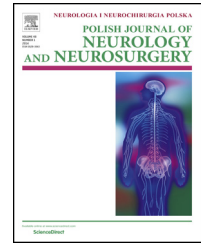


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Original research article

Surgery for sporadic vestibular schwannoma. Part IV. Predictive factors influencing facial nerve function after surgery



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ABSTRACT

Objective: To analyze the impact of various clinical, radiological and perioperative factors that could influence the facial nerve intraoperative disruption risk (CNVII-IDR) and its long-term function (CNVII-LTF) after vestibular schwannoma (VS) surgery.

Material and methods: The study included 212 patients operated on for sporadic VS with no history of previous treatment for VS or CNVII palsy. The mean size of the tumor was 30 mm. Gross (210) or near-total (2) resections were carried out using the retrosigmoid (210) or translabyrinthine (2) approach. Correlation studies and multivariate regression analysis (RA) were performed.

Results: In correlation studies, the CNVII-IDR was increased by: headaches and cerebellar ataxia if one of them was the first symptom of the tumor (33% and 29%, respectively, $p = 0.008$); preoperative hydrocephalus (40% vs. 9%, $p = 0.01$), tumor size >3 cm (18% vs. 5%, $p < 0.01$), tumor volume >10 cm³ (19% vs. 4%, $p < 0.01$), right-sided location 15% vs. 6%, $p = 0.047$, lateral “park-bench” position (19% vs. 5% for supine position, $p < 0.01$) and the procedure order (16% for the first 106 procedures vs. 6% for the last 106 procedures, $p < 0.05$). In RA the tumor volume ($p = 0.012$), side of the tumor ($p = 0.028$) and patient's position during surgery ($p = 0.016$) independently affected the CNVII-IDR. The following factors correlated significantly with satisfactory CNVII-LTF (HB grades I–III): tumor stage $<T4$ ($p = 0.000$), tumor size ≤ 3 cm ($p = 0.000$), tumor volume ≤ 10 cm³ ($p = 0.001$), and left-sided location ($p = 0.048$). Additional factors correlated significantly with very good CNVII-LTF (HB grades I–II): anterior CNVII displacement ($p = 0.044$), nimodipine use ($p = 0.016$), the absence of postoperative complications ($p = 0.019$), CNVII responsive on final intraoperative EMG stimulation ($p = 0.000$) and supine position during surgery ($p = 0.018$). However, an independent impact on very good CNVII-LTF proved to be the tumor size ($p = 0.0000$), side ($p = 0.0175$), and nimodipine use ($p = 0.0349$).

Conclusions: In our series, the factors related to size and side of the tumor confirmed an independent impact on CNVII-IDR and CNVII-LTF. The significance of patient positioning may reflect the impact of learning curve as only the first 91 patients were operated on using

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the lateral “park-bench” position. An independent impact on CNVII-LTF was exerted by the perioperative use of nimodipine.

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1. Introduction

The aim of the study was to analyze the impact of various clinical, radiological and perioperative factors that could influence the intraoperative facial nerve (CNVII) continuity preservation and long-term CNVII function after vestibular schwannoma surgery.

2. Material and methods

The characteristics of the study group is presented in the article titled “Surgery for sporadic vestibular schwannoma. Part I: General outcome and risk of tumor recurrence.” The following analyses excluded a patient who died after surgery, a patient with no follow-up data, and a patient with a history of prior hypoglossal-to-facial nerve anastomosis. In addition, the analyses excluded patients previously treated at different centers as the previous surgeries or radiosurgical procedures had been the cause of CNVII damage before the patients were admitted to our department. Overall, the following analyses were conducted on a group of 212 patients. The mean extrameatal diameter of the tumor was 30 mm. With the retrosigmoid (210) or translabyrinthine (2) approach, gross (210) or near-total (2) resections were carried out.

The long-term results of CNVII function were evaluated on the last follow-up visit at least 6 months after surgery. The House-Brackmann grades I–III were defined as satisfactory facial nerve function whereas grades IV–VI as unsatisfactory. Grades I–II were considered as very good results.

Statistical analyses were performed to identify factors affecting intraoperative preservation of CNVII continuity as well as long-term CNVII function after surgery. Correlation studies and multivariate regression analysis were performed on factors that might possibly impact the preservation of CNVII continuity during surgery. Factors taken into consideration included age, gender, surgical sequence, first tumor symptom, symptom triggering diagnostic examinations; independent examinations included preoperative symptoms (cerebellar symptoms, trigeminal symptoms, CNVII paresis, headaches and hydrocephalus), preoperative hearing according to AAO-HNS grading scale, symptom duration, tumor size (maximum extrameatal size, volume, tumor stage according to the Samii grading scale), side of the tumor (left/right), tumor structure (solid/cystic) and histological type (Antoni A, B and A + B), internal auditory canal (IAC) widening (+/–), the patient's position during the procedure (lateral “park-bench”/supine), approach (RSA/TLA) and CNVII displacement pattern (anterior/antero-medial/antero-lateral).

The analysis of long-term functional outcome included correlations with similar factors. Additionally, three factors were examined for possible influence on long-term CNVII function: (1) final EMG CNVII stimulation response, (2)

postoperative complications, (3) perioperative nimodipine administration. Postoperative complications were defined in the same manner as in the article titled: “Surgery for sporadic vestibular schwannoma. Part II. Complications (not related to facial and auditory nerves)”.

For the purpose of this study, the CNVII anastomosis results were not taken into account in the long-term functional assessment, i.e., the CNVII function was still considered as HB grade VI when the facial nerve continuity was not preserved intraoperatively, even if a satisfactory result of CNVII anastomosis was achieved.

2.1. Statistical methods

Descriptive statistics including numerical and percentage incidence, means and standard deviations were used. The results distributions were compared using chi-square test or Fischer's exact test. The significance of inter-group differences was determined by means of Mann–Whitney's *U*-test or Student's *t*-test for independent samples. Co-occurrence of variables was determined using Pearson's *r* or Spearman's rho correlation coefficients. Dependent variable predictors were assessed by Wald's stepwise logistic regression or enter methods. The lowest assumed significance level was $p < 0.05$. The analyses were carried out using SPSS 18 PL software.

3. Results

3.1. Factors impacting the risk of intraoperative CNVII disruption

3.1.1. Correlation analysis

As shown by the analysis of the first symptoms of the disease, an intraoperative CNVII disruption was more common when the first symptom was a headache or cerebellar ataxia. In these cases, intraoperative CNVII continuity loss rates were 33% and 29%, respectively. For comparison, when the disease was first manifested by symptoms related to CNVIII, the continuity loss rate was 8% ($p = 0.008$, Table 1).

The analysis of symptoms leading to diagnostic examination for vestibular schwannoma revealed no significant differences in CNVII preservation rates (Table 1). Examination of other clinical factors revealed no significant correlations between preservation of CNVII continuity and the patient's age or gender (Table 2). The symptom duration, cerebellar symptoms, trigeminal nerve symptoms, hearing class according to AAO-HNS scale, CNVII weakness or headaches as reported on admission did not significantly correlate with CNVII continuity preservation. Preoperative hydrocephalus was the only preoperative symptom that significantly correlated with CNVII disruption (40% vs. 9%, $p = 0.014$, Table 2).

The effect of the procedure order: the facial nerve was not preserved in 16% of the patients in the series of the first 106

Table 1 – Correlations of the first signs of the tumor and symptoms triggering the diagnostics with CNVII anatomical continuity preservation and the long term CNVII function. Pearson's Chi-square test.

	CNVII anatomical continuity		p
	Not preserved	Preserved	
The first symptom of the tumor			
CNVIII-related symptoms	14 (8.0%)	161 (92.0%)	p = 0.008
Headaches	6 (33.3%)	12 (66.7%)	
Cerebellar symptoms	2 (28.6%)	5 (71.4%)	
CNV-related symptoms	1 (14.3%)	6 (85.7%)	
	CNVII anatomical continuity		p
	Not preserved	Preserved	
The symptom triggering diagnostics			
CNVIII-related symptoms	11 (8.1%)	125 (91.9%)	p = 0.480
Cerebellar symptoms	6 (18.2%)	27 (81.8%)	
CNV-related symptoms	2 (11.8%)	15 (88.2%)	
Headaches	2 (16.7%)	10 (83.3%)	
	CNVII function in long term follow-up		p
	I-III HB	IV-VI HB	
The first symptom of the tumor			
CNVIII-related symptoms	141 (80.6%)	34 (19.4%)	p = 0.070
Headaches	11 (61.1%)	7 (38.9%)	
Cerebellar symptoms	3 (42.9%)	4 (57.1%)	
CNV-related symptoms	5 (71.4%)	2 (28.6%)	
	CNVII function in long term follow-up		p
	I-III HB	IV-VI HB	
The symptom triggering diagnostics			
CNVIII-related symptoms	109 (80.1%)	27 (19.9%)	p = 0.706
Cerebellar symptoms	25 (75.8%)	8 (24.2%)	
Headaches	8 (66.7%)	4 (33.3%)	
CNV-related symptoms	12 (70.6%)	5 (29.4%)	

procedures as compared to 6% in the last 106 procedures ($p < 0.05$). No statistically significant relationships were identified between preservation of CNVII continuity and the following tumor-related factors: tumor structure (solid vs. cyst-like), IAC width (dilated vs. not dilated), histological type (Antoni A vs. Antoni B vs. Antoni A + B). Facial nerve disruptions were more common in right-sided tumors (15% vs. 6%, $p = 0.047$). The most important factors were those related to tumor size. When the tumor diameter was larger than 30 mm, the risk of CNVII disruption was 18% as compared to 5% in case of tumors with diameters of ≤ 30 mm ($p < 0.01$). Likewise, the risk of CNVII disruption in case of tumors with volumes larger than 10 cm^3 was 19% as compared to 4% for smaller tumors ($p < 0.01$). The facial nerve was not preserved in 14% of patients with T4 tumors as compared to only 3% of patients with T2-T3 tumors ($p = 0.072$). The rate of intraoperative CNVII continuity loss was 19% for surgeries performed in lateral park-bench position and 5% for supine position with head rotated to the side. The difference was significant ($p < 0.01$). The three most common directions of CNVII displacement due to tumor growth, i.e., anterior, anteromedial and anterolateral directions, showed no statistically significant differences in correlations with maintained continuity of the CNVII. However, disruption occurred most often when the facial nerve was dislocated in the anterolateral direction (13%) (Table 2). The anatomical continuity could not be preserved in three cases where the facial nerve was

engulfed by the tumor. In one case of a giant tumor, the CNVII could not be identified by any means.

3.1.2. Multivariate regression analysis

Multivariate regression analysis revealed that the risk of intraoperative CNVII disruption was independently affected by tumor volume ($p = 0.012$), side of the tumor ($p = 0.028$) and patient's position during the procedure ($p = 0.016$; Table 7). Larger tumor volumes, right-sided location and lateral park-bench position increased the risk of CNVII disruption. For instance, the rate of CNVII disruptions in the group of patients with right-sided tumors larger than 30 mm, undergoing surgery in the lateral park-bench position, was as high as 35% (9/26 patients). By contrast, no CNVII disruptions were observed in patients with a combination of the opposite factors (supine position, left-sided tumor and size ≤ 30 mm, 0/44 patients).

3.2. Factors influencing the long-term postoperative CNVII function

3.2.1. Correlation analysis for satisfactory (HB grades I-III) CNVII function

Satisfactory CNVII function at long-term follow-up was observed most often when the first tumor symptoms were related to the vestibulocochlear nerve (81%) and least often in case of cerebellar symptoms occurring as the first symptom

Table 2 – Correlations of various factors with CNVII continuity preservation. Pearson's Chi-square or Fisher's exact test.

Factor	CNVII anatomical continuity		p
	Preserved	Not preserved	
Sex			
F	116 (90%)	13 (10%)	p – NS
M	73 (88%)	10 (12%)	
Age			
≤50 y.o.	107 (88%)	14 (12%)	p – NS
>50 y.o.	82 (80%)	9 (10%)	
Surgery sequence			
1-106	89 (84%)	17 (16%)	p < 0.05
107-112	100 (94%)	6 (6%)	
Cerebellar symptoms			
/-/	144 (92%)	13 (8%)	p – NS
/+/	45 (82%)	10 (18%)	
CNV-related symptoms			
/-/	136 (89%)	16 (11%)	p – NS
/+/	53 (88%)	7 (12%)	
Headache			
/-/	165 (91%)	17 (9%)	p – NS
/+/	24 (80%)	6 (20%)	
Hydrocephalus			
/-/	183 (91%)	19 (9%)	p = 0.014
/+/	6 (60%)	4 (40%)	
Hearing acc. to AAO-HNS scale			
Class A-C	48 (94%)	3 (6%)	p – NS
Class D	141 (88%)	20 (12%)	
CNVII weakness before surgery			
HB grade I	162 (91%)	17 (9%)	p – NS
HB grades II-VI	27 (82%)	6 (18%)	
Symptomatic period duration			
≤24 months	102 (89%)	12 (11%)	p – NS
>24 months	87 (89%)	11 (11%)	
Tumor stage acc. to Samii scale			
T2-T3	59 (97%)	2 (6%)	p = 0.072
T4	130 (86%)	21 (14%)	
Maximal extrameatal tumor size			
≤30 mm	112 (95%)	6 (5%)	p < 0.01
>30 mm	77 (82%)	17 (18%)	
Tumor volume			
≤10 cm ³	106 (96%)	4 (4%)	p < 0.01
>10 cm ³	83 (81%)	19 (19%)	
Tumor structure			
Solid	161 (90%)	18 (10%)	p – NS
Cystic	28 (85%)	5 (15%)	
Side of the tumor			
Right	88 (85%)	16 (15%)	p = 0.047
Left	101 (94%)	7 (6%)	
Widening of IAC			
/-/	24 (96%)	1 (4%)	p – NS
/+/	165 (88%)	22 (12%)	
CNVII displacement pattern			
Anterior	89 (92%)	8 (8%)	p – NS
Antero-medial	60 (92%)	5 (8%)	
Antero-lateral	39 (87%)	6 (13%)	
Histology pattern (Antoni)			
A	56 (89%)	7 (11%)	p – NS
B	23 (82%)	5 (18%)	
A + B	110 (91%)	11 (9%)	
Patient's position during surgery			
Lateral	74 (81%)	17 (19%)	p = 0.003
Supine	115 (95%)	6 (5%)	

Table 3 – Correlations for CNVII function in long-term follow-up. Independent samples t-test.

Factor	CNVII function	Number	Mean	SD	p
HB grades I-III vs. IV-VI					
Age	HB grades I-III	164	46.4	13.2	p = 0.999
	HB grades IV-VI	48	46.4	14.0	
Symptomatic period duration (months)	HB grades I-III	164	42.3	49.4	p = 0.970
	HB grades IV-VI	48	42.0	61.7	
Tumor stage	HB grades I-III	164	3.6	0.6	p = 0.000
	HB grades IV-VI	48	3.9	0.2	
Maximal extrameatal tumor size (mm)	HB grades I-III	164	28.4	10.3	p = 0.000
	HB grades IV-VI	48	35.7	9.5	
Tumor volume (cm ³)	HB grades I-III	164	11.9	12.0	p = 0.000
	HB grades IV-VI	48	23.7	20.4	
HB grades I-II vs. III-VI					
Tumor stage	HB grades I-II	141	3.5	0.64	p = 0.000
	HB grades III-VI	71	4.0	0.36	
Maximal extrameatal tumor size (mm)	HB grades I-II	141	27.4	9.5	p = 0.000
	HB grades III-VI	71	35.2	10.7	
Tumor volume (cm ³)	HB grades I-II	141	11.0	11.4	p = 0.000
	HB grades III-VI	71	21.6	18.8	

(43%). However, the differences were not statistically significant (Table 1). Likewise, when diagnostic examinations were initiated due to CNVIII symptoms, a satisfactory outcome was more common (80%) than headaches (67%, p – NS, Table 1).

Separate correlations of all symptoms presented on admission with long-term CNVII function revealed no significant differences (Table 5). Similarly, no significant differences were observed in the results depending on patient's age and gender or the duration of the symptomatic period either (Tables 3 and 5).

After splitting the study group into 4 subgroups according to the surgery sequence, a gradual improvement of the results was demonstrated (Table 4). The rate of satisfactory results was 66% in the group of the first 53 patients as compared to 83% in the last quarter ($p = 0.044$).

The rate of satisfactory results was significantly higher in the group of T2-T3 tumors as compared to T4 tumors (95% vs. 70%, $p = 0.000$). Likewise, better results were obtained for tumor sizes of ≤ 3 cm (87% vs. 65%, $p = 0.000$) and tumor volumes of ≤ 10 cm³ (87% vs. 67%, $p = 0.001$) (Tables 3 and 5). Satisfactory results were more common when the tumors were located on the left side (83% vs. 71%, $p = 0.048$). Other tumor-related factors such as the tumor structure, histological type, CNVII displacement pattern or the IAC width were of no significant importance for long-term CNVII function (Table 5).

Factors associated with the course of treatment, such as patient's position during the procedure, surgical approach, occurrence of postoperative complications and the use of

nimodipine in the perioperative period had no impact on the frequency of satisfactory long-term CNVII function (Table 5).

3.2.2. Correlation analysis for very good (HB grades I-II) CNVII function

An identical series of correlations of various factors was analyzed for very good long-term CNVII function (HB grades I-II). The priority role of factors associated with tumor size was confirmed (Table 3). The mean tumor size and volume in the group of patients with very good CNVII outcome was 2.7 cm and 11 cm³, as compared to 3.5 cm and 21 cm³, respectively, in the group of patients with HB grades III-IV ($p = 0.000$ for both correlations).

Correlations with other factors for very good results (HB grades I-II) revealed also several significant differences (Table 6). Significantly better prognosis was observed for patients with tumors located on the left side (HB grades I-II in 74% vs. 59%, $p = 0.02$). For both anterolateral and anteromedial CNVII displacements, the rates of very good outcome were 60%. For anterior displacement, HB grades I-II outcome was achieved in 76% ($p = 0.04$). The facial nerve function was significantly better in patients undergoing surgery in the supine position as compared to patients undergoing surgery in the lateral position (HB grades I-II: 74% vs. 57%, $p = 0.018$). In the group of patients receiving prophylactic nimodipine treatment, very good results were obtained in 81% of cases. When nimodipine was not administered, the respective rate was 62% ($p = 0.016$). In patients with preserved CNVII continuity but with no response to final EMG stimulation at the brain stem, the percentage of very good results in long term was fifty percent less than in cases when the response was obtained (41% vs. 82%, $p = 0.000$). The rate of very good results in patients with postoperative complications was also significantly lower (53% vs. 71%, $p = 0.019$).

3.2.3. Multivariate regression analysis

Wald's regression analysis of factors correlating with the final outcome revealed three variables that independently influenced satisfactory CNVII function. These included factors associated with tumor features, namely, the tumor size

Table 4 – Correlation between surgery sequence and long-term functional outcome. Pearson's Chi-square test; $p = 0.146$.

Surgery sequence	CNVII function	
	HB grades I-III	HB grades IV-VI
Patients 1-53	35 (66%)	18 (34%)
Patients 54-106	42 (79.2%)	11 (20.8%)
Patients 107-159	43 (81.1%)	10 (18.9%)
Patients 160-212	44 (83%)	9 (17%)

Table 5 – Correlations of various factors with CN.VII function in long-term follow-up. Pearson's Chi-square or Fisher's exact test.

Factor	CNVII function		p
	HB grades I-III	HB grades IV-VI	
Sex			
F	102 (79%)	27 (21%)	p – NS
M	62 (75%)	21 (25%)	
Age			
≤50 y.o.	93 (77%)	28 (23%)	p – NS
>50 y.o.	71 (78%)	20 (22%)	
Symptom duration			
≤24 months	85 (75%)	29 (25%)	p – NS
>24 months	79 (81%)	19 (19%)	
Cerebellar symptoms			
/-/	124 (79%)	33 (21%)	p – NS
/+/	40 (73%)	15 (27%)	
CNV-related symptoms			
/-/	121 (80%)	31 (20%)	p – NS
/+/	43 (72%)	17 (28%)	
Headache			
/-/	144 (79%)	38 (21%)	p – NS
/+/	20 (67%)	10 (33%)	
Hydrocephalus			
/-/	158 (78%)	44 (22%)	p – NS
/+/	6 (60%)	4 (40%)	
Hearing acc. to AAO-HNS scale			
Class A-C	45 (88%)	6 (12%)	p – NS
Class D	119 (74%)	42 (26%)	
CNVII before surgery			
HB grade I	140 (78%)	39 (22%)	p – NS
HB grades II-VI	24 (73%)	9 (27%)	
Tumor stage			
T2-T3	58 (95%)	3 (5%)	p = 0.000
T4	106 (70%)	45 (30%)	
Tumor size (max. extrameatal)			
≤30 mm	103 (87%)	15 (13%)	p = 0.000
>30 mm	61 (65%)	33 (35%)	
Tumor volume			
≤10 cm ³	96 (87%)	14 (13%)	p = 0.001
>10 cm ³	68 (67%)	34 (33%)	
Tumor structure			
Solid	141 (79%)	38 (21%)	p – NS
Cystic	23 (70%)	10 (30%)	
Side of the tumor			
Right	74 (71%)	30 (29%)	p = 0.048
Left	90 (83%)	18 (17%)	
IAC widening			
/-/	22 (88%)	3 (12%)	p – NS
/+/	142 (76%)	45 (24%)	
Histology pattern (Antoni)			
A	52 (83%)	11 (17%)	p – NS
B	17 (61%)	11 (39%)	
A + B	95 (79%)	26 (21%)	
CN.VII displacement pattern			
Anterior	80 (82%)	17 (18%)	p – NS
Antero-medial	52 (80%)	13 (20%)	
Antero-lateral	31 (69%)	14 (31%)	
Patient's position during surgery			
Lateral	63 (69%)	28 (31%)	p – NS
Supine	101 (83%)	20 (17%)	
Approach			
RSA	162 (77%)	48 (23%)	p – NS
TLA	2 (100%)	0 (0%)	
Nimodipine			
/-/	123 (75%)	42 (25%)	p – NS
/+/	41 (87%)	6 (13%)	

Table 5 (Continued)

Factor	CNVII function		p
	HB grades I-III	HB grades IV-VI	
Final EMG stimulation			
Response +/-	23 (79%)	6 (21%)	p – NS
Response -/-	137 (90%)	15 (10%)	
Postoperative complications			
-/-	128 (80%)	31 (20%)	p – NS
+/-	36 (68%)	17 (32%)	

Table 6 – Correlations of selected factors with a very good CNVII function in long-term follow-up. Chi-square test.

Factor	CNVII function		p
	HB grades I-II	HB grades III-VI	
Side of the tumor			
Left	80 (74%)	28 (26%)	p = 0.02
Right	61 (59%)	43 (41%)	
CNVII displacement pattern			
Anterior	74 (76%)	23 (24%)	p = 0.044
Antero-medial	39 (60%)	26 (40%)	
Antero-lateral	27 (60%)	18 (40%)	
Patient's position during surgery			
Lateral	52 (57%)	39 (43%)	p = 0.018
Supine	89 (74%)	32 (26%)	
Nimodipine			
-/-	103 (62%)	62 (38%)	p = 0.016
+/-	38 (81%)	9 (19%)	
Final EMG stimulation of CNVII			
Response -/-	12 (41%)	17 (59%)	p = 0.000
Response +/-	125 (82%)	27 (18%)	
Postoperative complications			
-/-	113 (71%)	46 (29%)	p = 0.019
+/-	28 (53%)	25 (47%)	

($p = 0.0045$), side ($p = 0.0261$) and stage ($p = 0.0366$; Table 7). For example, for right-sided, T4 tumors, larger than 3 cm, the rate of satisfactory results was 59% (29/49) as compared to 97% (34/35) for left-sided T2-T3 tumors.

The regression analysis for very good functional outcome revealed an independent impact of three factors, including tumor size ($p = 0.0000$), side ($p = 0.0175$) and nimodipine administration ($p = 0.0349$; Table 7). According to the obtained results, the best prognosis was observed for patients with small tumors (≤ 3 cm) located on the left side and treated with nimodipine. In this group, the percentage of HB grades I-II results was 94% (16/17) as compared to only 31% (12/39) in the group characterized by a combination of the opposite features.

4. Discussion

4.1. Factors influencing the intraoperative CNVII continuity preservation

As shown by the statistical analysis, when the first symptoms of the tumor included headaches or cerebellar symptoms, the risk of facial continuity loss rates was significantly higher

Table 7 – Multivariate regression analysis.

Factor	B	BS	Wald	p	Exp (B)	95% CI for EXP (B)
Dependent variable: CNVII anatomical continuity preservation ^a						
Tumor volume	0.031	0.013	6.325	0.012	0.969	0.946–0.993
Side of the tumor	1.121	0.511	4.804	0.028	3.067	1.126–8.356
Patient's position	1.251	0.518	5.825	0.016	3.494	1.265–9.648
Constant	1.686	0.423	15.900	0.000	5.400	
Dependent variable: CNVII function (HB grades I-III vs. IV-VI) in long-term follow-up ^b						
Tumor volume	0.035	0.012	8.059	0.0045	1.036	1.011–1.061
Side of the tumor	-0.7611	0.364	4.370	0.0261	0.467	0.229–0.954
Tumor stage	1.3717	0.616	4.952	0.0366	3.942	1.178–13.194
Constant	-6.7061	2.364	8.047	0.0046		
Dependent variable: CNVII function (HB grades I-II vs. III-VI) in long-term follow-up ^c						
Tumors size	0.075	0.017	18.966	0.0000	1.078	1.042–1.115
Side of the tumor	-0.779	0.328	5.648	0.0175	0.459	0.242–0.872
Nimodipine	-0.919	0.436	4.452	0.0349	0.399	0.170–0.937
Constant	-1.597	0.752	4.510	0.0337		

^a Chi-square = 20.685; $p < 0.0001$; Nagelkerke's R squared = 0.187. Variables that did not enter the model: tumor size, cerebellar symptoms and hydrocephalus.

^b Chi-square = 32.784; $p < 0.0001$; Nagelkerke's R squared = 0.218. Variables that did not enter the model: tumor size, the patient's position during surgery, histological type of tumor, postoperative complications and treatment with nimodipine.

^c Chi-square = 33.634; $p < 0.0001$; Nagelkerke's R squared = 0.209. Variables that did not enter the model: headache, CNVII weakness at admission, tumor stage, tumor volume, patient's position during surgery, IAC width, CNVII displacement pattern and postoperative complications.

reaching 33% and 29%, respectively. The same factors were pointed out in the analysis conducted by Gerganov et al. [1]. Likewise, when hydrocephalus was presented on admission, the risk of CNVII disruption was 40%. These variables should be considered as collinear with the tumor size, as confirmed by further multivariate analysis. The tumor volume was the most important independent factor influencing the CNVII continuity preservation ($p = 0.012$). The size of the tumor is a proven risk factor for intraoperative CNVII interruption [2,3].

No significant effects were observed for the tumor structure or CNVII displacement pattern. The literature contains data suggesting that cystic tumors, polycyclic shape and superior CNVII displacement pattern (i.e., *anteromedial displacement according to the nomenclature used in this study*), might increase the risk of CNVII damage [1,4–6]. According to other authors, cystic morphology of schwannoma does not worsen the CNVII preservation rate [7,8]. Nevertheless, this might be due to a trend toward less radical removal of cystic tumors, i.e., toward leaving the thin tumor capsule on the facial nerve [7].

The incidence of CNVII discontinuity was significantly higher with surgery performed in the lateral park-bench position as compared to supine position (19% vs. 5%, $p < 0.01$). This factor was found to be of an independent impact in the regression analysis ($p = 0.016$). The lateral position was used during the first 91 surgeries, while supine position was used in the last 121 patients. Therefore, the factor appears to reflect the role of another variable, namely, the order of surgeries. After the study group was divided into 2 subgroups of 106 patients each, the incidence of CNVII disruption was 16% and 6%, respectively ($p < 0.05$), whereas the largest drop in the incidence of CNVII disruption on the learning curve was observed after 72 surgeries, from 21% to 6% ($p < 0.01$).

An accidental discovery was that CNVII damage was more common in right-sided tumors (15% vs. 6%, $p = 0.047$). In addition, regression analysis revealed that this factor had an independent effect on outcome ($p = 0.0028$). Perhaps it was because of the surgeon's handedness. In right-sided tumors, instruments held with the right hand operate at a sharp angle to the posterior pyramid wall and CNVII. In left-sided tumors, this angle increases possibly facilitating the CNVII dissection in CPA. The side of the tumor has been rarely studied. It was of no importance in the study by Lalwani et al. [9].

4.2. Factors affecting the facial nerve function at long-term follow-up

The following factors correlated significantly with satisfactory long-term CNVII function: tumor grade $< T4$ ($p = 0.000$), tumor size ≤ 3 cm ($p = 0.000$), tumor volume ≤ 10 cm³ ($p = 0.001$), left-sided tumor location ($p = 0.048$). Correlations with very good long-term CNVII function were also identified for several other important factors: anterior CNVII displacement ($p = 0.044$), nimodipine use ($p = 0.016$), the absence of postoperative complications ($p = 0.019$) and supine position during surgery ($p = 0.018$). Significant correlations of outcome with the patient's position during surgery are indicative rather of the progress in the learning curve, as demonstrated above. Regression analysis confirmed the independent impact of three factors on satisfactory long-term outcome, namely, of the tumor volume ($p = 0.0045$) and grade ($p = 0.0366$) as well as side of the

tumor ($p = 0.0261$). An independent impact on very good long-term outcome was identified for tumor size ($p = 0.0000$) and side ($p = 0.0175$), as well as nimodipine use ($p = 0.0349$).

The literature underlines that the most important factors affecting the CNVII function include the tumor size as well as the surgeon's and site's experience [2,10–13]. In our case series, the key role of factors related to tumor size in CNVII function was confirmed in all study periods. The role of the learning curve will be presented separately. The possible influence of the tumor lateralization and patient positioning were discussed above.

Owing to routine nimodipine prophylaxis, an improvement of long-term results was achieved. This is confirmed by the results of experimental and clinical studies conducted in recent years [14–16]. A study in an animal model demonstrated that the calcium channel blocker promotes faster and more effective regeneration of damaged CNVII [14,15]. Positive results of nimodipine treatment when initiated prophylactically on the day before surgery or intraoperatively after neurophysiological features of functional nerve damage detection were demonstrated [17]. The possible mechanism of nimodipine's action includes improvement in circulation, acceleration of axonal growth, improved remyelination and protection against neuronal degeneration. Increased influx of calcium ions inside the cells may also have an inhibitory effect on apoptosis [16,17]. Strauss et al. [16] also suggest broadening the vasoactive treatment by administering hydroxyethyl starch solution.

Although the CNVII displacement pattern had no impact on preservation of the nerve's continuity during the procedure, it was correlated with long-term outcome. Anterior displacement was associated with a higher percentage of very good outcome as compared to anterolateral and anteromedial displacements. Although this factor was not shown to be independent, its importance has also been suggested by other authors [4,6]. In the cited articles, superior displacement (i.e., *anteromedial displacement according to classification used herein*) was associated with poorer outcome.

5. Conclusions

In our series, factors related to size and side of the tumor confirmed an independent impact on CNVII intraoperative preservation and its long-term function. The significance of patient positioning may reflect the impact of learning curve rather than positioning itself, as only the first 91 patients were operated on using the lateral “park-bench” position. An independent impact on long-term CNVII function was exerted by the perioperative use of nimodipine.

Conflict of interest

None declared.

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All authors report no any actual or potential conflict of interest including any financial, personal or other relationships with

other people or organizations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work.

Ethics

The work described in this article has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans; Uniform Requirements for manuscripts submitted to Biomedical journals.

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