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Rhinospirographic method of estimation of variability of nasal airflow in children

Rynospirograficzna ocena zmienności przepływów nosowych powietrza u dzieci

INTRODUCTION

The evaluation of nasal patency in children is an important part of the physical examination. It should be objective and performed using the methods most suitable for the age of a child. The evaluation of nasal patency is very helpful in understanding, diagnosis and treatment of multiple clinical problems concerning pathology of the upper respiratory tract: septal deviation, allergic rhinitis, tumours of the nose, malocclusion and other disorders in which specialist treatment by otolaringologist, orthodontist, allergic diseases specialist or pediatrician is required [22]. Objective evaluation nasal patency may be made on the basis of determining nasal airways resistance NAR, evaluation of nasal airflow and the measurement of volume or area of cross-section of nasal cavities [19]. One of the methods evaluating qualitative and semi-quantitative nasal airflow is rhinospirography (RSG) introduced by Betlejewski for clinical treatment of adults almost 30 years ago [2]. Parameters tested by RSG, and other methods of nasal patency evaluation (rhinomanometry, rhinospirometry, nasal peakflowmetry, acoustic rhinometry) may slightly vary [19], because nasal mucous membrane responds to various internal and external factors resulting in rapid or slow changes in nasal patency [7, 8, 9, 10].

Administration of allergen on nasal mucous membrane of allergic person (nasal provocation test — TPN) may result in a rapid decrease in nasal patency, and therefore it is used in the diagnosis of allergic diseases. A reliable evaluation of TPN results requires objective approach to changes in nasal patency and this is very important in treating children [21, 30]. Therefore many methods of objective evaluation of nasal patency are applied (most common is anterior or posterior rhinomanometry, the measurement of peak inspiratory flow and acoustic rhinometry), but no routine pro-

cedure in testing children, especially pre-school children, has been established [9, 24]. Scientific basis and our own experience suggest that RSG may be possible and suitable for this age group [9, 12].

The aim of this study was to determine the range of variability of parameters of a rhinospirographic curve (RSG) in children during a 15 minutes observation and a choice of most suitable parameters for the evaluation of this variability (establishing the standards of variability). It would enable the use of RSG for the evaluation of TPN results in children.

MATERIAL AND METHODS

The study was carried out on 48 children (28 boys and 20 girls) aged 3.5 to 15 years (average age: 8.2 ± 3.3 years) treated in Children's Rehabilitation Sanatorium in Krasnobród (Zamość District) and in Teaching Hospital for Junior Children, Institute of Paediatrics, Medical Academy in Lublin treated for chronic orthopaedic disorders (scoliosis — 12 children, coxal articulation problems — 7 children, equine and talipes foot — 5 children, others — 5 children) or diseases of the urinary tract (disorders of the urinary system — 8, urolithiasis — 5, infections of the urinary tract — 6 children). None of these children suffered from bronchial asthma or other allergic diseases of the respiratory tract (negative allergic and pneumonic history and physical examination). On the examination no symptoms of infection of the respiratory tract were found, and physical nasal examination revealed normal patency. Children were divided into two groups according to the age: junior children (n=20), age 3.5 to 6.9 and senior children (n=28), age 7.0 to 15.2.

Rhinospirographic examination was performed according to previously described technique [2, 12, 25]. The RSG curves were recorded separately from the left and right nasal cavity. 3 successful RSG curves were analysed using computer-aided picture of the rhinospirographic examination [29]. The arithmetic means from the most often tested curve parameters were calculated: duration of particular segments (KL, LM, MN, NK, KK) in seconds (s), the angle of a curve drop — alpha, and the angle of a curve rise — beta in degrees (^{0}) and the curve amplitude (A) in milimeters (mm), treated as a sum total of the maximum deflection upswing and downswing from the isoelectrical line [3, 12]. The shape of the RSG curve is presented in Fig. 1. Two tracings were recorded: the initial one and another after 15 minutes ("at rest test"). To describe the information included in the sets the following values were calculated: mean arithmetic value (x), standard deviation (SD), median (m), variability coefficient (w), minimum value (min) and maximum value (max). To assess the variability of RSG parameters involved in the TPN procedure a variability index was calculated (wz), that is the standard indicator of variability of a definite feature [6]. It was calculated according to the formula: $wz = (a-b)\ 100\%/a$, in which (a) represents the initial value of the feature, and (b) its final value. As it is seen from the above formula the variability coefficient may be positive (when $a>b$), equal to 0 ($a=b$), or be negative ($a<b$). In the first case it means the reduction in the value of specific feature after 15

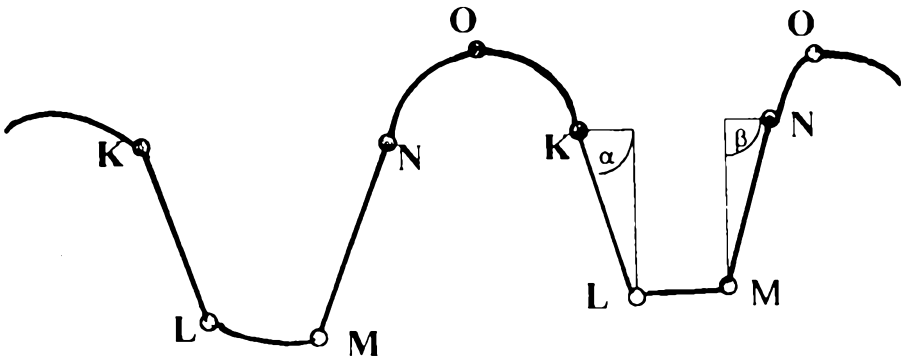

Fig.1. Rhinospirographic curve (RSG)

min., in the second case — no changes, and in the third case the increase in the value of the tested feature after 15 minutes of testing. A specific case is a situation in which wz equals 100%. It will occur when the value b is 0.

In order to evaluate the range of variability of parameters of RSG curve, absolute values wz were analysed. The following values were calculated: x, SD, x+1.65 SD, x+2.0 SD and also centile values: 90 c and 97 c. To compare the results of tests a test t-Student or Cochran-Cox were used. A statistical analysis of tests was performed using computer statistical programme STATGRAPHICS 2,0 (1986, STSC, Inc. — Statistical Graphics Corporation).

RESULTS

Table I and Table II present the results of rhinospirographic tests in the right and left nasal cavity. Parameters of RSG curve are represented by two figures because RSG curves were registered twice: the initial measurement [1] and after 15 minutes [2].

The values of parameters of RSG curve after 15 minutes [2] were not significantly different from the initial values [1] both in the right and in the left nasal cavity. As it may be seen from the calculations presented in Table III, no significant differences between corresponding initial parameters in the right and left nasal cavity were found.

In order to determine the variability of RSG curve during a 15-minute ("test at rest"), a variability index (wz) was calculated. Table IV presents values wz in the right (p) and left (l) nasal cavity in absolute values in % and also shows the significance of differences between corresponding wz from both nasal cavities. As it may be seen from Table IV no significant differences were found between corresponding wz means in the right and left nasal cavity. It may be concluded that tested parameters of RSG curve change after 15 minutes in a similar way in both nasal cavities. It may be also assumed that, taking into consideration a strong similarity between wz in both nasal

TableI. Results of rhinospirographic tests in the right nasal cavity

RSG curve parameters	mean (x)	SD	mediana	variability coefficient (w)	min	max	value of test function-to significance-p
KL1 (s)	0,25	0,05	0,24	20,12	0,15	0 39	to - 0,00
KL2 (s)	0,25	0,07	0,24	24,41	0,14	0,48	p > 0,9
LM1 (s)	0,75	0,32	0,69	42,09	0,30	2,12	to - 0,15
LM2 (s)	0,76	0,35	0,70	46,58	0,25	2,01	p > 0,9
MN1 (s)	0,28	0,09	0,25	32,16	0,15	0,65	to - 0,39
MN2 (s)	0,26	0,07	0,25	26,86	0,14	0,51	p > 0,8
NK1 (s)	1,72	0,52	1,64	30,41	0,65	3,47	to - 0,17
NK2 (s)	1,70	0,60	1,69	35,26	0,39	3,50	p > 0,8
KK1 (s)	3,02	0,82	2,92	27,06	1,50	6,24	to - 0,24
KK2 (s)	2,98	0,86	2,89	28,71	1,45	6,05	p > 0,9
A1 (mm)	13,14	4,77	12,45	36,29	5,40	29,70	to - 0,13
A2 (mm)	13,27	5,00	12,45	37,66	5,00	29,50	p > 0,9
Alfa1 (°)	65,69	6,58	66,15	10,02	47,80	77,30	to - 0,18
alfa2 (°)	65,38	7,70	64,75	11,77	45,50	79,80	p > 0,8
Beta1 (°)	65,84	7,21	66,20	10,95	46,70	81,70	to - 0,04
beta2 (°)	65,91	8,55	67,20	12,98	46,70	78,60	p > 0,9

Table II. Results of rhinospirographic tests in the left nasal cavity

RSG curve parameters	mean (x)	SD	mediana	variability coefficient (w)	min	max	value of test function-to significance-p
KL1 (s)	0,25	0,05	0,24	20,12	0,15	0,39	to - 0,00
KL2 (s)	0,25	0,07	0,24	24,41	0,14	0,48	p > 0,9
LM1 (s)	0,75	0,32	0,69	42,09	0,30	2,12	to - 0,15
LM2 (s)	0,76	0,35	0,70	46,58	0,25	2,01	p > 0,9
MN1 (s)	0,28	0,09	0,25	32,16	0,15	0,65	to - 0,39
MN2 (s)	0,26	0,07	0,25	26,86	0,14	0,51	p > 0,8
NK1 (s)	1,72	0,52	1,64	30,41	0,65	3,47	to - 0,17
NK2 (s)	1,70	0,60	1,69	35,26	0,39	3,50	p > 0,8
KK1 (s)	3,02	0,82	2,92	27,06	1,50	6,24	to - 0,24
KK2 (s)	2,98	0,86	2,89	28,71	1,45	6,05	p > 0,9
A1 (mm)	13,14	4,77	12,45	36,29	5,40	29,70	to - 0,13
A2 (mm)	13,27	5,00	12,45	37,66	5,00	29,50	p > 0,9
Alfa1 (°)	65,69	6,58	66,15	10,02	47,80	77,30	to - 0,18
alfa2 (°)	65,38	7,70	64,75	11,77	45,50	79,80	p > 0,8
Beta1 (°)	65,84	7,21	66,20	10,95	46,70	81,70	to - 0,04
beta2 (°)	65,91	8,55	67,20	12,98	46,70	78,60	p > 0,9

Table III. Results of comparison of initial parameters of RSG curve from the right and left nasal cavity

RSG Parameters	KL	LM	MN	NK	KK	A	alfa	beta
to	0,00	0,16	1,25	0,19	0,38	1,09	0,07	0,78
p<	0,9	0,9	0,2	0,9	0,8	0,3	0,9	0,5

Table IV. Variability index (wz) of specific parameters of RSG curve from the right (p) and the left (l) nasal cavity

wz	mean (x)	SD	mediana	variability coefficient (w)	min	max	value of test function-to significance-p
KLp	15,31	11,12	13,34	72,64	0,00	50,00	to - 0,50
KLl	16,51	11,93	13,94	72,26	0,00	45,45	p > 0,6
LMp	25,43	25,00	17,19	98,31	0,00	100,00	to - 0,48
LMl	28,00	27,08	20,91	96,70	0,00	164,58	p > 0,6
MNp	20,28	18,58	13,65	91,61	0,00	110,00	to - 1,52
MNl	15,41	11,62	12,29	75,38	0,00	57,89	p > 0,1
NKp	17,99	16,91	12,17	94,01	0,00	91,55	to - 0,79
NKl	20,81	17,43	16,47	83,76	0,00	77,33	p > 0,4
KKp	12,75	12,36	7,78	96,89	0,00	60,00	to - 1,09
KKl	15,42	11,41	11,88	73,98	0,34	45,96	p > 0,2
Ap	12,52	9,61	12,31	76,74	0,00	52,27	to - 0,79
Al	11,04	8,61	11,10	77,96	0,67	40,43	p > 0,4
alfap	9,56	9,55	6,51	99,89	0,00	41,04	to - 1,40
alfal	9,09	7,11	7,89	78,28	0,00	32,43	p > 0,1
betap	8,32	6,49	6,31	77,89	0,12	29,58	to - 0,44
betal	8,96	7,57	6,81	84,56	0,00	32,31	p > 0,6

Table V. Variability index of amplitude (wzA), angle of falling(wzalpha) and angle of rising (wzbeta) of RSG curve from both nasal cavities

Parameter	mean (x)	SD	mediana	variability coefficient (w)	min	max
wzA	11,78	9,15	12,04	77,69	0,00	52,27
wzalfa	9,32	8,42	7,03	90,34	0,00	41,04
wzbeta	8,64	7,06	6,66	81,72	0,00	32,31

Table VI. Variability index of amplitude (wzA), angle of falling (wzalpha) and angle of rising (wzbeta) of RSG curve from both nasal cavities in two age groups

Parameter	wzA		wzalfa		wzbeta	
	junior children	senior children	junior children	senior children	junior children	senior children
mean (x)	11,29	12,20	8,39	9,75	8,88	8,40
SD	8,66	9,53	7,19	9,20	7,40	6,76
mediana	10,86	12,07	6,48	7,03	6,93	6,14
W	76,74	78,09	85,72	94,32	83,35	80,50
min	0,00	0,67	0,00	0,13	0,00	0,12
max	40,43	52,27	30,73	41,04	32,31	29,58
value of test function - to significance - p	to - 0,46 p > 0,6		to - 0,76 p > 0,4		to - 0,32 p > 0,7	

cavities, analysed parameters of RSG curve belong to one set including 96 cases. Therefore such this set was used to establish a variability standard for RSG curve parameters. After analysing particular variability indexes it was found that 3 parameters have the lowest values: wzA, wzalpha and wzbeta. The values for the right nasal cavity (p) were : 12.52, 9.56 and 8.32 respectively and for the left nasal cavity (l): 11.04, 9.09, and

Table VII. Threshold values of the variability index of amplitude (wzA), angle alpha (wzalpha) and angle beta (wzbeta) calculated from standard deviation (SD) and centile values (c)

Parameter	mean (x)	SD	x + 1,65 SD	x + 2,0 SD	90c	97c
wzA	11,78	9,15	**26,88**	30,08	25,60	31,21
wzalfa	9,32	8,42	23,21	26,16	22,52	**31,89**
wzbeta	8,64	7,06	20,29	22,76	20,10	30,57

Table VIII. Rhinospirographic criteria helpful in the evaluation of TPN result in children

TPN negative (-)	wzA or wzalfa or wzbeta ≤ 26,88% (positive or negative)
TPN doubtful (+/-)	26,88% < wzA or wzalfa or wzbeta ≤ 31,89% (positive)
TPN positive (+)	wzA or wzalfa or wzbeta > 31,89% (positive)

8.96 respectively whereas the remaining parameters of RSG curve have considerably higher wz values (from 12,75 to 28,00). In order to establish normal changes in RSG curve at definite time the parameters wzA, wzalpha and wzbeta were chosen as the most stable. Table V presents calculations based on total values wzA, wzalpha and wzbeta from both nasal cavities.

In order to evaluate the effect of age on wz change, separate calculations for junior and senior children were performed, that is presented in Table VI. No significant differences in wzA, wzalpha and wzbeta values were demonstrated in 2 age subgroups. This observation was the basis for designing variability standards for these 3 wz taking into consideration data from the whole studied group. The range of standard for wzA, wzalpha, wzbeta was established using standard deviation (SD) and centile values. Taking into account that this study deals with the top range of variability standards, that is border value of extreme changes, the following ranges were established: <0, x+SD or >90 c/>97 c. According to a commonly accepted procedure for biological traits with normal distribution and accepting a confidence coefficient of 0.95 it has been established that values of discussed parameters in healthy children group will be situated in the range: <0, x+1.65 SD. That means that slightly under 5% of results will exceed thus established border line. In order to make a clear difference between normal and abnormal results of tests a confidence coefficient was established on the level 0.97. As a result a new range was established: <0, x+2.0 SD. The probability of abnormal result in this range is only 2.23%. With ranges established in this way all results may be classified as:

1. normal result, within the range [<0, x+1.65 SD],
2. doubtful result, within the range [<x+1.65 SD, ≥x+2.0 SD],
3. abnormal result, within the range [<x+2.0 SD].

When the range of standards is expressed in centiles, it is assumed that normal values of studied parameters are within the range from 10 c to 90 c [6]. That means 80% of results will be included in this range. As this evaluation is unilateral, only

those >97 c are considered as abnormal values, that means this range will include 3% of results, whereas questionable results will constitute >90 c x <97 c and this range will include 7% of results. On the basis of above considerations threshold values of analysed variability indexes were calculated and they are presented in Table VII. These threshold values were used as a basis for the evaluation of standards for variability of amplitude, alpha angle and beta angle for RSG curve. Having threshold values of discussed features calculated from x+SD and centile values, the feature of the highest value was finally chosen. Such a procedure results in more precise establishing of threshold values. Therefore after analysing data from Table VII it has been assumed that if any of studied wz >31.89%, it will be considered as abnormal, but a parameter in the range ?31.89% and >26.88%, will be a questionable result. Values ≥26.88% will be the evidence of normal wz. On the basis of these values rhinospirographic criteria for abnormal, questionable and normal results of TPN have been established and they are presented in Table VIII.

DISCUSSION

Physiological variations in nasal patency depend mainly on the degree of filling capacious vessels (large venous sinuses) in the submucosal layer of inferior and medial nasal concha [26]. In a smaller degree these variations depend on vasomotor reactions of other nasal vessels that are regulated centrally and locally, e.g. on dilatation of arteriovenous anastomosis at the entry to venous sinuses [31] or active and passive change in the shape of vestibule of the nose and its anterior part [5]. Variations in NAR connected with nasal cycle, range from 80 to 200% depending on the method of evaluation, although values over 100% are rare (in about 10% of people) [18]. Only when this phenomenon is tested using acoustic rhinometry, results of cross-section of nasal cavities may vary even over 400% [17]. On testing NAR or airflow in nasal airways it should be remembered that parameters evaluating nasal patency in the same groups of patients or healthy controls may considerably vary. Depending on the method applied this variability may range from 30% to even 200%, and is usually higher than variability of parameters for bronchial patency. There are several factors that may contribute to such great variability of parameters evaluating nasal patency [27, 32]: choosing a testing technique that is unsuitable for this particular case and clinical problem, a certain degree of "subjectivity" in every objective method, e.g. in the evaluation of maximum breathing effort or free breathing, lack of standards for research protocols and the possibility of releasing artefacts by a probe inserted into nasal airways or mouth. Therefore it seems advisable to employ a method with considerably small variability index for the evaluation of nasal patency.

RSG is a simple method representing changes in the nasal patency in the objective way. It is based on the use of laminar flowmeter and monitoring the airflow during quiet breathing (with tidal volume) through the nose with the mouth closed [2]. This method is used in tests evaluating the variability of nasal patency affected by various physiological stimuli [4]. There are several reports demonstrating usefulness of RSG

for the evaluation of patency disorders in the upper and lower respiratory tract in preschool and school children [11, 13]. A pilot study in children has been carried out to find out the suitability of this method for the evaluation of TPN with allergen [14], and then it was used to assess objectively TPN with carbachol [15].

Figures presenting RSG curve in studied children, that may be seen in Table I and II, are similar to those presented in other reports [12, 28]. Slight differences in duration of particular segments, amplitude and angles alpha and beta of RSG curve may result from the selection of groups and slightly different technique of the analysis of RSG curve.

The aim of a test for the range of variability of RSG curve in healthy children was to establish the range of normal variability of RSG curve during a 15-minutes observation, affected by natural variability of nasal patency (nasal cycle) and the effect of external or emotional factors connected with the test itself. Similar procedure is described by Pelikan et al. where the author performed "initial test" [23].

The performed tests demonstrate that values of parameters for RSG curve after 15 minutes were not significantly different from initial values, both in the right and in the left nasal cavity. Therefore it may be concluded that after 15 minutes RSG curve does not differ significantly in both nasal cavities. However, a slight range of variability was found, for the evaluation of which a variability index was used (wz).

The next aim of this study was the choice of wz most suitable for the evaluation of variability of RSG curve. One of the factors determining this choice was wz value, and from the statistical point of view the least variable wz was considered. After analysing particular wz of RSG curve (Table IV) the lowest values were found in 3 parameters: wzA, wzalpha, and wzbeta, and these parameters considered most "stable" were chosen to establish normal changes in RSG curve in time. The choice of such parameters of RSG curve was also supported by theoretical considerations and results from experimental and clinical reports [2, 3]. An additional argument for the choice of wzA were our own experiments for the evaluation of changes in RSG curve following intranasal application of carbachol or allergen. The experiments indicated the amplitude of RSG curve as the simplest parameter that reflects the quantitative character of changes in RSG curve following the provocative factor [14, 15].

As it may be seen from the calculations presented in Table III, no significant differences between corresponding initial parameters from both nasal cavities were found. These findings were the first premise for designing variability standards for RSG curve using 96 RSG recordings, that is 48 from the left and 48 from the right nasal cavity. Test results presented in Table IV reveal that there are no significant differences also between corresponding wz from the right and left nasal cavity. It may be concluded that studied parameters of RSG curve change in a similar way in both nasal cavities after 15 minutes; this is the second premise helpful in designing variability standards for RSG curve using 96 RSG recordings. Taking into account the similarity of specific parameters of RSG curve and their wz from both nasal airways it has been assumed that analysed parameters of RSG curve constitute one set including 96 cases. It has been established that the decrease in the value of amplitude of deflection of RSG

curve (that is decrease in the nasal airflow) of >32% as compared to the initial value should be considered excessive and this value should be accepted for the interpretation of TPN results. It is close to values suggested by other authors, although obtained by slightly different technique of research. According to Malberg et al. [20] the decrease in the nasal airflow of at least 25% in comparison to the initial value should be considered excessive. Bachert et al. [1] reveals critical value of 30%, while Fernandes et al. [16] mentions the necessity to obtain at least 40% of the decrease in the nasal airflow. This report is the fist study dealing with the variability of nasal airflow in children using rhinospirographic method, that enables to use it for the evaluation of TPN.

CONCLUSIONS

1. Parameters of rhinospirographic curve change after 15 minutes in a similar way in both nasal cavities.
2. From the analysed parameters of RSG curve its amplitude, angle of falling and rising are the most helpful in the evaluation of variability of the curve in time, e.g. during nasal provocation test with allergen.
3. Variability of nasal airflow tested with the use of rhinospirography is comparable to the variability of nasal airflow evaluated using other objective methods.

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STRESZCZENIE

Obiektywne badanie drożności nosa ułatwia zrozumienie, diagnostykę i leczenie różnorodnych problemów klinicznych z zakresu patologii górnych dróg oddechowych. Jedną z metod oceniających jakościowo i półilościowo przepływ nosowy powietrza jest rynospirografia (RSG). Celem pracy było określenie zakresu zmienności parametrów krzywej rynospirograficznej (krzywa RSG) u dzieci w trakcie 15 minutowej obserwacji oraz wybór parametrów na-

jbardziej przydatnych do oceny tej zmienności (ustalenie normy zmienności). Pozwoliłoby to na zastosowanie RSG do oceny wyniku TPN u dzieci. Badaniem objęto 48 dzieci (28 chłopców i 20 dziewcząt) w wieku od 3,5–15,0 lat. Parametry krzywej rynospirograficznej zmieniają się po 15 minutach w podobny sposób w obu jamach nosowych. Z pośród analizowanych parametrów krzywej, jej amplituda, kąt wznoszenia i opadania są najbardziej przydatne do oceny zmienności krzywej w czasie, np.: podczas testu prowokacji nosowej z alergenem. Zmienność przepływu nosowego powietrza badana przy pomocy rynospirografii jest porównywalna ze zmiennością przepływu ocenianego innymi obiektywnymi metodami.