ORIGINAL ARTICLE

Vestibular compensation after vestibular schwannoma surgery: normalization of the subjective visual vertical and disability

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Abstract

Conclusions: The degree of caloric weakness before surgery influences faster or slower recovery of patients undergoing vestibular schwannoma surgery. The Dizziness Handicap Inventory (DHI) is a good index to show the recovery of patients as it relates directly to an improvement or not of the subjective visual vertical (SVV). Objective: To evaluate the process of recovery of patients as measured by the SVV and the DHI after surgical removal of vestibular schwannoma. Methods: We studied 24 consecutive patients of the University Hospital of Salamanca who underwent vestibular schwannoma surgery. We assessed age, tumour size, degree of canalicular weakness and preoperative SVV, and their relationship with DHI and SVV at discharge and also at 1, 3 and 6 months postoperatively. Results: Patients with lesser degrees of caloric weakness took longer to normalize SVV than those with a higher caloric weakness before surgery (p < 0.05). There was a significant correlation between DHI and improvements in SVV with time. The differences disappeared in 6 months where all patients, with greater or lesser degree of caloric weakness, had the same results.

Keywords: Vertigo, caloric test, videonystagmography, vestibular areflexia

Introduction

The perception of the subjective visual vertical (SVV) is the ability of a subject to judge whether an object is correctly located on the vertical axis. The participation of different vestibular receptors in this task is a matter of debate; however, vestibular lesions influence gravity perception mostly via ocular torsional effects rather than by disrupting any internal representation of verticality, thus SVV inclines towards the lesioned side [1]. There is a very close relationship between the torsional eye position measurements and the SVV tilts in patients with vestibular disorders, and in those patients with large tilts in the SVV the ability to correctly perceive verticality is maintained by other means [2].

After vestibular schwannoma (VS) surgery there is a tilt in the SVV towards the operated side in weak correlation with the preoperative amount of vestibular deficiency as registered with the caloric test [3]. In the follow-up the tilt returns to normal and may even deviate to the normal side [4]. In the short term, it is more intense in patients relying more on vision to control balance before surgery than in those who rely less; in both groups, the long-term results are similar [5]. They do not correlate with the amount of distressing unsteadiness or imbalance after surgery [6].

The Dizziness Handicap Inventory (DHI) is a standardized, validated 25-item questionnaire used to determine if subjects perceive a handicap due to dizziness, and its subscales reflect physical, emotional and social limitations [7].
The purpose of this study was to assess the results in the SVV test in patients with VS before and after surgery, and to analyze correlations with the DHI and caloric stimulation.

Material and methods

Subjects

The study evaluated 24 patients diagnosed with a unilateral VS who were prospectively scheduled for surgery between May 2008 and June 2010. All were subjected to retro-labyrinthine or translabyrinthine VS surgery and were reviewed at 1, 3 and 6 months postoperatively. The study was performed in accordance with the ethical guidelines of the 1975 Declaration of Helsinki. Patients with other pathologies that could directly affect postural control were excluded.

Auditory and vestibular evaluation

Audiometric findings were reported in terms of the pure-tone averages (PTA), calculated by taking the average of the readings at four frequencies (0.5, 1, 2 and 3 kHz).

In all the patients the head-impulse test (HIT) was performed before caloric testing. The physician stood in front of the patient and grasped the patient's head with both hands at a distance of approximately 30 cm. The patient was told to maintain eyes fixed on the examiner's nose. The head of the patient was slowly turned through 20° in the horizontal plane to the opposite side from that the physician wished to explore (i.e. to the left if the right side was being explored). The patient's head was then rapidly rotated to the other side, maintaining it in the horizontal plane. In normal conditions (healthy patients), the physician should observe that the patient is able to maintain the eyes fixed on the stationary target (the physician's nose) during the high-speed head rotation. When unilateral vestibular weakness exists, the eyes drift in the same direction as the head, and then compensatory refixation saccades are used to reset the visual fixation on the target. The test was repeated three times on each side and was considered as positive (pathological) when refixation saccades were observed in at least two of the three repetitions.

The Fitzgerald and Hallpike bithermal caloric test was used, in which eye movements were recorded by means of a video-based system (Ulmer VNG, v. 1.4, SYNAPSIS, Marseille, France). The maximum slow phase velocity (SPVmax) of nystagmus was calculated after each irrigation. The total response from each ear (TotE) was calculated, and caloric weakness (CW) and directional preponderance (DP) were determined according to Jongkees' formula.

Subjective visual vertical (SVV)

The SVV was examined using a custom-made faintly illuminated bar visible in the darkness; no other visual references were available during the test. The patient was sitting in a chair facing the bar with his/her head resting in such a manner that the Reid’s angle was horizontal. The bar was 1 meter in front of the patient and placed deviating from the vertical. The range of the baseline deviation of the SVV rod was displaced in all cases and varied between each test.

The patient was then asked to set the bar precisely in a vertical position with the use of a control module. The different pretest tilts of the bar were presented to the patient randomly in clockwise (CW) and counter-clockwise (CCW) directions. Once the patient considered the procedure was complete, the amount of tilt was measured and the result was positive if CW deviated and negative if CCW deviated. The SVV was determined from the average of four consecutive measurements with the patient starting from a random offset position. A tilt of more than 2° with regards to the true vertical position was considered pathological [8]. This test was performed before surgery, again on day the patient was discharged from the hospital, and 1, 3 and 6 months later.

Disability and handicap assessment

The DHI questionnaire was translated and adapted to the Spanish language following the method of cross-translation. The reliability of the scale was evaluated and the Cronbach alpha coefficient was 0.9226 [9]. The aim of the questionnaire was explained by the doctor, and the patient filled out the questionnaire. Where necessary, the technician in charge of the vestibular tests (who was well versed in the scope of the work and who had considerable experience in the vestibular laboratory) helped to clarify some items. The questionnaires were answered in a similar fashion to the original English version. In the DHI, the patient had to answer 'yes', 'sometimes' or 'no' to each question, the responses being given a value of 4, 2 and 0, respectively. The questionnaire has 25 items, so the total score (DHITS) ranged from 0 to 100. The questionnaire was completed on the same day as the SVV evaluation.

Statistical analysis

The statistical software program SPSS 12.0.1 for Windows was used to analyze the data; a p value of
<0.05 was considered to be statistically significant. Since the data were not normally distributed, non-parametric tests were used. We calculated frequencies, means and ranges for the variables studied. To record and analyse the relation between variables, contingency tables were used and the measure of association was done with the $\chi^2$ test. Spearman’s rank correlation coefficient (rho) was the non-parametric measure used to assess statistical dependence between variables.

Following radiological evaluation, patients were classified according to Koos et al. [10]: grade I when the tumour was in the internal auditory canal (IAC); grade II when the tumour was in the pontocerebellar angle (PCA) and <2 cm; grade III when the tumour was in the IAC and 2–4 cm; and grade IV if the tumour was in the IAC and >4 cm. According to canal paresis the patients were classified into three groups: group 1 or normal when canal paresis was <20%, group 2 or moderate if canal paresis was 21–70% and group 3 or severe if it was >71% [11].

**Results**

**Patients**

During the period of this study (May 2008 to June 2010), 24 patients were surgically treated: 15 women and 9 men, with a mean age of 48 ± 14 years. In 58%, the right side was affected. With regard to radiological evaluation 4 patients were classified as grade I, 11 patients as grade II, 5 as grade III and 4 as grade IV. Mean hearing level in the ear with the VS was $56 \pm 30$ dBHL. Mean canal paresis was $50 \pm 46\%$ (in the lesion side in all the patients) and the patients were classified into three groups: 7 patients in group 1 (0–20% canal paresis), 7 in group 2 (21–70% canal paresis) and 10 in group 3 (71–100% canal paresis). The head impulse test was correlated with the amount of canal paresis ($\chi^2$ test, $p = 0.002$). Mean SVV was $1.25 \pm 1^\circ$ and it was considered normal in 21/24 patients. Mean DHI was $18 \pm 10$. Age, sex and tumour side did not correlate with the mean canal paresis or with the mean SVV (Figure 1). The size of the tumour and canal paresis were positively correlated (Spearman rho = 0.47, $p = 0.022$).

**Post-treatment results**

Figures 2 and 3 show the results for the SVV and DHI during the post-surgical study period: at the time of hospital discharge (mean 12 ± 4 days), and 1, 3 and 6 months later. There was a good correlation between SVV and DHI results in each of the periods of assessment (Pearson, $p = 0.001$).

The amount of canal paresis before surgery was well correlated (Pearson, $p = 0.0001$) with a better result in the SVV test and DHI at post-surgery hospital discharge, and at 1- and 3-month follow-up. That
is, patients with a normal caloric test before surgery had worse results in SVV and DHI at 1 and 3 months after surgery, and patients with great caloric weakness had better results in SVV and DHI at 1 and 3 months after surgery. This correlation was not found in the 6-month post-surgery results. Patients with more caloric weakness had better results for SVV and DHI at the time of discharge and at 1- and 3-month follow-up.

Discussion

The main findings in our study are the high correlation between the caloric weakness before surgery and the SVV and DHI outcomes after surgery. The head impulse test correlated with the amount of canal paresis, as did the size of the tumour (patients with large tumours had higher canal paresis).

Balance is one of the most important aspects regarding VS. Preoperative unsteadiness is common and balance dysfunction is the most difficult aspect of recovery in 10% of patients. For this reason this aspect must be taken into account in patients with VS. There are many variables that may influence the recovery of patients after VS surgery as far as balance is concerned. Most of them have been studied accurately without reaching agreement on the main factors affecting recovery. As in other studies, we found no relationship between age or sex, or the affected side and period of time for recovery of the patients [7]. In this work we were interested in the follow-up of two measures of vestibular compensation: the SVV and the DHI.

Normal subjects are able to align an illuminated bar within ±2° of accuracy in darkness, but patients who have an acute unilateral peripheral vestibulopathy systematically tilt the bar towards the affected ear above that measure and, when compensation occurs, the results return to normal limits. This is because the subjective visual perception of the verticality of a line projected ahead is affected by the head and body position relative to gravity. In this case, the relative contribution of utricular and vertical canal afferents to the SVV is controversial.

In the present study we have shown that, before surgery, 87.5% of the patients displayed normal results for the SVV independently of the amount of canal paresis or tumour size, as has been shown by others when studying the subjective visual horizontal [12]. We have seen that they systematically tilt the bar to the side of the disease close to 2° before surgery. We believe that this finding reflects that compensation is proceeding to a normal extent in response to a deficient unilateral utricular nerve and function. This is expected, as in a recent study 75% of the patients with VS showed utricular dysfunction as measured with ocular vestibular evoked myogenic potentials [13].

Long-term post-surgical evaluation of the SVV in our patients has shown that the majority recovered to normal values set at ±2° in accordance with what

Figure 3. Dizziness Handicap Inventory (DHI) follow-up score. Results are given for patients according to results in canal paresis groups. Group 1, 0–20%; group 2, 21–70% and group 3, 71–100%, at visit 1 (1 week after surgery), visit 2 (1 month after surgery), visit 3 (3 months after surgery) and visit 4 (6 months after surgery).
others have obtained [3]. We consider that, for the follow-up of vestibular compensation in the ocular component of the disrupted vestibulo-ocular reflex, this is of great value as others have shown in the case of vestibular neurectomy for Meniere’s disease [14] or VS [3,15].

The importance of SVV relies on its sensitivity to the behavioural component of the compensation process as shown by the visit-to-visit modification that shows close similarity between SVV and DHI. It would be interesting to analyse in detail whether or not visual dependence modifies this close similarity as expected by findings in dynamic SVV [15] or dynamic visual acuity [16].

Regarding the DHI, there is a close similarity between our results and those reported by Uehara et al. [17]. In both studies the amount of disequilibrium at hospital discharge is correlated with the degree of damage during surgery but also with the amount of canal paresis before treatment. In that sense patients with an important vestibular deficiency before surgery display a lower amount of disability or handicap in the immediate postoperative period. This was not the case when only the size of the tumour was taken into account, which confirms the importance of preoperative vestibular evaluation in these patients. This confirms the importance in the treatment of these patients of pretreatment before surgery with intratympanic gentamicin; in that way post-surgical rehabilitation will be facilitated [18].

It is interesting to note that the results are not significantly different at the 6-month postoperative follow-up. This is probably related to the existence of different variables that influence recovery throughout that period and the exposure of the patient to very different environments in which all the sensory influences for equilibrium and previous experience cooperate to provide good visual stability [19].

As noted before, both measures behave in a parallel fashion throughout the period of follow-up [20]. At hospital discharge the perception of disability is very high as well as the degree of misalignment in the subjective vertical. With the passage of time, the patient returns to normality in both measures. In this way we can recommend the follow-up of the patient after surgery with assistance of the SVV analysis as the main objective measure, because it is easy to perform and the information is valuable. It would be interesting to address the issue of the relevant importance of utricles and vertical canals in these patients in a more detailed way, i.e. by placing the patient in a deviated position with regard to the earth-vertical axis [21].

Regarding the methodology, performing the study under binocular condition is not a limitation as it has been found that there were no significant differences in the tilts of the SVV between binocular and monocular measurements in VS patients [22].

**Declaration of interest:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

**References**


