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Posturography in differential diagnosis of patients with enlargement of brain ventricles

Posturografia w diagnostyce różnicowej pacjentów z poszerzeniem układu komorowego

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Abstract

Background and purpose: This study aimed to quantitatively evaluate balance disturbances by means of static posturography in patients with enlargement of the ventricular system (Evans ratio > 0.3).
Material and methods: Fifty-four patients were diagnosed and treated in our Department of Neurosurgery. Thirty-six of them were qualified as patients with brain atrophy and 18 others were identified as patients with normal pressure hydrocephalus (NPH). Average sway radius and developed area of the posturogram were evaluated with eyes open and closed. These parameters constituted a base to calculate vision indices related to radius and area as a result of division of the difference of a given parameter (radius or area) measured with eyes closed and open by its corresponding sum.
Results: The sway range was significantly greater in patients with NPH in comparison to the control group. In NPH, there were no differences of sways observed with eyes open or closed – the vision indices were not statistically different from zero (vision index related to radius: –6.1 ± 18.9%, vision index related to area: –5.1 ± 34.7%). This may indicate no participation of sight in postural stability control. Values of the vision index related to radius (9.3 ± 19.4%) and to area (22.1 ± 28.2%) in the atrophy group significantly differed from zero, which indicated the participation of sight in postural stability control.

Streszczenie

Wstęp i cel pracy: Celem pracy była ilościowa ocena zaburzeń równowagi przy użyciu statycznej posturografii u pacjentów z poszerzeniem układu komorowego (wskaźnik Evansa > 0,3).
Materiał i metody: Materiał obejmował 54 chorych, diagnozowanych i leczonych w Klinice Neurochirurgii IMDiK PAN, w tym 36 chorych z zanikiem mózgu i 18 chorych z rozpoznaniem wodogłowia normotensyjnego (*normal pressure hydrocephalus* – NPH). Porównywano średni promień wychwiań i pole powierzchni rozwiniętej posturogramu przy oczach otwartych i zamkniętych. Na podstawie tych parametrów obliczano indeks wzrokowy promienia oraz pola. Indeks jest ilorazem różnicy wartości danego parametru (promienia lub pola) mierzonego przy oczach zamkniętych i otwartych oraz sumy odpowiednich wartości danego parametru.
Wyniki: W grupie chorych z NPH zakres wychwiań był znacząco większy w porównaniu z wychwianiami u osób zdrowych. U chorych z NPH nie obserwowano różnic wychwiań mierzonych przy oczach otwartych i zamkniętych – indeks wzrokowy dla promienia: –6,1 ± 18,9%, indeks dla pola: –5,1% ± 34,7% – indeksy te nie różnią się istotnie statystycznie od zera. Może to wskazywać na brak udziału narządu wzroku w utrzymaniu stabilności posturalnej. Wartość indeksu wzrokowego w grupie chorych z zanikiem mózgu wynosi dla promienia: 9,3% ± 19,4%, a dla pola: 22,1% ± 28,2%. Są to wartości statystycznie znamiennie różne od zera, co wskazuje na udział wzroku w utrzymywaniu stabilności posturalnej u tych chorych.

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Conclusions: Introduction of a new measure called the 'vision index' seems to be a promising clinical practice method of differentiation of hydrocephalus and brain atrophy.

Key words: normal pressure hydrocephalus, atrophy, balance disturbance, posturography.

Wnioski: Wprowadzenie parametru „indeks wzrokowy" dla oceny stabilności posturalnej wydaje się obiecującą, przydatną w praktyce klinicznej metodą różnicowania wodogłowia normotensyjnego i zaniku mózgu.

Słowa kluczowe: wodogłowie normotensyjne, zanik mózgu, zaburzenia równowagi, posturografia.

Introduction

Differential diagnosis of normal pressure hydrocephalus (NPH) (Hakim disease) and brain atrophy-related syndromes is difficult [1] due to the similarities in clinical symptomatology and imaging [2-4]. Even a thorough neuropsychological evaluation does not ensure unequivocal diagnosis in all of the cases [5,6]. Still, a proper differentiation of these two pathological states is of vital importance, since the choice of appropriate therapy and related consequences might be serious.

Since most diagnostic modalities are invasive, with the infusion test [7] being one of them, other, less invasive methods have been explored such as somatosensory evoked potentials [8]. Recently, the possibility of using gait and balance studies for this particular purpose has been proposed [9-11].

Posturographic studies involve the evaluation of the degree of body tilt in an upright position. In this position, the center of gravity (COG) continuously performs tiny, unordered movements with several millimeters amplitude that are called sways. A posturogram (or stabilogram) is a registration of movement trajectory of the center of pressure (COP) of the foot in the XY system of coordinates in the horizontal plane.

In our department, we have implemented the 'vision index', which evaluates the degree of posture stability disturbances that arise from vision's contribution to gait control in the diagnostic protocol of hydrocephalus. The aim of the present study was to evaluate the usefulness of the vision index for differential diagnosis of NPH and brain atrophy.

Material and methods

Posturographic studies were performed in a group of 54 patients with ventricular expansion (Evans index > 0.3) aged 32 to 82 years (mean age 64 ± 13 years).

Patients were divided into 2 groups. The first group consisted of 36 patients with diagnosed brain atrophy. The second group comprised 18 patients with NPH. Posturographic parameters were analyzed for all of the patients (54 patients).

In order to define normal values for posturographic parameters (control) we used the work of Katarzyna Dmitruk from Ludwik Rydygier's *Collegium Medicum* in Bydgoszcz prepared as a doctoral dissertation in 2000 [12]. These values were obtained from posturographic studies performed with the same device as the one used in the present study. The cited elaboration consisted of 47 healthy patients aged 50 to 69 years (mean age 59.9 ± 7 years).

All of the studies were performed with the posturographic platform Pro-Med [11]. Patient's state of equilibrium was assessed with eyes open (EO) and closed (EC). Evaluated posturographic parameters included (1) average sway radius measured with eyes open (R_{EO}) and closed (R_{EC}) and (2) developed area of posturogram measured with eyes open (A_{EO}) and closed (A_{EC}).

Subsequently, the difference between mean values of sway radii (DR) and the difference of developed areas of the posturogram (DA) measured with eyes open and closed were calculated: $DR = R_{EC} - R_{EO}$ and $DA = A_{EC} - A_{EO}$.

Vision index (IR) values were subsequently calculated for each posturographic parameter by dividing either DR or DA by the sum of radii or areas, respectively, measured with eyes opened or closed. The vision index for sway radius was calculated according to the formula $IR = (R_{EC} - R_{EO}) / (R_{EC} + R_{EO}) \times 100\%$ while the index for area was calculated according to the formula $IA = (A_{EC} - A_{EO}) / (A_{EC} + A_{EO}) \times 100\%$. The theoretical variability range for the index varies from –100% to +100%; these maximal values cannot be the subject of deliberations for they exist only in a situation when one of the measured parameters reaches zero. In practice, the index values do not exceed ±50%.

Definitions of zero-dimensional rates analogous to the IR that are relevant for posturographic measurements registered with eyes open or closed have been published in articles by Mraz [13,14].

Statistical analysis was performed with SPSS statistical software and the graphical/statistical software package

ORIGIN. In order to evaluate changes in posturographic parameters, non-parametric statistical methods were usually implemented: Wilcoxon paired test, Kruskal-Wallis test and Kolmogorov-Smirnov test. Null hypotheses were rejected at p-value < 0.05 with a single exception for 'post hoc' analysis with Bonferroni correction [15]. The p-value required for three-group comparisons was 0.016. In order to verify the hypothesis that index values come to zero, we used Student's t-test for one sample.

Results

Figures present typical trajectories of the COP point for all of the groups examined (controls, patients with brain atrophy and patients with NPH). Figure 1 shows posturographic measurements acquired with eyes open from a healthy person, a patient with brain atrophy and one with diagnosed hydrocephalus. Figure 2 presents posturographic measurements acquired with eyes closed in the same patients. Sways in healthy controls were significantly smaller in comparison to other groups of patients with eyes closed as well as with eyes open. The highest sway radii were found in the hydrocephalus patients, similarly with eyes open and closed.

Statistical analysis of posturographic data in the three groups examined (controls, patients with brain atrophy and patients with NPH) showed that for each posturographic parameter analyzed no matter whether attained

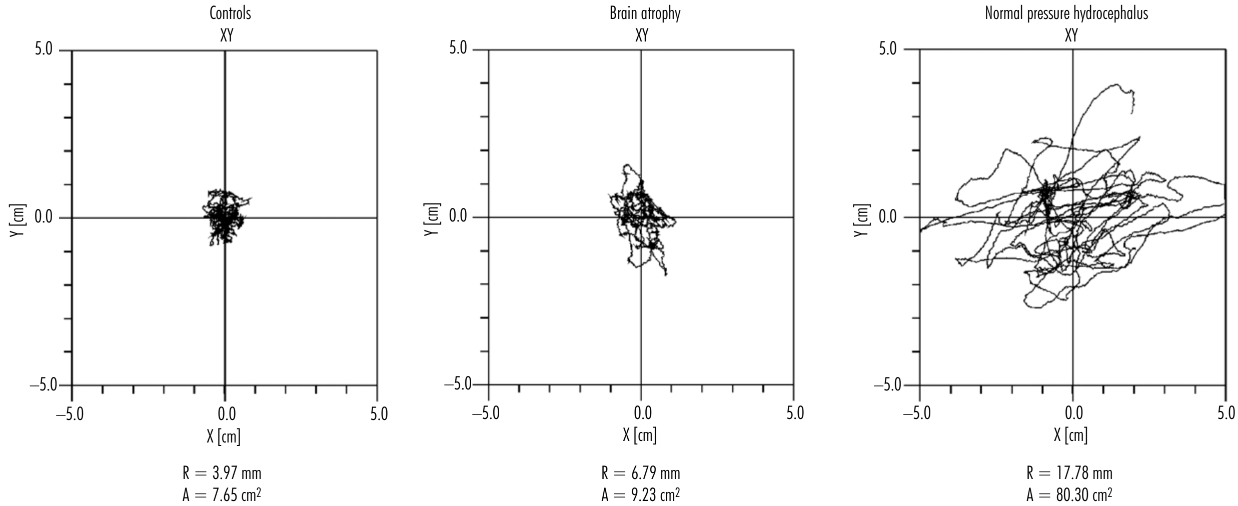

Fig. 1. Examples of stabilograms measured with eyes open

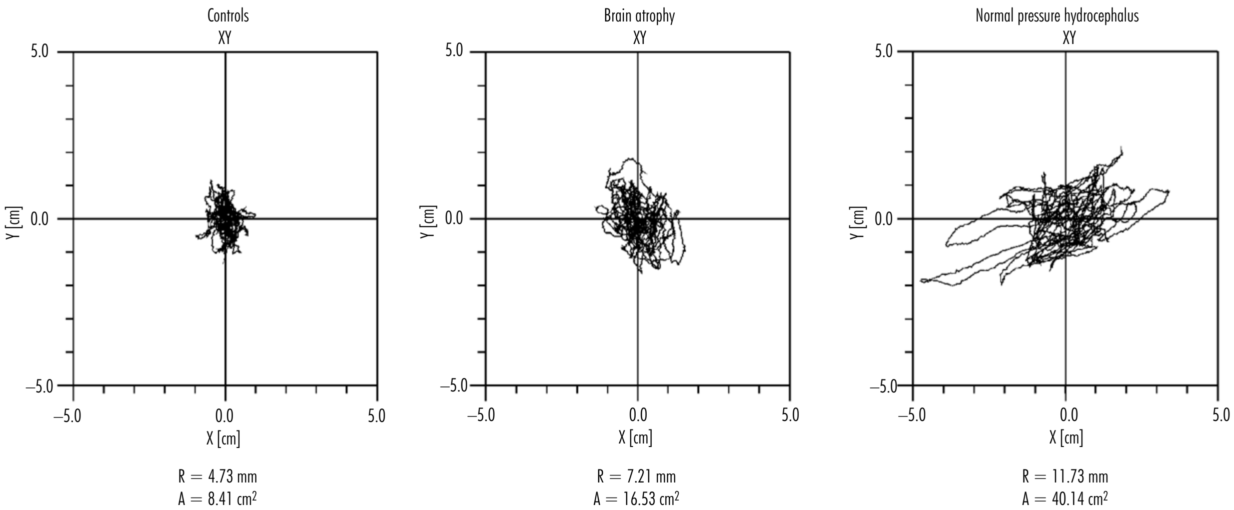

Fig. 2. Examples of stabilograms measured with eyes closed

Table 1. Results of non-parametric ANOVA Kruskal-Wallis test among three investigated groups: controls, patients with brain atrophy and patients with normal pressure hydrocephalus

Posturographic parameters	χ^2 Kruskal-Wallis	*P*-value
Sway radius with eyes open	55.9	< 0.001
Sway radius with eyes closed	43.8	< 0.001
Difference of sway radii	10.4	< 0.005
Vision index related to sway radius	10.5	< 0.005
Developed area of posturogram with eyes open	59.1	< 0.001
Developed area of posturogram with eyes closed	46.7	< 0.001
Difference of developed areas of posturogram	8.9	< 0.012
Vision index for developed areas of posturogram	10.3	< 0.006

with eyes open or closed as well as for all of the differences of DR and DA or vision indices (IR and IA), there was a clear, statistically significant difference between the groups (Kruskal-Wallis ANOVA – results in Table 1). It allowed all of the post-hoc tests to be performed; the results are presented in Tables 2 and 3.

Tables 2 and 3 show lists of results of posturographic measurements performed with eyes open and closed along with calculated differences and vision index values for mean sway radius and developed areas of the posturogram in patients with brain atrophy, patients with NPH and healthy controls.

The NPH group showed the highest sway measured by either sway radius or developed area of the posturogram, when measured with eyes open (Tables 2 and 3). Conversely, the smallest sways were found in controls (Tables 2 and 3). The differences are statistically significant in all three pairs, i.e. NPH patients vs. controls, NPH patients vs. patients with brain atrophy, and patients with brain atrophy vs. controls ($p < 0.001$ for each comparison).

While measured with eyes closed, all aforementioned relationships remain the same with the exception of the difference between patients with NPH and patients with brain atrophy, which is not significant after Bonferroni's correction [15].

The influence of the sense of sight on postural stability was assessed independently for each group of patients with separate comparisons of sway radii and developed areas of posturograms measured with eyes closed and with eyes open. Statistically significant differences of sways between measurements collected with

Table 2. Analysis of radius values measured with eyes open and closed in three investigated groups

		Controls n = 47		Patients with brain atrophy n = 36		Patients with normal pressure hydrocephalus n = 18	
		Eyes open	Eyes closed	Eyes open	Eyes closed	Eyes open	Eyes closed
Sway radius		4.2 ±1.4	4.8 ± 1.7	6.6 ± 2.5	8.2 ± 3.9	13.9 ± 3.8	12.4 ± 3.9
P-values for the differences between eyes open and eyes closed in each studied group		< 0.001		< 0.004		NS	
P-values for the differences between groups in each condition (eyes open or eyes closed)	Controls vs.	–	–	< 0.001	< 0.001	< 0.001	< 0.001
	Patients with brain atrophy vs.	–	–	–	–	0.0001	0.005
Differences of radii recorded with the eyes open and eyes closed		0.6 ± 1.2		1.7 ± 3.1		–1.5 ± 4.5	
P-values for the differences between groups	Controls vs.	–		< 0.001		< 0.004	
	Patients with brain atrophy vs.	–		–		< 0.005	
Vision index for radius (IR)		6.5 ± 12.1		9.3 ± 19.4		–6.1 ± 18.9	
P-value for the difference from IR = 0		< 0.001		< 0.007		NS	
P-values for the differences between groups	Controls vs.	–		< 0.041*		< 0.001	
	Patients with brain atrophy vs.	–		–		< 0.002	

*NS – non-significant; *NS after Bonferroni correction*

Table 3. Analysis of area measured with eyes open and closed in three investigated groups

		Controls $n = 47$		Patients with brain atrophy $n = 36$		Patients with normal pressure hydrocephalus $n = 18$	
		Eyes open	Eyes closed	Eyes open	Eyes closed	Eyes open	Eyes closed
Developed area of posturogram		4.3 ± 3.2	7.2 ± 7.2	17.9 ± 26.5	34.5 ± 56.2	51.0 ± 33.5	45.1 ± 29.5
P-values for the differences between eyes open and eyes closed in each studied group		< 0.001		< 0.001		NS	
P-values for the differences between groups in each condition (eyes open or eyes closed)	Controls vs.	–	–	< 0.001	< 0.001	< 0.001	< 0.001
	Patients with brain atrophy vs.	–	–	–	–	0.0001	0.031*
Differences of areas recorded with the eyes open and eyes closed		3.0 ± 5.6		16.5 ± 33.4		–5.9 ± 39.9	
P-values for the differences between groups	Controls vs.	–		< 0.001		< 0.001	
	Patients with brain atrophy vs.	–		–		< 0.002	
Vision index for area (IA)		19.8 ± 23.5		22.1 ± 28.2		–5.1 ± 34.7	
P-value for the difference from IA = 0		< 0.001		< 0.001		NS	
P-values for the differences between groups	Controls vs.	–		NS		< 0.006	
	Patients with brain atrophy vs.	–		–		< 0.031*	

*NS – non-significant; *NS after Bonferroni correction*

eyes open and closed were found in controls and in patients with brain atrophy. Such differences were absent in the NPH group.

Sway differences with eyes open and closed were expressed as sway radius differences (DR) and developed area difference (DA) and subsequently as vision indices, i.e. relative (percent) differences of radii (IR) and developed areas of posturograms (IA). In the NPH group, vision index values did not differ significantly from zero (IR = –6.1% ± 18.9%, IA = 5.1% ± 34.7%). These results prove then that postural stability in this group of patients does not require visual support. Opposite results have been found in patients with brain atrophy, whose vision index values for radius and developed field differed significantly from zero (IR = 9.3% ± 19.4%, IA = 22.1% ± 28.2%). This suggests substantial participation of vision in postural stability maintenance in this group of patients, similarly to healthy controls (IR = 6.5% ± 12.1%, IA = 19.8% ± 23.5%), whose vision index values also differed significantly from zero (Figs. 3 and 4).

Multiple comparisons of vision indices calculated for sway radii and developed areas of posturograms between the three pairs of patients compared, i.e. NPH patients vs. controls, NPH patients vs. patients with brain atrophy, and patients with brain atrophy vs. controls, revealed statistically significant differences between patients with NPH and healthy controls. For the vision index calculated for radius, the difference between patients with brain atrophy and controls was not significant after Bonferroni correction. For the vision index calculated for developed area of the posturogram, only the difference between patients with NPH and healthy controls proved to be statistically significant.

Discussion

The diversity of diagnostic methods used for differentiation of NPH from brain atrophy proves the difficulty of proper diagnosis in these two pathological syndromes. Analysis of postural parameters seems to be a helpful, complementary method in addition to the standard diagnostic tools.

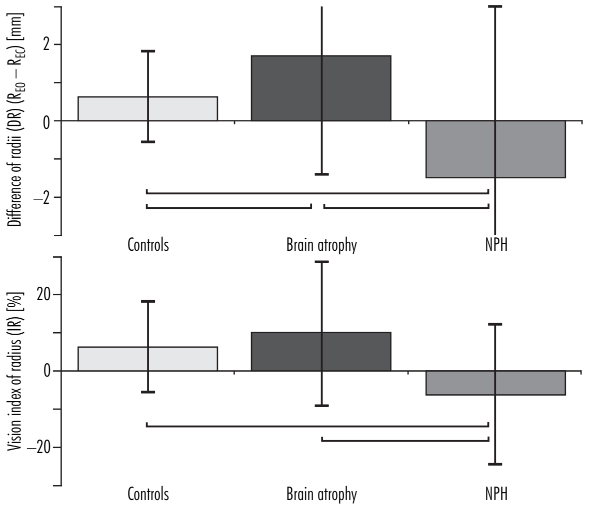

Fig. 3. Comparison of the radius differences (DR) and vision index for radius (IR) calculated for mean sway radius in three investigated groups

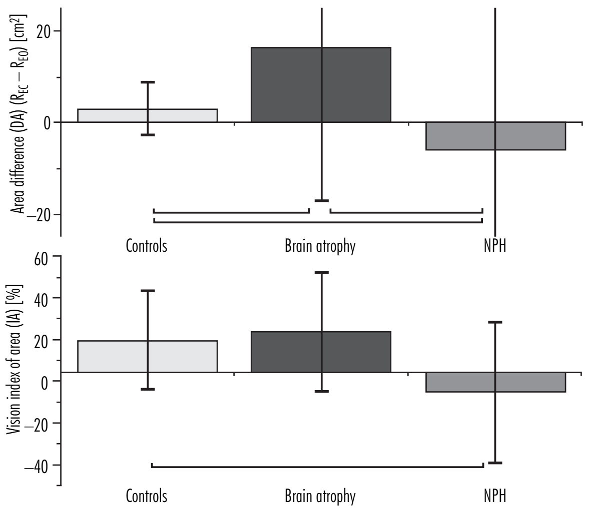

Fig. 4. Comparison of the area differences (DA) and vision index for area (IA) calculated for area in three investigated groups

We observed an increase of mean values of posturographic parameters in tests performed without visual control (eyes closed) in comparison to values acquired during measurements with the eyes open (Tables 2 and 3). Maintaining an upright position results from a dynamic equilibrium between activities of certain antagonist muscle groups that stabilize particular joints [16,17]. Changes of position and, even minimal, deflections from equilibrium are effectively detected visually [18].

In healthy people upon closing the eyes visual information that reaches the CNS while eyes are open is replaced by somatosensory information (muscle tension and muscle's proprioceptors). Healthy persons still might efficiently correct their posture and regain balance; still a slight increase of sway radii is present, which proves the existence of proper CNS compensation without visual information.

Analysis of postural parameters in patients with brain atrophy revealed a response pattern similar to the healthy population, i.e. they respond to eyes' closure (loss of visual control). Sway radius increase is more pronounced upon closure of eyes when compared to healthy people. It results from inaccurate motor coordination of patients with brain atrophy. The efficacy of balance control depends on motor capabilities, i.e. compensation for the lack of visual information is less proficient in comparison to healthy controls.

To recapitulate, visual control in both healthy and brain atrophy groups has a significant influence on postural stability parameters.

Czechowicz *et al.* [19] reported that visual control influenced postural parameters in patients with Parkinson disease. Jagielski *et al.* [20] also addressed the influence of visual control on postural stability in patients with Parkinson disease. They found that visual control was disturbed in patients with Parkinson disease. They also stressed that pallidotomy as a treatment of this disease improves posturographic parameters.

Our observations confirm that visual control influences the maintenance of postural control; this influence is statistically significant in healthy people and patients with brain atrophy. Conversely, in patients with NPH our results show no influence of visual control on posturographic parameters assessed. A distinctive symptom for this group of patients is a lack of the influence of eye opening on sway radius. Balance disorders are comparable with eyes closed and open. One can conclude then that for these patients vision does not constitute a significant source of information necessary for balance disorder maintenance or they cannot make any use of this channel of information. In our opinion, this observation is of particular value for it may significantly facilitate diagnostics and differentiation of NPH and other types of brain atrophy syndromes.

Balance disorders in patients with hydrocephalus are thought to arise from an impairment of neurotransmission to and from the cerebellum, from the sensorimotor cortex to the reticular formation and anomalous cooperation of two systems: visual and vestibular [10,11].

A clear improvement of postural parameters that follows shunt implantation in a significant percentage of patients supports the hypothesis that deterioration of compensatory mechanisms for balance control in hydrocephalus patients arises from tension of optic radiation fibers by enlarged ventricles. It seems that the new, computable parameter – the vision index – presented in our study describes this phenomenon measurably, i.e. quantitatively and repeatably [10,11].

Conclusions

Postural parameters (including vision indices) might act as an important tool for differential diagnosis of NPH and brain atrophy.

Disclosure

Authors report no conflict of interest.

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