et al. [13] in a group of 24 volunteers (without obstruction) R5 was in the range 0.34–0.43 kPa/L/s, while in a group of 21 patients with severe asthma it was 0.36–0.64, and in 24 COPD patients (with mean FEV_1%pred of 56.6%) it was 0.49–0.70 kPa/L/s. In our study, patients without obstruction had a value of R5 between 0.23 and 1.16 kPa/L/s and obstructed patients (mean FEV_1%pred value of 43.7%) in the range 0.18–1.63. However, it should be underlined that our group of patients was much older.

Oscillometric parameters (R5, R5-R20 and Fn) showed strong, significant correlation with FEV_1 values: r = –0.503, –0.570 and –0.673, respectively. Similar results were obtained in children [14] as well as in adults. Anderson and Lipworth [15] reported that in a group of 57 COPD patients, correlation coefficient between FEV_1 and R5-R20 was –0.499.

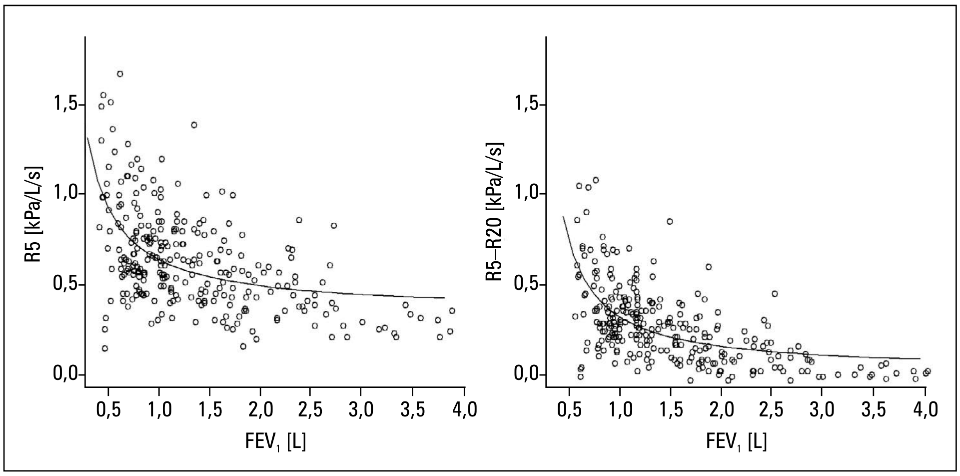

Figure 1. Scatterplots illustrating correlation between R5 and 1/FEV$_1$ ($r = -0.505$, $p < 0.001$); and R5-R20 with 1/FEV$_1$ ($r = -0.582$, $p < 0.001$)

Specificity and sensitivity reached high values, especially when R5-R20 and Fn were taken into account. Similar results have already been observed in children [16].

The value of oscillometric tests is sometimes questioned, especially when trying to assess respiratory system properties from a single test. Crimm et al. [17], who presented results from the ECLIPSE study, reported that in a large group of COPD patients (n = 2054) mean values of oscillometric parameters were significantly different from those obtained in healthy smoking persons as well as in healthy non-smokers. Concurrently, they noticed that 29–86% of COPD patients had results within 90% confidence interval of the results coming from healthy people. From that, they drew the conclusion that IOS is of limited value in detecting pulmonary pathology. This may be caused by greater variability of IOS-derived indices (compared to spirometry) and also by the lack of robust reference values from the analysis in a large group of healthy non-smoking individuals. Analysis of the reference values published by Schulz [11] shows that the upper limit of the normal value corresponds to increased values of resistances of about 35–50% in men and 50–80% in women; while in spirometry the lower limit of normal for basic parameters differs from the mean predicted value by less than 20%.

Despite the limited value of a single oscillometric test, its usefulness was confirmed in serial measurements, e.g. in bronchodilation and provocation tests [18]. Also, the ability of IOS in tracing changes in respiratory system mechanics seems to be very promising [19].

Potentially, the most important field of application of IOS is in the evaluation and control of peripheral airways condition. In 2007 Oppenheimer et al. [20] reported significant correlation between R5-R20 and frequency dependence of dynamic compliance. They stated that IOS enabled evaluation of peripheral airway properties in a similar way to dynamic compliance. This enables new opportunities for IOS measurements. In our study R5-R20 differed significantly between non-obstructed and obstructed groups: 0.17 ± 0.13 kPa/L/s vs. 0.35 ± 0.20 kPa/L/s ($p < 0.001$). In other papers it was shown also that there are significant differences between healthy controls and patients with severe asthma and COPD [13]. Jareback et al. [21], in an analysis obtained from COPD patients, showed statistically significant differences between values of R5 and R5-R20 with increasing disease severity (based on severity of obstruction) in comparison to healthy persons and COPD patients at early stage of the disease (GOLD1, FEV$_1$%pred > 70%). It is known that peripheral airways resistance accounts for about 10–30% of the total respiratory resistance in physiological conditions [22]. In the course of obstructive diseases, in which obstruction is localised in peripheral airways, the contribution of peripheral resistance in total resistance will be much greater. In our analysis the ratio of R5-R20 to R5 was 33% in patients without obstruction and 50.7% in those with airway obstruction. In the above-cited work concerning COPD patients, this contribution was 15% in the control group and 24%, 32%, 34% and 46% in patients with severity of disease changing from GOLD1 to GOLD4, respectively. It is clear that deterioration in small airways is reflected by the results of the measurements.

Moreover, Haruna et al. [23] proved in 65 patients with stable COPD a significant correlation between R5-R20 and the quality of life measured with SGRQ questionnaire as well as with dyspnoea measured by MRC scale. This makes IOS measurements even more interesting, as it could not only be used in evaluation of the peripheral airways resistance in the course of obstructive diseases, but also in prospective observational studies aimed at comparison of different therapeutic approaches oriented to small airways.

Conclusions

This is the first Polish study exploring impulse oscillometry values in the examination of adults. Currently there are two pulmonary medicine centres for adults that have the possibility to apply IOS in diagnostic procedures. The results of our work show not only the possibility of the implementation of the IOS for diagnosing individuals in whom classic techniques cannot be used, but also point out the opportunity of using IOS as an independent diagnostic research tool.

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Conflict of interest

The authors declare no conflict of interest.

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