Romanian Journal of Rhinology, Vol. 7, No. 26, April-June 2017

ORIGINAL STUDY

The clinical value of foam posturography in assessing patients with peripheral vestibular dysfunction – our experience

Raluca Enache[1], Dorin Sarafoleanu[1], Codrut Sarafoleanu[1,2,3]

[1]ENT Sarafoleanu Medical Clinic, Bucharest, Romania

[2]"Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania

[3]ENT&HNS Department, "Sfanta Maria" Hospital, Bucharest, Romania

ABSTRACT

BACKGROUND. Computerized dynamic posturography is the most important battery test designed to assess the ability to use visual, vestibular and proprioceptive cues in the maintenance of posture. Foam posturography reduces the availability of proprioceptive inputs, which makes more difficult the balance control.

OBJECTIVE. The objective of the study was to assess the clinical use of foam posturography in evaluating peripheral vestibular dysfunction.

MATERIAL AND METHODS. We evaluated 41 patients with vestibular disorders and 41 normal patients by using the sensory organization test in eyes opened, eyes closed and mislead vision conditions with and without the foam. We measured several parameters: the position of the center of pressure, the displacement in the center of pressure in anteroposterior and mediolateral planes and Romberg's ratio on static and foam rubber.

RESULTS. The values of all parameters were significantly higher in patients with peripheral vestibular disorders than in the control group ($p<0.05$). Also. comparing the Romberg test results, the foam surface used by the patient was larger than the static one.

CONCLUSION. Foam posturography can be a reliable test in assessing patients with peripheral vestibulopathy, being also able to identify the visual and proprioceptive dependence levels.

KEYWORDS: foam posturography, vestibular disorders, dynamic posturography, Romberg's ratio.

INTRODUCTION

Vestibular disorders, as a result of a lesion located in different parts of the brain or inner ear, are characterized by gaze impairment or vertigo, postural control deficit and vegetative phenomena[1]. The inputs received from the sensory systems (visual, vestibular and proprioceptive), muscle effectors and central nervous system are used for maintaining balance[2,3]. The central nervous system receives information from the visual and vestibular systems, analyses them and, associated with the somatosensory inputs, keeps the body's center of pressure within the base of support.

With the evolution of medicine, different tests have been developed for the positive and differential diagnosis of vestibulopathies. Posturography is a test designed to assess the ability of visual, vestibular and somatosensory systems to maintain postural gait[4,5]. Its purpose is to evaluate balance and to help understand the pathophysiology of postural control by measuring the position of the center of pressure.

There are several types of posturography tests that can be performed. Static posturography gives information about the spontaneous movements of the body on a static platform[5-8]. Dynamic posturography, performed on a moving platform, or the posturography on a foam rubber (foam posturography) assess postural control in the presence of an induced external perturbation, thus evaluating the contribution of visual, vestibule and somatosensory inputs[4-6,9]. The infor-

Corresponding author: Raluca Enache, MD, PhD, ENT Sarafoleanu Medical Clinic, 1 Lt. Av. Iuliu Tetrat Street, District 1, Bucharest, Romania
e-mail: r.enache@rinologie.ro

mation gain with this test can determine which type of input can or cannot be used to maintain balance.

Several studies reported in the literature sustain that both dynamic and foam posturography can be used as preliminary tests in the evaluation and diagnosis of patients with peripheral vestibular disorders[5,10]. Even if foam posturography cannot identify the dysfunctional vestibular organ, authors like Allum, Black or Baloh showed in their studies that patients with peripheral vestibulopathies may present severe balance deficits compared to healthy subjects[11-13].

Considering the data found in the literature, the aim of this study was to assess the clinical value of foam posturography in evaluating and identifying those patients with peripheral vestibular deficit.

MATERIAL AND METHODS

Patients

Subjects included in the study consisted of 41 patients with peripheral vestibular dysfunction (V+) and 41 controls, healthy subjects (V-). The control group (25 women and 16 men, mean age ± SD = 48.53±10.41 years, range = 30-77) presented normal results at videonystagmoscopy, smooth pursuit and saccades.

The patients group included 21 women and 20 men, with a mean age (±SD) of 57.3±13.06 years, range=32-76. All patients underwent an audiometric test, a videonystagmoscopy evaluating the presence or absence of spontaneous or gaze nystagmus, smooth pursuit and saccades tests. We included in the study those patients diagnosed with peripheral vestibular dysfunction, as follows: vestibular neuronitis (n=8), Meniere's disease (n=17), sudden hearing loss associated with vestibular dysfunction (n=6), drug toxicity (n=5) and peripheral vestibular deficit due to VPPB (n=5). An excluding criteria was the history of orthopaedic or neurological pathology, and those patients with central vestibular deficits.

The subjects were recruited between September 2015 and May 2016. Both normal subjects and patients were informed about the study and an informed consent was obtained from all individuals participants included in the study.

Posturography evaluation

The posturography evaluation was made using the Synapsis Posturography System® (SPS®, version 3.0, SYNAPSIS, Marseille, France). All patients performed the Sensory Organization Test (SOT), this test representing the association between static and foam posturography under three conditions – eyes open (eo), eyes closed (ec), mislead vision. SOT objectively analyses the three sensory systems that contribute to postural control: somatosensory, visual and vestibular, by systematically eliminating useful visual or support information, creating also sensory conflict situations. Also, SOT stresses the adaptive responses of the central nervous system.

We registered the results obtained under four conditions: eyes open and eyes closed on static surface and foam. The feet position of the patient on the platform was – 2 cm spacing apart of the heels and a 30° angle between, corresponding to the foot size. Each test was performed barefoot, in standing position, 2 trials of 20 seconds for each test. The foam mattress (50x50x5.5cm) was fitted on the firm surface of the platform.

The parameters evaluated were:

- the statokinesigram (SKG) – a graph of the successive positions of the centre of pressure (COP) at 100Hz recorded by the platform (mm^2)
- the Romberg's quotient (RQ)
- the degree of the displacement in the centre of pressure, the maximum deviations, in the antero-posterior (AP) and medio-lateral (ML) plans (mm).

Data analysis

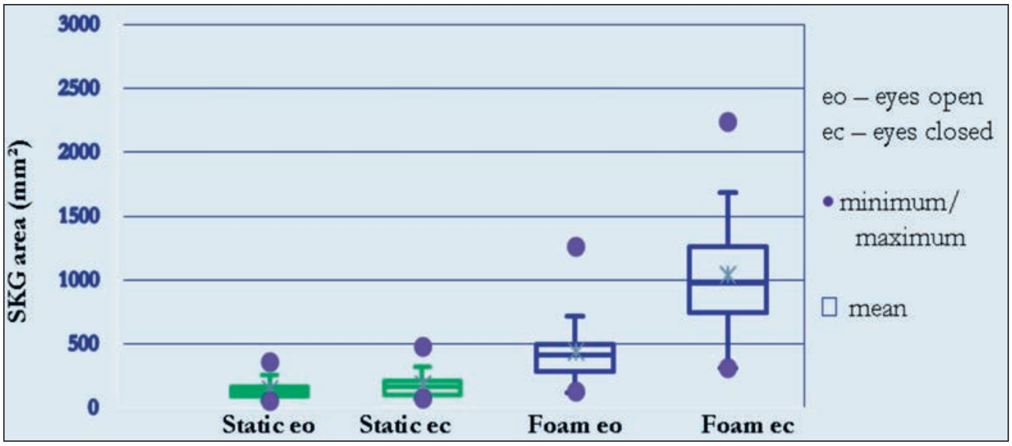
Data analysis was performed with XLSTAT® for Microsoft Excel. Due to the abnormal distribution of the parameters, the Mann-Whitney nonparametric test was used to evaluate the two groups. A *p*-value less than 0.05 was considered to be a sign of a statistically significant difference. The receiver operating characteristics (ROC) curves were used to compare sensitivity and specificity for the parameters ability to predict the existence of peripheral vestibular disorders.

RESULTS

Control group

The evaluation of the healthy subjects revealed that the successive position of the COP was greater on foam (Graph 1). The statistic results showed that in the "eyes closed" condition the mean value was higher in both static and foam platform, 183.355, respectively 1042.106. Comparing the two samples "static-eyes closed" and "foam-eyes closed" using the Mann-Whitney nonparametric test, there was a significant statistical difference between the two samples ($p<0.0001$) (Table 1).

Also related to the SKG, the Romberg's quotient presented increased values on foam in the control group (Graph 2), even if there were subjects with scores outside the normal values, 85-241. The group analysis performed with Mann-Whitney nonparametric test revealed a significantly statistical difference between the scores obtained on foam and static platform, in favour of the first parameter ($p<0.0001$) (Table 2).

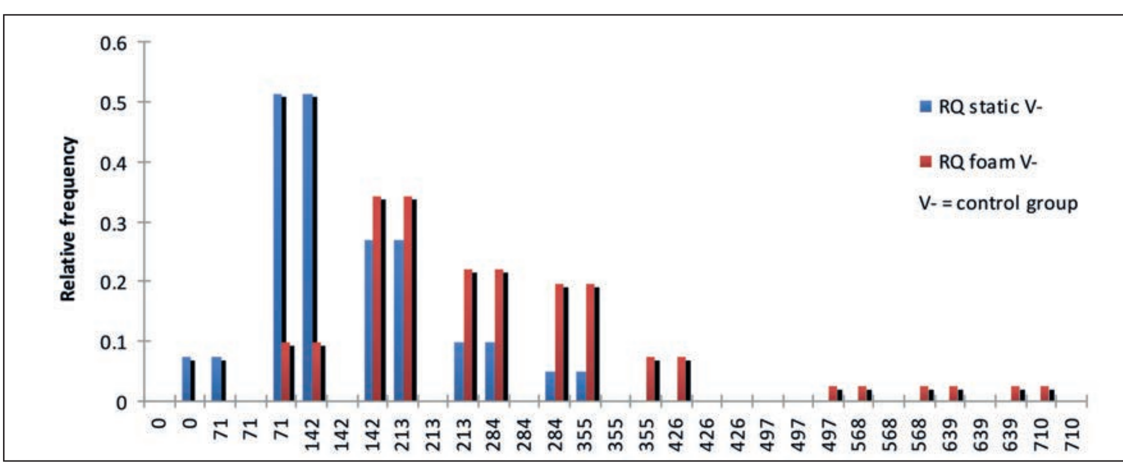


Graph 1. The distribution of the successive position of the center of pressure on static platform and foam rubber in the control group.

Table 1
Statokinesigram statistic results

Statistic	Static eo	Static ec	Foam eo	Foam ec	p-value
Minimum	49.830	71.160	121.650	314.520	
Maximum	359.510	475.090	1261.450	2238.000	
1st Quartile	89.480	102.990	288.640	740.440	
Median	123.500	163.740	409.720	978.340	
3rd Quartile	163.390	215.090	492.320	1257.290	
Mean	139.980	183.355	436.406	1042.106	<0.0001
Std. dev.	79.164	97.674	207.463	425.453	

eo – eyes open; ec – eyes closed; Std. dev. – Standard deviation



Graph 2. Representation of Romberg's quotient (RQ) values in the control group.

Table 2
Statistical analysis of Romberg's quotient in the control group

Variable	Minimum	Maximum	Mean*	Std. dev.
RQ static V-	51	311	148.610	60.728
RQ foam V-	115	703	266.537	124.558

V- = control group; Std. dev. – Standard deviation; *p-value < 0.0001

An important parameter in our study was represented by the maximum deviation of the centre of pressure in the AP and ML plane (the maximum amplitudes). This parameter can provide information about the fall risk of the patients. In the normal subjects group, the displacement in the AP plane was greater than in the ML plane, on both static platform and foam (Table 3), the anomaly being significantly prominent in the eyes closed condition ($p<0.0001$).

Comparing the deviation degree on foam in AP plane in both eyes open (mean=27.09) and eyes closed (mean=48.94) conditions, we observed that during the latter the degree of the displacement was significantly higher ($p<0.0001$). The same observations can be made in what the displacement in the ML plane is concerned (Table 4).

Patients group

The comparison of the statokinesigram between the peripheral vestibulopathy group and the control group revealed a significant difference between the two groups on static platform and foam rubber in both conditions – eyes open ($p=0.002$ static platform; $p<0.0001$ foam rubber) and eyes closed ($p<0.0001$) (Table 5).

As it can be seen in the distribution of the area values on static platform and foam rubber in the eyes open and eyes closed conditions (Graph 3), the values are higher in those patients with peripheral vestibular dysfunction, the difference being even more important in "foam-eyes closed" condition. It is well known that patients with vestibular disorders need a bigger area of support for their centre of pressure. Also, the presence of visual dependency is high in these cases.

Table 3
Statistical analysis of the maximum deviation of the centre of pressure

	Max. ampl. Static (mm)				Max. ampl. Foam (mm)			
	APeo	MLeo	APec	MLec	APeo	MLeo	APec	MLec
Mean*	15.63	13.37	19.28	14.77	27.09	25.88	48.94	38.40
Minimum	9.70	7.00	11.40	7.90	13.90	13.50	26.00	23.70
Maximum	27.40	23.10	32.20	23.60	41.40	43.00	68.70	62.50
***p-value**	0.033		<0.0001		0.422		<0.0001	

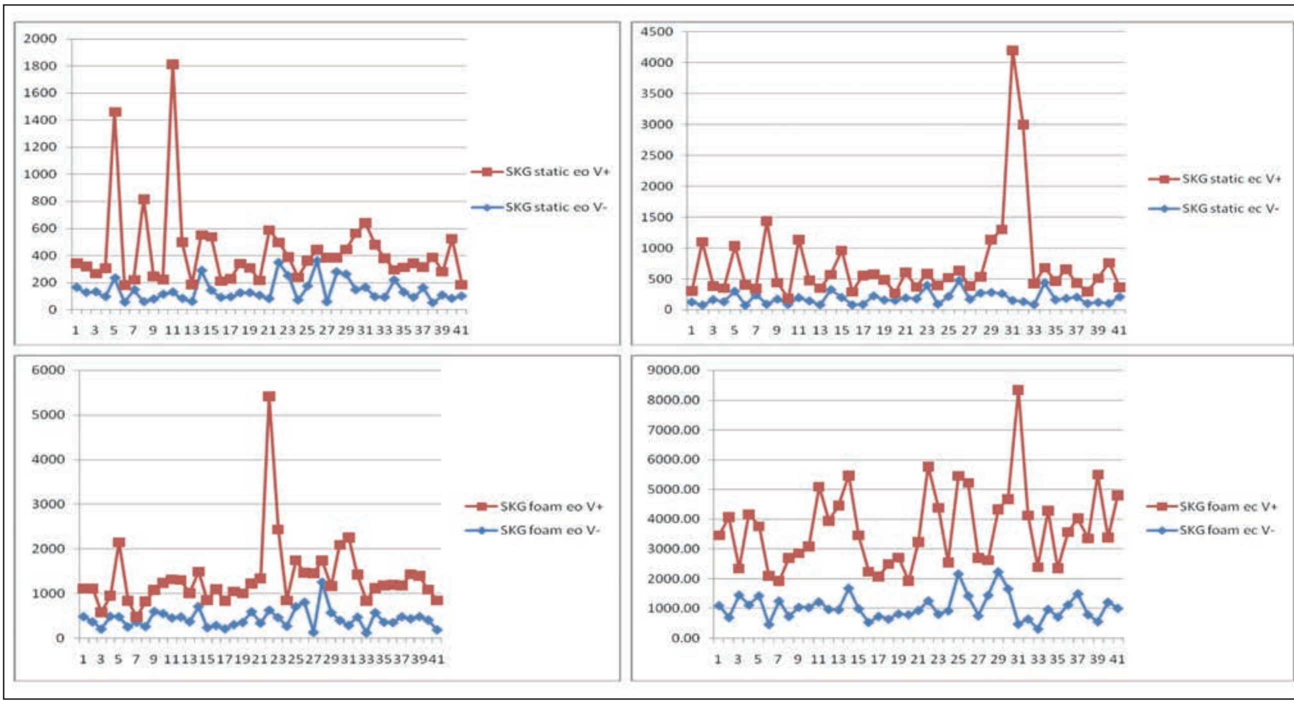
Table 4
Statistic comparison between AP and ML displacement

Condition	AP eo	AP ec	ML eo	ML ec
Static	15.63	19.28	13.37	14.77
Foam	27.09*	48.94*	25.88^	38.4^
p-value	<0.0001	<0.0001	<0.0001	<0.0001

alpha = 0.05; *p<0.0001; ^ p<0.0001
AP eo – antero-posterior eyes open; AP ec – antero-posterior eyes closed;
ML eo – medio-lateral eyes open; ML ec – medio-lateral eyes closed

Table 5
Statistical analysis of statokinesigram and Romberg's quotient values between the two groups

	Condition	Eyes	Control group		Patients group		p- value
			Mean	Std. dev.	Mean	Std. dev.	
Area (mm²)	Static	Open	139.98 (49.83-359.51)	79.16	192.62 (72.71-1686.14)	308.40	0.002
		Closed	183.35 (71.16-475.09)	97.67	546.13 (94.93-4052.18)	740.60	<0.0001
	Foam	Open	436.41 (121.65-1261.45)	207.46	911.57 (115.26-4782.95)	733.97	<0.0001
		Closed	1042.11 (314.52-2238)	425.45	2655.34 (668.49-7872.34)	1294.47	<0.0001
Romberg's quotient	Static		148.61 (51-311)	59.98	195.78 (28-850)	168.78	0.373
	Foam		266.54 (115-703)	123.03	340.34 (94-663)	140.91	0.007



Graph 3. The graphic representation of the distribution of the statokinesigram values on static platform and foam rubber in the eyes open and eyes closed conditions (comparison between the two groups).

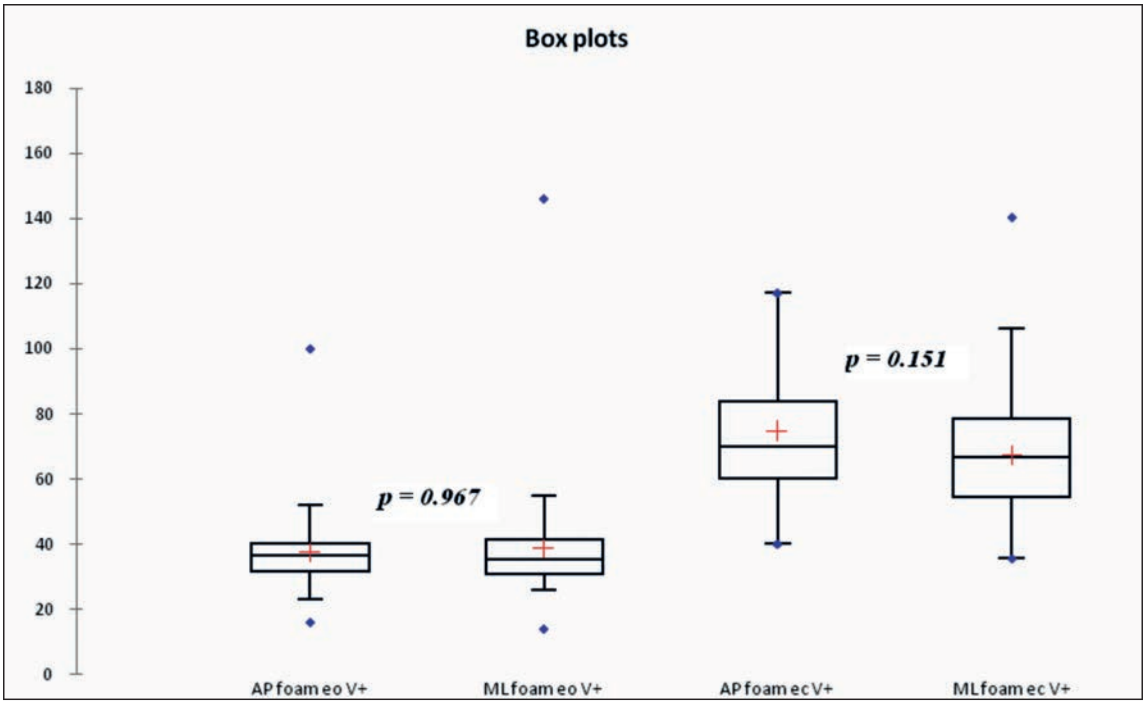
Going further and analysing the RQ, its values on the static platform did not give us conclusive information for differentiating patients with peripheral vestibular disorders from those included in the control group (p=0.373). On foam rubber, on the other hand, there was a statistically significant difference, p-value=0.007, between RQ values of vestibular patients and normal subjects (Table 5).

The measurements of the displacement of the centre of pressure in AP and ML plane revealed statistically significant differences between the two study groups on both foam and static platform (Table 6). Evaluating the data obtained in the peripheral vestibulopathy group, these emphasized the importance of foam posturography in identifying patients with peripheral vestibular dysfunction (p-value<0.0001). Comparing the AP and ML displacement degree, there was a greater deviation in the AP plane, but with no statistical difference between the two planes on foam in both eyes open (p=0.967) and eyes closed (p=0.151) conditions (Graph 4).

Table 6
Statistical analysis of the difference of the maximum deviation of the centre of pressure in the AP and ML planes between the two groups

Max. ampl. (mm)	Condition	Control group	Patients groups	p-value
Static	AP eo	15.63 (9.70-27.40)	21.26 (12.20-55.60)	0.000
	AP ec	19.28 (11.40-32.20)	31.82 (13.30-96.30)	<0.0001
	ML eo	13.37 (7.00-23.10)	18.29 (9.00-42.00)	0.001
	ML ec	14.77 (7.90-23.60)	24.79 (11.30-93.40)	<0.0001
Foam	AP eo	27.09 (13.90-41.40)	37.66 (15.90-99.80)	<0.0001
	AP ec	48.94 (26.00-68.70)	74.53 (40.10-117.20)	<0.0001
	ML eo	25.88 (13.50-43.00)	38.83 (13.80-146.10)	<0.0001
	ML ec	38.40 (23.70-62.50)	67.36 (35.60-140.30)	<0.0001

p<0.0001
AP eo – antero-posterior eyes open; AP ec – antero-posterior eyes closed;
ML eo – medio-lateral eyes open; ML ec – medio-lateral eyes closed



Graph 4. Antero-posterior and medio-lateral displacement degree on foam in both eyes open and eyes closed conditions.

In all evaluated parameters, a statistically significant difference was found between the two groups on both static platform and foam rubber. The Romberg's quotient was the only parameter that had comparable results for both groups on static platform (p=0.373), but with significant differences on foam (p=0.007).

Also, even if the displacement in the AP and ML plane presented an overall significant difference between groups and between static platform and foam in eyes open and eyes closed conditions, the difference between the two oscillations planes was not significant on foam.

Considering the results which showed that foam posturography, and especially the condition "foam - eyes closed", is the most important in identifying those patients with peripheral vestibular dysfunction, we evaluated the sensitivity and specificity of the parameters for the conditions taken into consideration. For that, we evaluated the receiver operating characteristics (ROC) curves to compare sensitivity and specificity for the parameters ability to predict the existence of the peripheral vestibular dysfunction. Important for the accuracy of the test is the area under the curve (AUC); this is normally between 0.5 and 1.0.

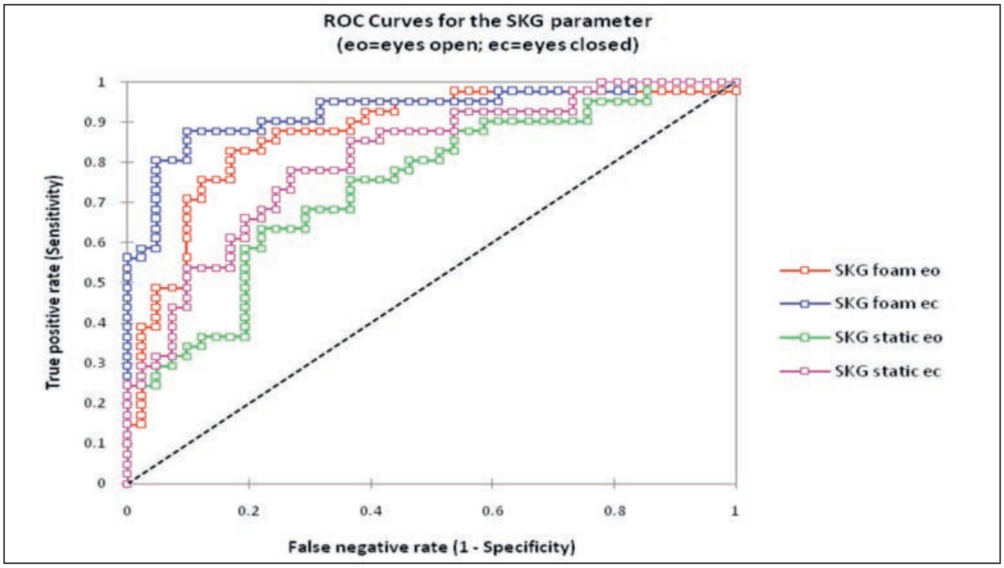
Evaluating the importance of the statokinesigram in identifying patients with peripheral vestibular deficit, the test registered on foam with eyes closed proved to have 87.8% sensitivity and 90.2% specificity. The overall specificity was between 73.2 and 90.2%, and the sensitivity between 63.4 and 87.8%. The AUC on both static platform and foam was greater than 0.5 with a p-value<0.0001, these results sustaining the hypothesis that the statokinesigram can discriminate between abnormal patients and normal controls, the most important being the "foam-eyes closed" condition (Graph 5).

The overall specificity of Romberg's quotient in identifying patients with vestibular dysfunction proved to be between 61% and 85.4%, while the sensibility was evaluated between 46.3 - 63.4%. Evaluating the ROC curves on both foam and static platform (Graph 6), the AUC on foam was of 0.674 with a p-value equal to 0.003, while on the firm surface AUC=0.557, p=0.372. Considering the results, we can say that Romberg's quotient on static platform is not reliable in identifying patients with peripheral vestibular deficit.

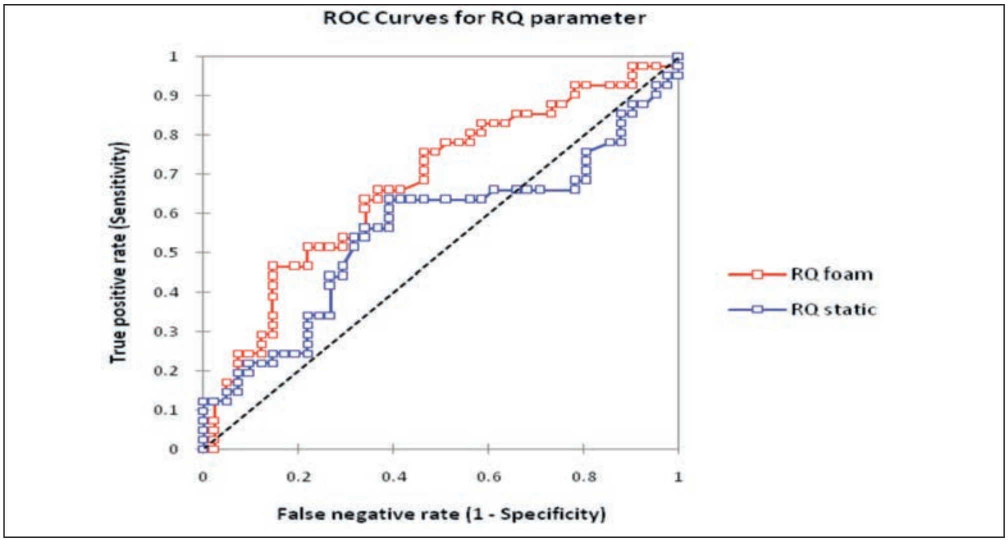
In what the displacement of the centre of pressure in the AP and ML plane is concerned, this parameter presented an overall specificity between 48.8% and 82.9%, a sensibility of 61 to 90.2% on firm surface, respectively 78 - 87.8% specificity and 70.7 – 85.4% sensitivity on foam rubber. With an AUC value greater than 0.5 (Graph 7) and a small p-value (<0.0001), the parameter can be used with success to diagnose patients with peripheral vestibular dysfunction.

DISCUSSIONS

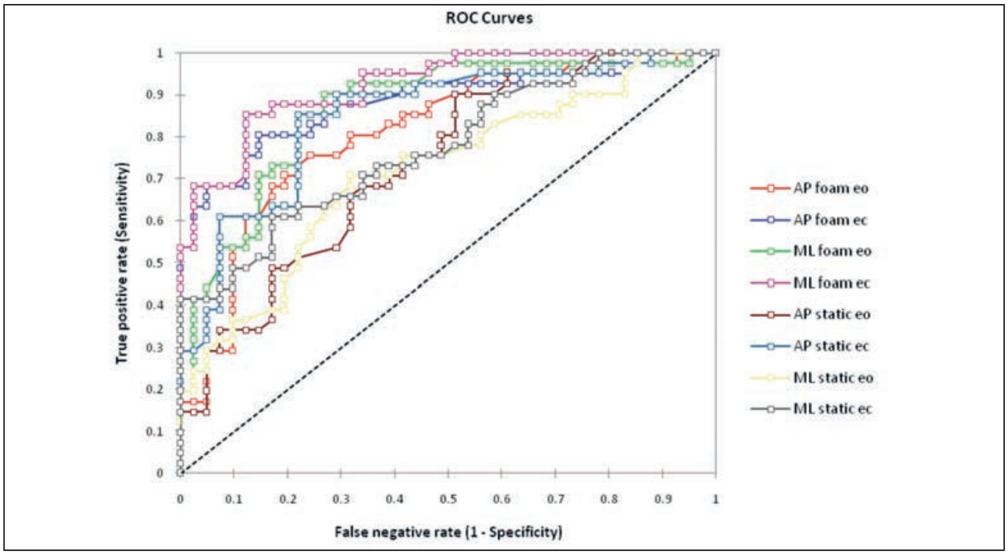
Despite all data that can be found in the literature and despite the fact that increases in body sway while standing on a moving or foam platform with eyes closed seems to be specific for the vestibular dysfunction, the role of foam posturography in clinic diagnosis of peripheral vestibulopathy is still controversial[12,14].



Graph 5. ROC curve evaluation for the statokinesigram parameter.



Graph 6. ROC curve representation for Romberg's quotient on both static surface and foam rubber.



Graph 7. ROC curves representation for the maximum deviation of the centre of pressure in the AP and ML plane, on both foam and static platform (eo – eyes open, ec – eyes closed).

It has been shown that there can be a large variance in normal subjects' measurements on both static platform and foam rubber. Also, in our study, the normal and abnormal results overlapped. Regardless of this fact, we demonstrated that the "trusted" area in case of the SKG proved to be larger in the case of vestibular patients group. The difference between the two groups was greater in the "foam-eyes closed" condition. The same observations were reported by Celebisoy et al. in a study published in 2013[14]. Fujimoto et al, in a study from 2009 and one published in 2012, showed that the velocity of the movement of the COP and the area traced by the movements of the COP in eyes closed/foam rubber condition were significantly higher in the patients group compared to controls (p<0.001)[4,15].

From the statokinesigram point of view, and as other studies demonstrated and our study also sustains, the degree of the displacement of the COP in the AP plan is greater than in the ML plane[4,15]. The variation was higher on foam, with a larger displacement in the AP plane in both eyes open and eyes closed conditions. There are also studies that show no significant difference of the shift recorded in the patients group compared to healthy controls[14].

Fujimoto, in his study published in 2009, demonstrated a RQ on foam significantly higher in peripheral vestibulopathy patients compared to controls[4]. The same results were found in our study (p-value on foam = 0.007, p-value on static platform = 0.373).

Analysing the diagnosis utility of foam posturography in the peripheral vestibular dysfunction, there are studies reporting promising results, with more than 50% sensitivity and specificity in case of the statokinesigram[10,14,16,17]. In our study, the successive positions of the centre of pressure on foam platform presented more than 80% sensitivity and specificity, the values being higher in the eyes closed condition (87.8% sensitivity and 90.2% specificity).

Analysing the overall sensitivity and specificity of both static and dynamic posturography, these tests proved to be about 50% sensitive and specific[16,17].

Considering the sensory organisation test, performed on both firm surface and foam rubber, it proved to have 15-63% sensitivity and 34-95% specificity in diagnosing patients with peripheral vestibular dysfunction[18-23]. Hamid et al, for example, report a sensitivity for the posturography of almost 95%[20].

Romberg's quotient was reported by several authors to have a sensitivity of 79% and specificity of 80%[4,10,14]. In our case, those patients with peripheral vestibular dysfunction presented difficulties in maintaining their postural balance on foam, the RQ in this case having a specificity of 85.4%.

Evaluating all parameters which have been taken into consideration in our study, we can conclude that the measurements results were greater on foam in eyes closed conditions, these sustaining the visual dependency present in patients with peripheral vestibular disorders.

CONCLUSIONS

Foam posturography can be useful as a preliminary test in identifying patients with peripheral vestibulopathy. Romberg's quotient and the statokinesigram proved to be suitable parameters for assessing patients with vestibular deficit.

We found the foam – eyes closed condition to be the most reliable test for the diagnosis of peripheral vestibular dysfunction, considering the high level of visual dependency these patients have.

But we have to mention that foam posturography has to be correlated and associated with other tests for the evaluation of the vestibular function, because it cannot directly evaluate the function of each vestibular organ.

Conflict of interest: The authors have no conflict of interest.

Contribution of authors: All authors have equally contributed to this work.

REFERENCES

1. El-Kashlan H.K., Handelsman J.A. - Computerized vestibular testing. In: Weber P.C. (ed.) - Vertigo and disequilibrium: a practical guide to diagnosis and management. Thieme, New York, 2008;p.4-14.
2. McPherson D.L., Whitaker S.R., Wrobel B.B. - DDX: Disequilibrium of Aging. In: Goebel J.A. (ed.) - Practical management of the dizzy patient, 2nd edn. Lippincott Williams & Wilkins, Philadelphia, 2008;p.297-343.
3. Massion J., Woollacott M.H. - Posture and equilibrium. In: Bronstein A.M., Brandt T., Woollacott M.H., Nutt J.G. (eds.) - Clinical disorders of balance, posture and gait. London, Arnold, 2004;p.1-19.
4. Fujimoto C., Murofushi T., Chihara Y., Ushio M., Sugasawa K., Yamaguchi T., Yamasoba T., Iwasaki S. - Assessment of diagnostic accuracy of foam posturography for peripheral vestibular disorders: Analysis of parameters related to visual and somatosensory dependence. Clin Neurophysiol., 2009;120(7):1408-1414. doi: 10.1016/j.clinph.2009.05.002.
5. Nashner L.M. - Computerized dynamic posturography. In: Goebel J.A. (ed.) - Practical management of the dizzy patient, 2nd edn. Lippincott Williams & Wilkins, Philadelphia, 2008;p.153-182.
6. Furman J.M.R., Baloh R.W., Barin K., Hain T.C., Herdman S., Horst R.K., et al. - Assessment posturography. Report of the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology. Neurology, 1993;43(6):1261-1264.
7. Kuo A.D., Speers R.A., Peterka R.J., Horak F.B. - Effect of altered sensory conditions on multivariate descriptors of human postural sway. Exp Brain Res., 1998;122(2):185-195.
8. Peterka R.J. - Sensorimotor integration in human postural control. J Neurophysiol., 2002;88(3):1097-1118.
9. Visser J.E., Carpenter M.G., van der Kooij H., Bloem B.R. - The clinical utility of posturography. Clin Neurophysiol., 2008;119(11):2424-2436.

10. Di Fabio R.P. - Sensitivity and Specificity of Platform Posturography for Identifying Patients with Vestibular Dysfunction. Phys Ther., 1995;75:290-305.
11. Allum J.H., Adkin A.L., Carpenter M.G., Held-Ziolkowska M., Honegger F., Pierchala K. - Trunk sway measures of postural stability during clinical balance tests: effects of a unilateral vestibular deficit. Gait Posture, 2001;14:227-237.
12. Baloh R.W., Jacobson K.M., Beykirch K., Honrubia V. - Static and dynamic posturography in patients with vestibular and cerebellar lesions. Arch Neurol., 1998;55:649-654.
13. Black F.O., Wall C., Nashner L.M. - Effects of visual and support surface orientation references upon postural control in vestibular deficient subjects. Acta Otolaryngol., 1983;95:199-210.
14. Celebisoy N., Karapolat H., Gulluoglu H., Celebisoy M., Kose T. - Foam posturography: a cheaper way to analyze postural stability in peripheral vestibular disorders. Int Adv Otol., 2013;9(1):89-95.
15. Fujimoto C., Murofushi T., Sugasawa K., Chihara Y., Ushio M., Yamasoba T., Iwasaki S. -Assessment of postural stability using foam posturography at the chronic stage after acute unilateral peripheral vestibular dysfunction. Otol Neurotol., 2012;33(3):432-436. doi: 10.1097/MAO.0b013e3182487f48.
16. Di Fabio R.P. - Meta-analysis of sensitivity and specificity of platform posturography. Arch Otolaryngol Head Neck Surg., 1996;122:150-156.
17. Norre M.E., Forrez G., Beckers A. - Posturographic findings in two common peripheral vestibular disorders. J Otolaryngol., 1987;16:340-344.
18. Stockwell C.W. - Vestibular function testing: 4-year update. In: Cummings C. (ed.) - Otolaryngology Head and Neck Surgery: Update II. Mosby-Yearbook, Chicago, Ill, 1990;p.39-53.
19. Voorhees R.L. - The role of dynamic posturography in neurotologic diagnosis. Laryngoscope, 1989;99:995-1001.
20. Hamid M.A., Hughes G.B., Kinney S.E. - Specificity and sensitivity of dynamic posturography: A retrospective analysis. Acta Otolaryngol Suppl (Stockh), 1991;481:596-600.
21. Asai M., Watanabe Y., Ohashi N., Mizukoshi K. - Evaluation of vestibular function by dynamic posturography and other equilibrium examinations. Acta Otolaryngol Suppl (Stockh), 1993;504:120-124.
22. Keim R.J. - Clinical comparisons of posturography and electronystagmography. Laryngoscope, 1993;103:713-716.
23. Parker S.W. - Vestibular evaluation: Electronystagmography, rotational testing, and posturography. Clin Electroencephalogr., 1993;24:151-159.