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Exercise with visual feedback improves postural stability after vestibular schwannoma surgery

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Abstract We analyzed the effect of 2-week individualized visual feedback-based balance training on the postural control of patients undergoing retrosigmoid microsurgical removal of vestibular schwannoma. We performed prospective evaluation of 17 patients allocated into two groups: feedback group (9 patients, mean age 37 years) and standard physiotherapy group (8 patients, mean age 44 years). Patients in both the groups were treated once per day by intensive rehabilitation from 5th to 14th postoperative day. Rehabilitation of patients in the feedback group was performed using the visual feedback and force platform. Results were evaluated on the beginning and at the end of rehabilitation program (e.g. 5th and 14th postoperative day). Outcome measures included posturography during quiet stance under four different conditions by the modified Clinical Test for Sensory Interaction of Balance. Body sway was evaluated from center of foot pressure. Compensation of Center of pressure (CoP) parameters in stance on firm surface was similar in the control and feedback groups. However, in stance on foam surface with eyes closed the patients from the feedback group were better compensated and CoP parameters differed significantly ($p < 0.05$). This prospective clinical study suggests that specific exercises with visual feedback improve vestibulospinal compensation in patients after vestibular schwannoma surgery and thus can improve their quality of life.

Keywords Vestibular schwannoma · Vestibular rehabilitation · Visual feedback · Center of pressure · Posturography · Quality of life

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Introduction

Vestibular schwannomas are benign, slowly growing tumors that arise from the Schwann cells of the superior or inferior vestibular nerves. Tumor growth may result in sensorineural hearing loss, tinnitus, instability and cranial nerves lesion. Continuous expansion may eventually lead to brain stem compression, hydrocephalus with intracranial hypertension and finally to death. Management options

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include observation, stereotactic radiosurgery and microsurgery.

Microsurgery is mainly indicated in large and growing tumors, tumors with annoying symptomatology (vertigo, tinnitus) and according to the patient′s preference. With improvement of microsurgical technique incidence of permanent complications decreased. Facial nerve dysfunction is rare and hearing preservation is possible in the significant proportion of cases [1, 2]. There is still risk of developing balance problems after the surgery, but most patients recover well. Vestibular compensation follows tumor removal and deafferentation. Different factors can influence speed and level of compensation as well. This process takes typically from weeks to months. In some patients it is never completed and resulting balance problems represent significant difficulties in daily activities affecting seriously their quality of life [3–5].

Human experiments have shown that central vestibular compensation of unilateral peripheral vestibular lesions can be improved by vestibular exercise [6]. Thus, evidence is available to support the use of vestibular rehabilitation after vestibular schwannoma surgery [7, 8]. Visual feedback represents a promising method of vestibular rehabilitation. However, there is a lack of data whether visual feedback-based balance training can improve the postural stability after vestibular schwannoma surgery. The aim of this study was to evaluate the effect of a 2-week individualized visual feedback rehabilitation exercise on the postural control in patients having undergone vestibular schwannoma surgical removal.

Patients and methods

In the period from January 2007 to July 2009 the 69 patients underwent vestibular schwannoma surgery at the Department of Otorhinolaryngology and Head and Neck Surgery, Faculty Hospital Motol, 1st Faculty of Medicine, Charles University, Prague. All the patients were operated by the same team of surgeons, using the retrosigmoid-transmeatal approach in the supine position. Microsurgical-endoscopy assisted techniques with intraoperative neuromonitoring were used. Radical removal of tumors was achieved in all cases. Section of both vestibular parts of 8th cranial nerve was performed even in the cases where continuity could be preserved.

As much as 17 (24.6%) out of 69 patients entered the study. Of these there were 13 men and 4 women, their age varied from 19 to 62 (mean age 40.5 years). There were three tumors in grade 2, five tumors in grade 3 and nine tumors in grade 4a. The indication for microsurgical removal of all small tumors (grade 2) was proven growth according to the repeated magnetic resonance imaging.

All the patients underwent examination of vestibular system before the surgery. Vestibular examination consisted of (1) clinical examination, (2) electronystagmography (spontaneous nystagmus, gaze directional test, saccades, smooth pursuit, caloric test and head shaking test), (3) subjective visual vertical and (4) posturography. The body sway during posturography was quantified by displacement of the Center of foot pressure (CoP) in the anterior–posterior (AP) and medio-lateral (ML) directions. Tested subjects stood on a commercial force platform (Balancemaster, Neurocom International, Inc., Clackamas, Oregon, USA). All the subjects were tested by the modified Clinical Test for Sensory Interaction of Balance consisting of four different conditions of quiet stance: stance on firm surface with eyes open (EO), stance on firm surface with eyes closed (EC), stance on foam surface with eyes open (FEO) and stance on firm surface with eyes closed (FEC) [9, 10]. The subject′s feet were positioned 15-cm apart. If the feet moved at any time during the test, they were repositioned and the test was repeated.

Prior to the surgery the patients were randomly assigned to one of the two rehabilitation groups (9 in the feedback group and 8 in the standard physiotherapy) (Table 1). All the patients with a proven preoperative vestibular loss, with central nervous system or other musculoskeletal system deficits were excluded from the study. The study was performed in accordance with the Helsinki Declaration. The study protocol was approved by the local ethical committee, and all patients gave their informed consent.

Rehabilitation program took place at the Department of Rehabilitation and Exercise Medicine, 2nd Faculty of Medicine, Faculty Hospital Motol, Charles University, Prague. Patients in both the groups were treated once per day by intensive rehabilitation, which started on 5th postoperative day. Standardized rehabilitation protocol was performed by the same experienced physiotherapist in all the patients. Participants in feedback group were treated by

Table 1 Patient and tumor characteristics of the two different groups of patients undergoing visual feedback (feedback group) and standard physiotherapy (control group) of vestibular rehabilitation after vestibular schwannoma surgery (feedback group and control group) shown as mean ± standard deviation (range)

	Feedback group	Control group
Age (years)	37 ± 10 (19–56)	44 ± 12 (26–62)
Tumor size (mm)	24 ± 5 (18–35)	27 ± 6 (18–37)
Tumor grade		
2	1	2
3	2	3
4a	4	5
Male	8	5
Female	1	3

rehabilitation using visual feedback (Balancemaster, Neurocom Internacional, Inc., Clackamas, Oregon, USA). During the training participants stood on a force platform and were instructed to shift their CoP represented by a cursor on a monitor screen in indicated directions. Various exercises were used to target different aspects of balance function, namely steadiness, symmetry and dynamic stability (e.g. a patient stood with feet shoulder-width apart with eyes open, looking at a monitor screen and shifting the body weight to place the cursor into targets marked on the monitor—Fig. 1). Patients in the control group received rehabilitation without feedback. The design of exercises was identical to the feedback group. Moreover, the patients in both groups received vestibular adaptation exercises designed to increase vestibulo-ocular gain. During these exercises patients performed horizontal and vertical head movements while maintaining visual fixation on a target placed either within arm′s length or across the room. The duration of each treatment was increased gradually—from 5 min to 40 min on the day of discharge, which was either the 14th or 15th postoperative day. During the hospital stay the patients were monitored each day for better compliance.

All patients after the surgery have undergone regular follow-up with clinical examination 1, 3, 6 and 12 months after the surgery. The control MRI scans were scheduled 3 and 12 months after the surgery and then annually. According to the MRI all patients remain in remission. Significant postoperative changes in the region of cerebellum among all the patients were not observed in both groups. As much as 16 out of 17 patients returned to their work activities including the professions that necessitate good balance function (e.g. policeman, woodcutter or actor) the remaining 1 patient was retired. All patients returned to their previous daily activities including the sports that necessitate good balance function (e.g. motorbiking, biking, skiing or climbing).

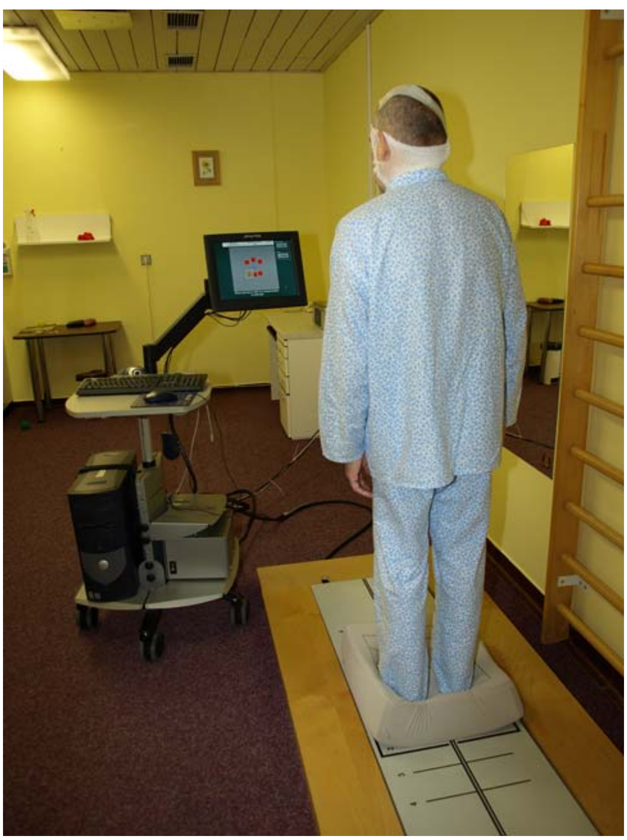

Fig. 1 Rehabilitation using visual feedback

The patients were examined before the surgery then on the beginning of the rehabilitation program (5th postoperative day) and on the day of discharge (14th postoperative day). The following CoP parameters were calculated during each trial: velocity of CoP in antero-posterior (V_{AP}) and medio-lateral (V_{ML}) directions as described by Prieto et al. [11]. Amplitudes of CoP in antero-posterior (A_{AP}) and medio-lateral (A_{ML}) directions, root mean square (RMS), line integral (LI) and total area (TA) were quantified from the CoP path as described by Hlavacka et al. [12]. Customized software MATLAB (The MathWorks, Inc., Natick, Massachusetts, USA) was used to quantify body sway. The CoP parameters were evaluated in eyes closed to eliminate the visual contribution and while standing on a foam surface to reduce the contribution of foot–ankle proprioception.

Statistical analysis

Since the sway data did not have a normal distribution, the Wilcoxon signed rank test (a nonparametric test analogous to the paired *t* test) was used to analyze this data. The level of confidence was $p < 0.05$.

Results

We evaluated six standard [11, 12] CoP parameters in the course of postoperative rehabilitation after vestibular schwannoma removal. We compared data of standard rehabilitation with visual feedback-based training. The two groups of patients did not differ in the mean age (feedback group: 37 ± 10 years; control group: 44 ± 12 years [mean ± SD]) or tumor size (feedback group: 24 ± 5 mm; control group: 27 ± 6 mm [mean ± SD]). However, their sex varied.

The analysis of the studied parameters in both groups before the rehabilitation training did not show any significant differences as tested on firm and foam surfaces with eyes closed, measured by all CoP parameters.

After the 2-week rehabilitation exercise compensation of CoP parameters in stance on firm surface with eyes closed was similar in control and feedback groups.

Table 2 Comparison of center of foot pressure (CoP) parameters during posturography in patients undergoing visual feedback rehabilitation (feedback group) and standard rehabilitation (control group), shown as mean ± standard deviation

CoP parameters	Feedback group	Control group	*p* values
A_{AP} (cm)	6.2 ± 4.3	8.6 ± 6.6	0.277
A_{ML} (cm)	6.2 ± 4.5	11.9 ± 4.7	0.021
V_{AP} (cm s^{-1})	13.3 ± 4.2	19.2 ± 4.1	0.008
V_{ML} (cm s^{-1})	5.7 ± 2.8	8.3 ± 1.4	0.059
LI (cm)	154.3 ± 56.8	224.9 ± 44.9	0.015
TA (cm^2)	133.3 ± 94.7	273.4 ± 73.2	0.011
RMS (cm)	2.6 ± 1.1	4.1 ± 0.75	0.027

Measured CoP parameters: velocity of CoP in antero-posterior (V_{AP}) and medio-lateral (V_{ML}) directions, amplitudes of CoP in antero-posterior (A_{AP}) and medio-lateral (A_{ML}) directions, root mean square (RMS), line integral (LI) and total area (TA) quantified from the CoP path

Significant differences of the studied parameters between the feedback and control groups were observed after 2-week rehabilitation exercises. Patients in the group of visual feedback-based rehabilitation program demonstrated significant difference in amplitude of CoP in medio-lateral direction ($p = 0.021$), velocity of CoP in anterio-posterior direction ($p = 0.008$), line integral ($p = 0.015$), total area ($p = 0.011$) and root mean square ($p = 0.027$) tested on foam surface with eyes closed (Table 2).

The assessment of stance on foam surface with eyes closed had proven better compensation in patients in the feedback group too (Figs. 2 and 3) and CoP parameters differed significantly.

Reviewing the results, we found statistically significant improvement in 5 out of 7 CoP parameters (A_{ML}, V_{AP}, LI, TA, RMS) during stance on foam surface with eyes closed after 10 day training period.

Discussion

In this prospective study, we compared results of two different strategies for early vestibular rehabilitation after vestibular schwannoma surgery (visual feedback rehabilitation and standard physiotherapy rehabilitation). This study showed that after 2 weeks of exercises subjects receiving visual-based rehabilitation treatment had better postural control than those receiving only rehabilitation without feedback.

Vestibular schwannoma resection induces several common complaints, such as hearing loss, tinnitus, facial nerve dysfunction, headache and balance problems [4, 13–15]. In the literature, the frequency and impact of these symptoms vary considerably, but the growing awareness of quality of life issues has drawn more attention to these postoperative problems [3]. Balance problems are most apparent in the acute stage after vestibular schwannoma surgery and usually improve gradually over time. Despite the trend for improvement of vestibular lesion, balance problems are reported by the majority of patients after vestibular schwannoma surgery and are associated with decreased quality of life. Some factors have been identified that may contribute to a poor recovery e.g. age and sex, central vestibular dysfunction, size of tumor, progressive and intermittent vestibular pathology, physical and psychological factors including orthopedic, neurological cardiovascular disorders, impairment of vision, anxiety and depression [3]. There is evidence available to support the use of vestibular rehabilitation after surgery for vestibular schwannoma [7, 8]. Vestibular rehabilitation is recommended for these patients during the acute postoperative period to speed up vestibular compensation. Rehabilitation using visual biofeedback for postural control can reduce sway during stance and improve postural control. There is a lack of knowledge of how visual feedback can speed up

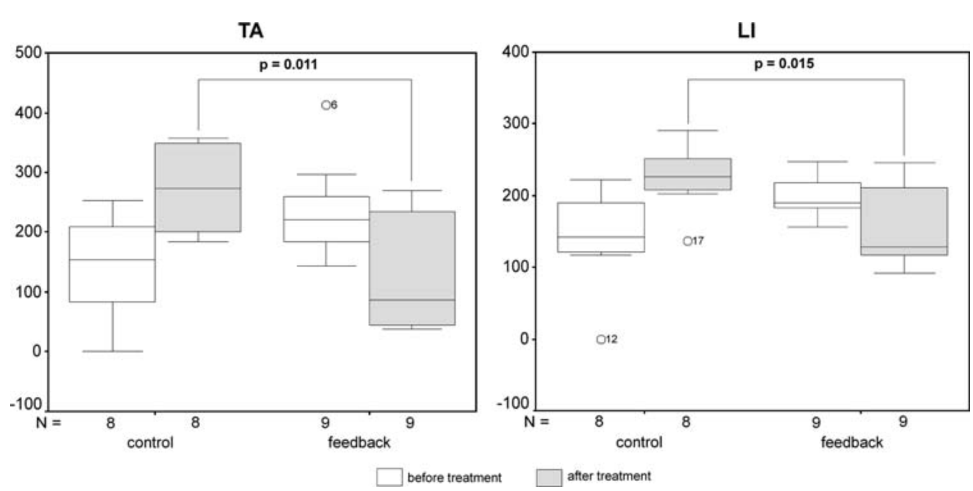

Fig. 2 Comparison of total area (TA) and line integral (LI) in patients undergoing visual feedback rehabilitation (feedback) and standard rehabilitation (control)

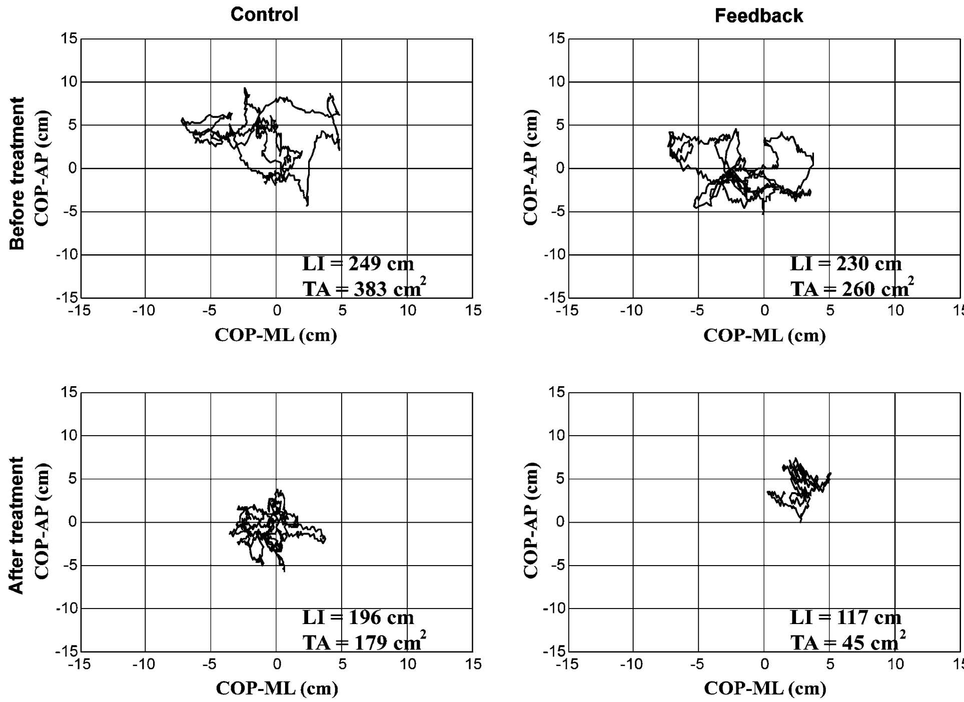

Fig. 3 Examples of typical statokinesiograms of subjects undergoing visual feedback rehabilitation (feedback) and standard rehabilitation (control)

improvement of the balance abilities of people after vestibular schwannoma surgery.

Originally, we assumed that subjects given visual feedback exercises would recover faster, as indicated by differences on the posturography measurements. Careful analyses of these data using appropriate statistical techniques provided support for that hypothesis.

As differences between the groups with respect to the degree of peripheral vestibular hypofunction resulting from the tumor, and central compensation prior to surgery would have complicated the interpretation of the results considerably only patients without proven preoperative vestibular loss enrolled the study. Other factors (e.g. central nervous system or other musculoskeletal system deficits) that could interfere with process of rehabilitation were used as an exclusion criterion, too. Thus the main limitation of our study is the relatively limited number of patients. Our two groups did not differ in the tumor size and preoperative vestibular function test. Furthermore, patients perceived the same amount of postural sway before surgery and no significant differences between preoperative posturography test results could be observed.

From the clinical point of view our findings strongly support empirical prescription of early vestibular rehabilitation after vestibular schwannoma surgery. The observed results of this study support employment of visual feedback exercises into the rehabilitation program in patients with a unilateral peripheral vestibular lesion. Based on the presented data, we recommend visual feedback for patients in acute stage after vestibular schwannoma surgery.

Conclusion

This prospective randomized clinical study suggests that specific exercises with visual biofeedback improve vestibulospinal compensation in patients after vestibular schwannoma microsurgical removal. As balance problems after surgical treatment represent significant factor affecting quality of life further studies to improve strategies for vestibular compensation in these patients are needed.

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