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**The Impact of Hypotension due to
the Trigemino-cardiac Reflex on Auditory Function
in Vestibular Schwannoma Surgery**

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Abbreviations

AEP – Auditory evoked potential

CPA – Cerebellopontine angle

CT – Computed tomography

IAC – Internal auditory canal

MABP – Mean arterial blood pressure

MRI – Magnetic resonance imaging

NF-2 – Neurofibromatosis type 2

OCR – Oculocardiac reflex

SDS – Speech discrimination score

SSEP – Somatosensory evoked potential

TCR – Trigemino-cardiac reflex

VAE – Venous air embolism

Index

1. Introduction.....	6
Trigemino-cardiac Reflex	8
Anatomy of the Trigeminal Nerve at Skull Base.....	9
Vestibular Schwannomas	11
<i>Diagnosis</i>	11
<i>Histopathology</i>	11
<i>Treatment Options for Vestibular Schwannomas</i>	12
<i>Surgical Treatment of Vestibular Schwannomas</i>	12
Suboccipital Retrosigmoid Approach.....	13
Middle Fossa Approach	14
Translabyrinthine Approach.....	15
2. Purpose & Main Questions of this Study	18
Purpose	18
Main Questions.....	18
3. Clinical Material and Methods	19
Definition of Trigemino-cardiac Reflex	19
Tumor Classification	19
Hearing Tests	22
Intraoperative Electrophysiological Monitoring and Surgical Resection	23
Anesthesiological set up	24
Anesthesiological Monitoring	24
Intraoperative Management of the TCR.....	24
Statistical Analysis	25
4. Results	26
5. Discussion	34
Predicting the occurrence of TCR.....	35
Methods Used in the Present Study	37
Choosing the Suboccipital Retrosigmoid Approach	37
Suboccipital Retrosigmoid Approach – Technical Considerations.....	39
1. <i>Semi-sitting Position</i>	39

2. <i>Preoperative Evaluation</i>	42
a. <i>Cervical Spine Study</i>	43
b. <i>Posterior Fossa Bone Window CT</i>	43
3. <i>Intraoperative Monitoring</i>	46
4. <i>Positioning</i>	47
5. <i>Incision and Craniectomy</i>	48
6. <i>Closure</i>	56
Operating in the Semi-Sitting Position	58
Surgical Results of the Different Approaches to the CPA	59
Anatomy of the Trigeminal Nerve and TCR in Skull Base Surgery	63
Neurophysiology and Monitoring	64
a. <i>Indication for AEP</i>	65
b. <i>Importance of Waves I, III and V</i>	65
c. <i>Anatomic and Physiologic Correlations</i>	65
Analysis of the Results	66
Perspectives	67
<i>Treatment and Morbidity of TCR</i>	67
<i>Auditory Function</i>	68
6. <i>Conclusion</i>	71
7. <i>References</i>	72
Abstract	90
Acknowledgements	91
Biography	92

1. Introduction

Vestibular schwannomas are benign tumors that arise from Schwann cells surrounding the vestibular portion of the vestibulocochlear nerve. Tinnitus and hearing loss are the most common initial symptoms. As the tumor grows, it may compress other nervous structures, such as the facial, cochlear and the trigeminal nerve, the lower cranial nerves, the cerebellum and brainstem.

Dramatic improvement in patient's outcome following surgical treatment of cerebellopontine angle lesions is relatively recent, and has followed the development of the history of neurosurgery. Such achievements were conspicuously marked in the last 30 years, with a better understanding of the microsurgical anatomy, the current use of the operating microscope, and the great advances in neuroanaesthesia, in neurophysiology, and in operative techniques.

The goal of a vestibular schwannoma resection has changed significantly during the past decades. While life preservation was the main challenge in the past, function preservation is the aim nowadays. Satisfactory rates of facial nerve preservation have been achieved in the present, with reported rates of up to 97% of anatomical and up to 90% of functional facial preservation (Samii and Matthies 1997 [3]). However, hearing preservation is still a challenge. Through the suboccipital route, anatomic cochlear nerve preservation has been reported in 79% to 96% of patients with some preoperative hearing, while functional hearing has been preserved in 44 to 47% of the cases in the best series, with progressive increasing rates according to the surgeon's experience (Mazzoni et al. 1993, Samii and Matthies 1997 [1]). Some new treatment modalities have been developed aiming to improve the rates of functional preservation, such as tumor irradiation by radiosurgery. Nevertheless, surgery is still the treatment of choice in the majority of the cases in order to achieve tumor control and to preserve the function of the cranial nerves.

Deafness can occur after vestibular schwannoma removal even in cases with cochlear nerve preservation. Accidental injury of the labyrinth, for example, is followed by hearing loss in the majority of the cases despite of cochlear nerve preservation (Tatagiba et al. 1992).

Several prognostic factors have already been described to be favorable for postoperative hearing function in vestibular schwannomas. Small tumor size (Matthies and Samii 2002, Samii and Matthies 1997 [1]), good preoperative hearing (up to 40 dB loss), short preoperative duration of hypoacusis (<1,5 yr) or of vestibular disturbances (<0,7 yr) (Samii and Matthies 1997 [1]), short wave V AEP (auditory evoked potential)-latency and tumor origin from the superior part of vestibular nerve (Brackmann et al. 2000) and even male gender (Samii and Matthies 1997 [1]).

Severe changes of the IAC verified in preoperative bone-window computed tomography are described to be associated with poor preoperative hearing function as well as with an unfavorable postoperative hearing outcome (Yamakami et al. 2002). Also, the extent of the IAC (internal auditory canal) widening and the tumor growth in anterior and caudal direction to the IAC are significant predictors for postoperative auditory function in large tumors (Matthies et al. 1997). Somers et al. evaluated magnetic resonance imaging findings and found low intralabyrinthine signal intensity on gradient echo images to be followed by a lower rate of hearing preservation (Somers et al. 2001). The authors hypothesized that vascular compression in the IAC by the tumor has been responsible for the decrease of intralabyrinthine signal intensity.

Ischemic changes of the auditory apparatus may lead to loss of the hearing function, as seen in cases of vasospasm or direct lesion of the labyrinthine artery. Theoretically, an intraoperative hypotension, as observed in cases of intraoperative hemorrhage, hypovolemia, drugs' side effects, and the

trigemino-cardiac reflex (TCR), could lead to temporary hypoflow and ischemia of the auditory apparatus and to following definitive hearing loss.

The present study aims to analyze the impact of intraoperative hypotension on the outcome of the auditory function following resection vestibular schwannomas. As the trigemino-cardiac reflex is a natural phenomenon, which may occur during the resection of these tumors, it was the mechanism selected to analyze this suspected correlation.

Trigemino-cardiac Reflex

The trigemino-cardiac reflex, a phenomenon consisting of bradycardia or even asystolia along with arterial hypotension, can be elicited by accidental surgical manipulation of the trigeminal nerve on its intra- or extracranial course.

The most common manifestation of the TCR is the oculocardiac reflex (OCR), which has been described as sinus bradycardia elicited by ocular manipulation, pressure on the globe or traction of extraocular muscles (Nimmo et al. 1994), especially the medial rectus muscle (Miller 1994, Oppenheimer 1982). Other possible arrhythmias induced through this reflex include junctional rhythm, A-V block, multifocal premature ventricular contractions, ectopic beats, ventricular tachycardia, ventricular fibrillation and asystolia (Miller 1994, Nimmo et al. 1994). As the efferent limb of the TCR is vagal, it causes most often a decrease of the heart rate of 10 to 50% (Oppenheimer 1982).

Related reflexes during eye surgery are the blepharocardiac reflex, the oculo-respiratory reflex and the sudden infant death syndrome (Yamashita 1986).

The TCR may also be elicited by stimulating the maxillary and mandibular divisions of the trigeminal nerve in cranio-maxillofacial surgeries (Lang et al. 1991, Stott 1989), as described for temporomandibular joint arthroscopies (Roberts et al. 1999), maxillary tuberosity cuttings (Campbell et al. 1994), Le

Fort I osteotomies (Ragno et al. 1989), nasal fracture reconstructions (Locke et al. 1999), zygomatic arch fracture elevations (Loewinger J et al. 1987, Shearer et al. 1999) and midface disimpactions (Robidaux 1978).

In neurosurgery, the TCR is described to occur during stimulation of the trigeminal ganglion (Brown and Preul 1988, Dominguez et al. 1994, Kuchta et al. 1998), trigeminal sensory root rhizotomy (Cha et al. 2002) and dorsal root entry zone radiofrequency thermocoagulation of the trigeminal nucleus caudalis (Delgado-López et al. 2003). In 1999, Schaller et al. first reported the occurrence of a TCR in 11% of their cases during tumor surgery in the cerebellopontine angle (CPA) (Schaller et al. 1999).

Anatomy of the Trigeminal Nerve at Skull Base

The trigeminal nerve joins the brainstem about halfway between the upper and lower borders of the pons. In the posterior fossa the nerve runs towards the petrous apex. (Rhoton 2000 [2]). At the CPA, the trigeminal nerve is located superiorly to the seventh (facial) and eighth (vestibulocochlear) cranial nerves (Figure 1).

At the petrous apex, the nerve enters the middle fossa in Meckel's cave, which is located on the petrous part of the temporal bone (Rhoton 2000 [2]). The ophthalmic, maxillary and mandibular branches of the trigeminal nerve start from the trigeminal ganglion.

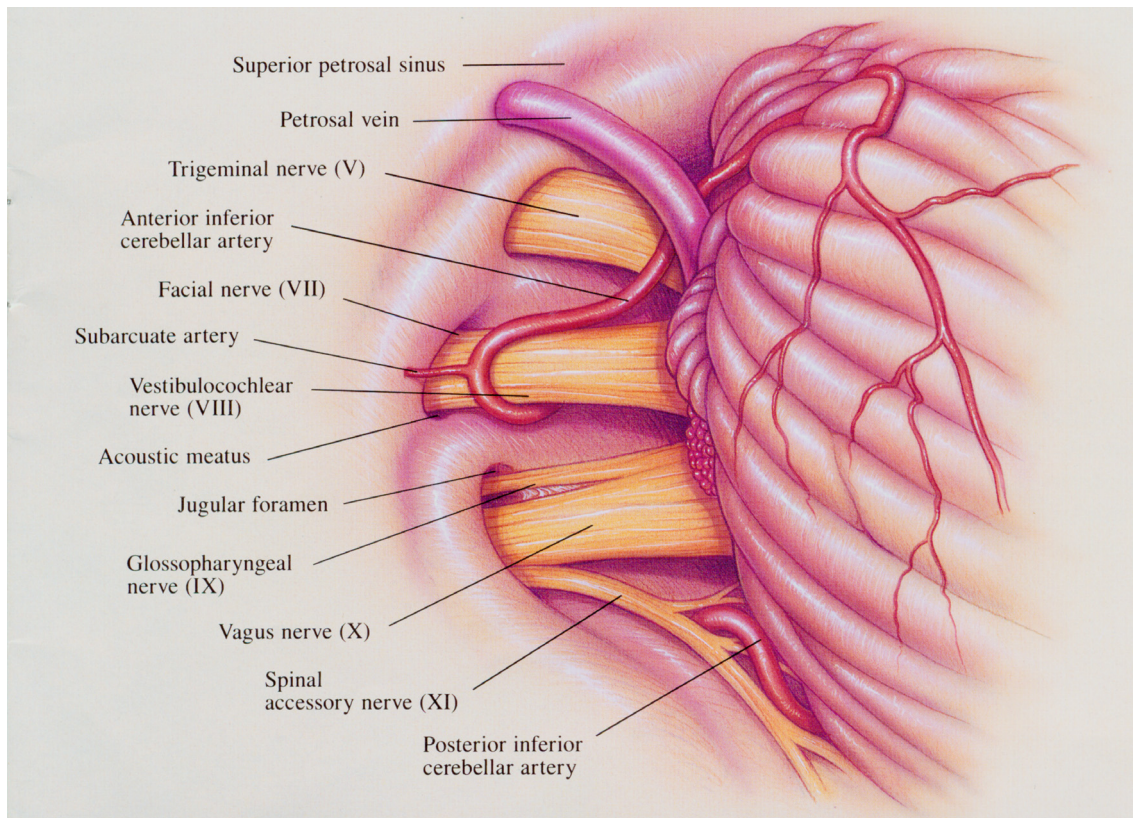


Figure 1 – Anatomy of the trigeminal nerve at the CPA and its relationship to the petrosal vein (Samii and Tatagiba 1994 – with permission).

The ophthalmic division passes forward near the medial surface of the dura forming the lower part of the lateral wall of the cavernous sinus to reach the superior orbital fissure (Rhoton 2002 [1], Rhoton 2002 [2]). As the nerve approaches the superior orbital fissure, it splits into the lacrimal, frontal and nasociliary nerves (Rhoton 2002 [1]).

The maxillary nerve passes through the foramen rotundum to enter the pterygopalatine fossa, where it divides into infraorbital and zygomatic branches and communicating rami to the sphenopalatine ganglion (Rhoton 2002 [1]).

The mandibular nerve passes through the foramen ovale reaching the infratemporal fossa, where it gives rise to the pterygoid, buccal, masseteric, and temporal branches, as well as to the lingual, inferior alveolar and auriculotemporal branches (Rhoton 2002 [3]).

Vestibular Schwannomas

Vestibular schwannomas (so-called “acoustic neuromas”) may occur sporadically in patients without genetic diseases, or bilaterally in patients with neurofibromatosis type 2 (NF-2). NF-2 is an autosomal dominant disorder linked to a genetic defect on chromosome 22 (Tatagiba et al. 1994). It shows a high penetrance rate and the highest spontaneous mutation rate of any human genetic disease (50%) (Moffat et al. 2003). The lack of the gene product schwannomin (or merlin) results into a tendency of increased tumor formation such as schwannomas, meningiomas and ependymomas (Rouleau et al. 1993, Kluwe et al. 2005).

Diagnosis

Vestibular schwannomas manifest initially with hearing loss and tinnitus, as well as with dizziness, unsteadiness and vertigo. In large tumors, facial hypoesthesia, dysphagia, facial paresis, cerebellar symptoms and hydrocephalus may be present. The characteristic audiographic finding is a sensorineural hearing loss characterized by poorer speech discrimination than would be anticipated from the findings on pure-tone audiometric testing (Ojemann 1996).

MRI (magnetic resonance imaging) is the radiological examination of choice and can detect even small intracranial tumors. Bone window CT (computed tomography) scans show the bone features and are useful for preoperative planning.

Histopathology

Vestibular schwannomas present the same histological features as those of schwannomas that arise from other nerves (Russell and Rubinstein 1989, Ojemann 1996). Schwannomas are constituted by tissue composed of densely

packed elongated spindle cells in interlocking fascicles with a tendency toward palisading (Antoni type A tissue). They are often intermingled with loosely textured tissue with extracellular clear spaces and are sometimes associated with cyst formation (Antoni type B tissue) (Russell and Rubinstein 1989, Ojemann 1996).

Treatment Options for Vestibular Schwannomas

The mean tumor growth rate of vestibular schwannomas has been reported to be 1 mm/year (range 0.84 - 9.65 mm/year) (Raut et al. 2004). Due to the slow growth, observation and tumor control by serial MRI has been advocated in elderly patients with small tumors.

Radiosurgery and even fractionated radiotherapy constitute options for the treatment of vestibular schwannomas and may be indicated in selected tumors up to 3 cm in diameter.

Surgical treatment remains the treatment of choice in the majority of cases and is indicated principally in young patients with large tumors.

Surgical Treatment of Vestibular Schwannomas

Vestibular schwannomas may be resected mainly by three different surgical approaches:

- the suboccipital retrosigmoid approach
- the middle fossa approach
- the translabyrinthine approach

Suboccipital Retrosigmoid Approach

(Figure 2)

The suboccipital route is the most common approach used in neurosurgery to treat vestibular schwannomas. It allows the removal of tumors of different sizes, while keeping the chance to preserve facial and hearing function.

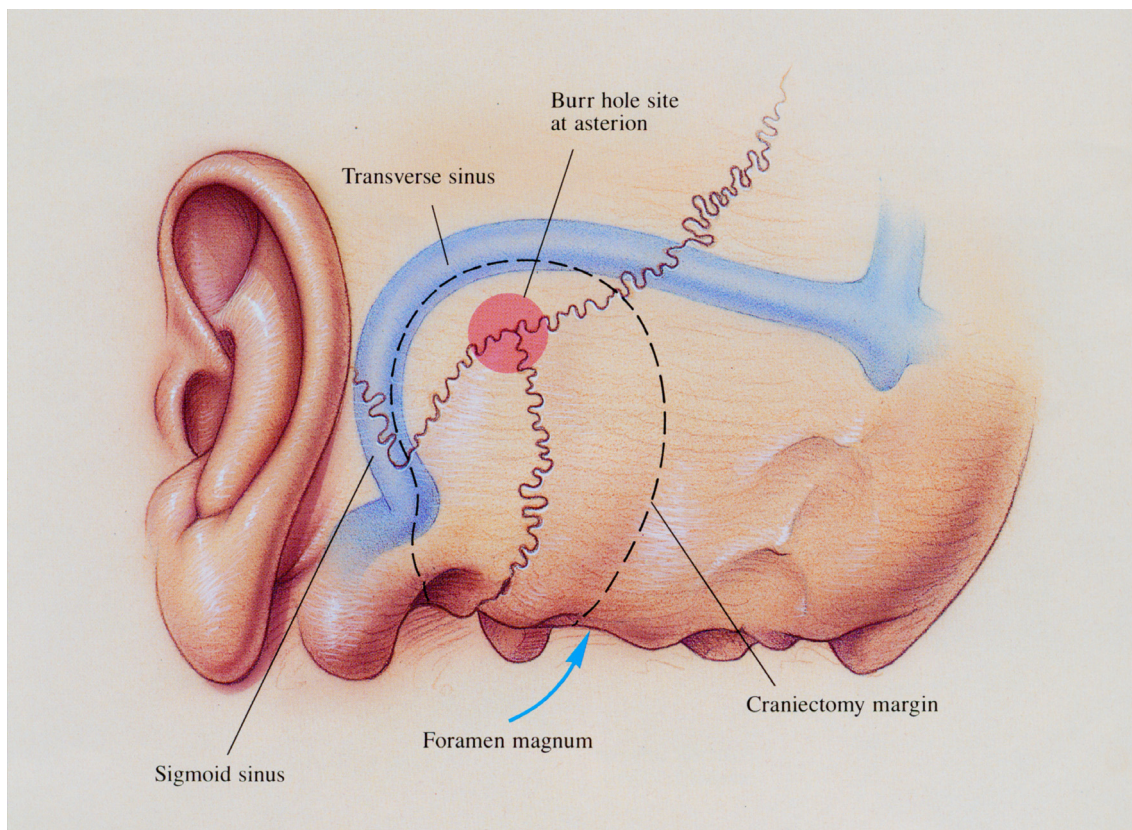


Figure 2 – Retrosigmoid suboccipital approach: relationship of the asterion, sigmoid and transverse sinuses, and site of the craniectomy (Samii and Tatagiba 1994 – with permission).

The suboccipital retrosigmoid approach allows the treatment of diverse affections of the CPA, such as meningiomas, arachnoid cysts, epidermoid cysts, metastases, neuro-vascular compression syndromes, aneurysms, and vascular malformations (Samii et al. 1999).

Middle Fossa Approach

(Figure 3)

The middle fossa approach to the internal auditory canal was developed by House in 1963 in an effort to remove otosclerotic labyrinthine foci, which compress the eighth nerve (House WF 1963). He further applied this via to treat vestibular schwannomas.

Fisch has modified the middle fossa approach, contributing to its current use (Fisch 1970). The middle fossa approach offers access to the internal auditory canal, to the labyrinthine portion of the facial nerve without sacrificing hearing, to the geniculate ganglion, to the intrapetrous horizontal portion of the internal carotid artery, to the Eustachian tube, and to the petrous apex.

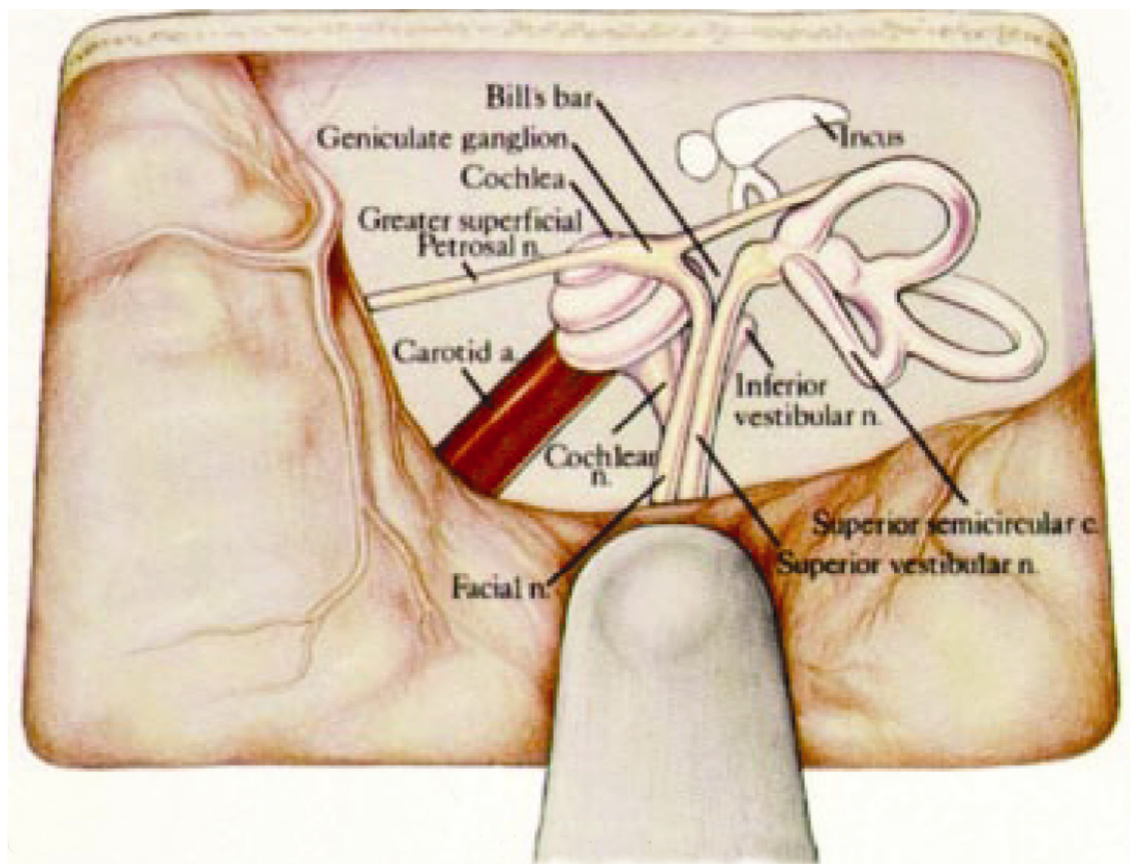


Figure 3: The internal auditory canal may be exposed by the middle fossa approach. The relationship of the structures of the region is shown (from Brackmann DE, in *Neurosurgical Operative Atlas*, 1993).

This approach may be used to remove vestibular schwannomas located within the internal auditory canal. Large vestibular schwannomas that extend outside the IAC toward the CPA are not suitable for the middle fossa approach, however. Irreversible facial paralysis and persistent cerebrospinal fluid leaks associated to fractures of the petrous pyramid may also be treated by this approach (Samii M, Draf 1989 [2]). Its indication concerns principally to extensive fractures with hearing preservation because it avoids enlarging the traumatic bone defect, when compared with the translabyrinthine approach, and allows auditory function preservation as well.

The retrosigmoid suboccipital and the middle fossa approaches are comparable in regard of preservation of auditory function in vestibular schwannoma surgery. Brackmann advocates the use of the middle fossa approach for small and laterally placed vestibular schwannomas (Brackmann 1993). He selects patients with tumors, which do not extend more than 1 cm into the CPA. When the tumor does not extend up to the fundus and is located medially, the retrosigmoid via is preferred (Brackmann 1993).

Regarding facial nerve preservation in the middle fossa approach, the tumor size is a significant factor influencing the postoperative function (Wiet et al. 2001). Patients with tumors larger than 10 mm extension into the CPA, carry an increased risk of facial nerve dysfunction after surgery (Satar et al. 2002).

Translabyrinthine Approach

(Figure 4)

The translabyrinthine approach accesses the internal acoustic meatus and the CPA through the mastoid and the labyrinth. This via has been used to remove different posterior fossa tumors, such as schwannomas, meningiomas, chordomas, ependymomas, epidermoid cysts, and chondrosarcomas, as well as for the management of traumatic cerebrospinal leaks of the petrous bone (Batra et al. 2002, Sluyter et al. 2001, Rinaldi A et al. 2000, Samii M, Draf W

1989 [3]). The main applicability of this approach consists in the resection of vestibular schwannomas.

Advantages of the translabyrinthine via are the early exposure of the facial nerve obtained at the fundus of the internal auditory meatus and the absence of cerebellar retraction for exposing the CPA. However, the brainstem vasculature and the lower cranial nerves are not well visualized during the procedure, constituting disadvantages of this route.

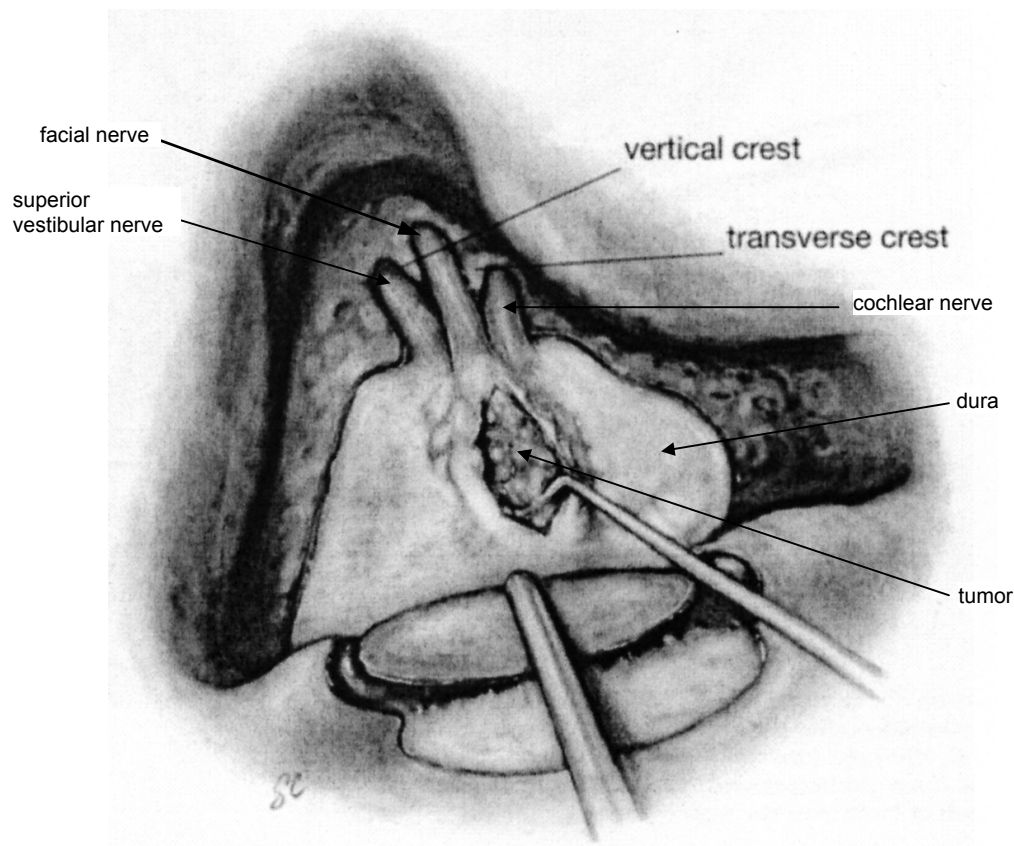


Figure 4: Resection of a vestibular schwannoma by the translabyrinthine approach (from King and O'Connor, in Neurosurgical Operative Atlas 1995).

This approach has been used to remove large tumors, with acceptable low rates of morbidity and mortality (Mamikoglu et al. 2002).

The destruction of the labyrinth is incompatible with preservation of the auditory function. Therefore, its use is restricted to patients with no useful preoperative hearing. Some authors defend the use of the translabyrinthine approach in

acoustic neuromas larger than 2 cm or in patients with certain unfavourable preoperative hearing parameters (speech reception threshold greater than 50 dB, a speech discrimination score of 50% or less) (Somers 2003).

The risk of cerebrospinal fluid leak via the Eustachian tube, as well as the risk of postoperative infection, are increased due to opening the middle ear (King and O'Connor 1995). The presence of a mastoid cavity, after a previous surgery, or an otitis media in the recent patient's history, are relative contraindications to select the translabyrinthine approach, because a potentially infected field would be crossed (King and O'Connor 1995).

The lower occurrence of postoperative headache after the translabyrinthine approach comparing to the retrosigmoid approach has been reported as an advantage of the translabyrinthine route.

There is a general agreement that the translabyrinthine approach is not the method of choice in patients with some preoperative functional hearing.

To summarize the results obtained by the three above-mentioned surgical approaches to the CPA, it can be said that the rate of preservation of facial nerve function is similar comparing the suboccipital and translabyrinthine approaches, while the rate of hearing preservation in small vestibular schwannomas is similar comparing the suboccipital and middle fossa routes.

Although higher rates of anatomical preservation of the cochlear nerve have been achieved in recent years, postoperative hearing function still remains a difficult task. Among several prognostic factors, ischemic changes to the nerve, e.g. due to intraoperative hypotension, may result in hearing loss.

The present study aims to analyze the impact of intraoperative hypotension on the outcome of the auditory function following resection vestibular schwannomas. As the trigeminocardiac reflex is a natural phenomenon, which may occur during the resection of these tumors, it was the mechanism selected to analyze this suspected correlation.

2. Purpose & Main Questions of this Study

Purpose

This study was designed to evaluate the impact of hypotension due to the trigeminal cardiac reflex on the postoperative auditory function following the surgery of vestibular schwannomas. There is no study available in the literature so far, which deals with this issue.

Main Questions

The following main questions should be answered by the present study:

- 1 – How frequent does the TCR occur in vestibular schwannoma surgery?
- 2 – How frequent does intraoperative hypotension occur due to the TCR during the tumor resection?
- 3 – What is the severity of such hypotension?
- 4 – Is there a relationship between intraoperative occurrence of TCR and the postoperative hearing function in these patients?

In order to answer these questions, a prospective study was carried out, which included several clinical, anesthesiological, audiological and surgical parameters.

3. Clinical Material and Methods

One hundred consecutive vestibular schwannomas operations were carried out from June 2001 through July 2002 and were evaluated prospectively to analyze the intraoperative occurrence of the TCR and to determine which parameters might influence the postoperative auditory function.

The study included the following parameters: gender, age, pre- and postoperative auditory function (according to the Hannover classification), preoperative mean arterial blood pressure (MABP), preoperative medical diseases or medication (e.g. antiarrhythmic drugs), tumor size (according to the Hannover classification, T1 to T4) and localization, and the intraoperative occurrence of the TCR.

Definition of Trigemino-cardiac Reflex

In this study, TCR has been defined, as reported by Schaller et al., as the onset of bradycardia with a heart rate lower than 60 beats/minute accompanied by a drop of the MABP of 20% or more caused by intraoperative manipulation or traction of the trigeminal nerve (Schaller et al. 1999). The heart rate and the MABP are expected to return spontaneously to normal levels with cessation of manipulation or traction of the nerve.

Following the above-mentioned definition, the occurrence of bradycardia alone without any signs of hypotension, even during trigeminal nerve manipulation, has not been considered a TCR in this study.

Tumor Classification

Tumor extension was classified according to Samii and Matthies' classification, as follows: Class T1, purely intrameatal; T2, intra- and extrameatal; T3a, filling the cerebellopontine cistern; T3b, reaching the brainstem; T4a, compressing the brain stem; T4b, severely displacing the brain stem and compressing the

fourth ventricle (Figures 5-8) (Matthies and Samii 1997 [1], Matthies and Samii 1997 [3], Matthies et al. 1997, Samii and Matthies 1997 [1], Samii and Matthies 1997 [2]). The tumor classes T1 and T2 were considered as small size lesions, and T3 and T4 classes were considered as large tumors.

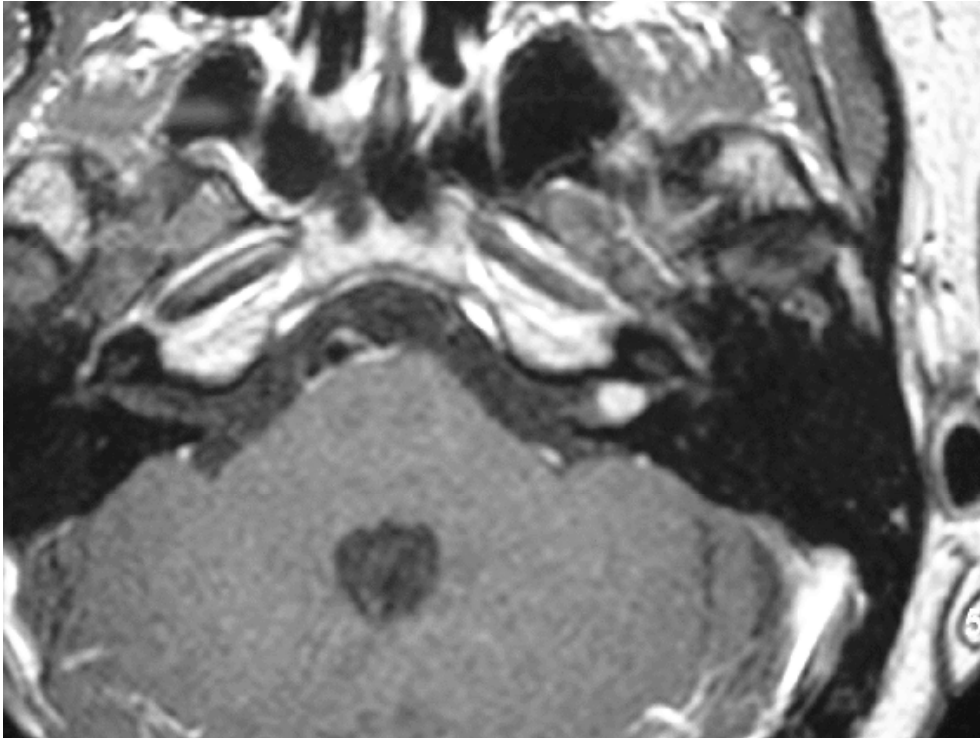


Figure 5. Tumor class T1 on MRI axial view – Intracanalicular vestibular schwannoma on the left side.



Figure 6 – Tumor class T2 on axial MRI view – Vestibular schwannoma with intracanicular and extracanicular component on the left side.

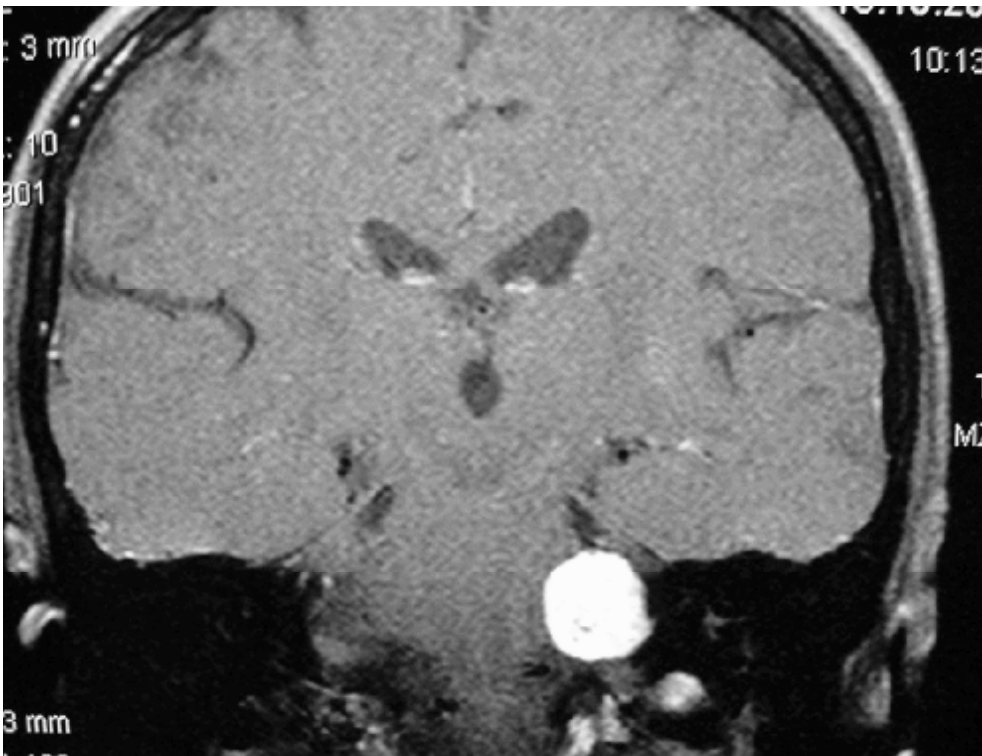


Figure 7 – Tumor class T3b on MRI coronal view – Vestibular schwannoma on the left side filling the cerebellopontine angle and reaching the brainstem.

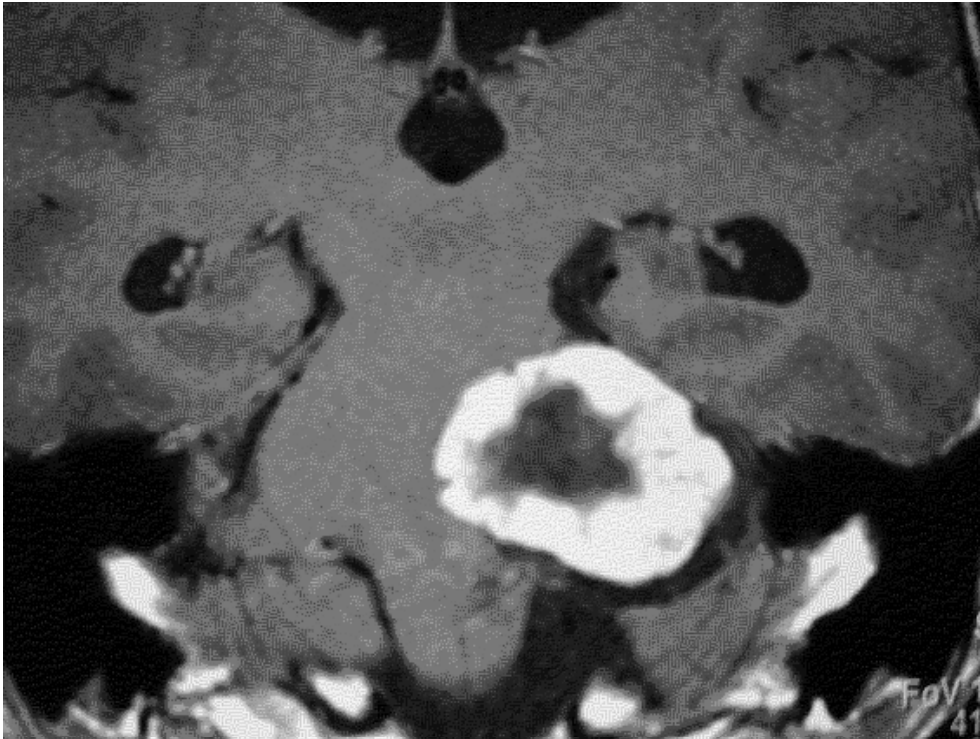


Figure 8 – Tumor class T4b on MRI coronal view – Vestibular schwannoma on the left side compressing the brainstem and causing hydrocephalus.

Hearing Tests

Hearing tests were performed before surgery and 1 to 2 weeks postoperatively in all cases.

Pre- and postoperative auditory function was analyzed according to the Hannover classification (table 1), as follows: H1 (normal hearing), 0-20 dB and 100-95% speech discrimination score (SDS); H2 (useful hearing), 21-40 dB and 95-70% SDS or better; H3 (moderate hearing), 41-60 dB and 65-40% SDS or better; H4 (poor hearing), 61-80 dB and 35-10% SDS or better; H5 (no functional hearing), >80 dB and 5-0% SDS or better (Samii and Matthies 1997 [1]). Each patient's best SDS is taken for classification of speech discrimination.

Table 1 – New Hannover Classification

Class	Hearing	Audiometry	Speech discrimination
H1	Normal hearing	0-20 dB	100-95% SDS
H2	Useful hearing	21-40 dB	95-70% SDS or better
H3	Moderate hearing	41-60 dB	65-40% SDS or better
H4	Poor	61-80 dB	35-10% SDS or better
H5	No functional hearing	>81 dB	5-0% SDS or better

SDS – speech discrimination score

Patients found to be class 5 (H5) of the Hannover classification before surgery were considered deaf and excluded from statistical analysis.

Intraoperative Electrophysiological Monitoring and Surgical Resection

Intraoperative monitoring of somatosensory evoked potentials (SSEP), AEP and electromyography of the facial nerve have been performed routinely in all cases, with the exception of AEP monitoring in patients with preoperative deafness.

Continuous monitoring of AEP is designed to control and predict auditory function during tumor removals at the CPA. The disappearance or changes of certain AEP components in relation to surgical actions may orient the surgeon to adopt certain intraoperative maneuvers in order to preserve the auditory function.

All patients underwent a suboccipital craniectomy in the semi-sitting position using a technique described elsewhere (Samii and Draf 1989, Samii and Matthies 1997 [2]).

Anesthesiological set up

After oral pre-medication with midazolam, anesthesia was induced with propofol followed by sufentanil and rocuronium. Anesthesia was maintained with propofol and, when it seemed clinically necessary, an additional bolus of sufentanil and rocuronium was administered.

After the trachea was intubated, the lungs were mechanically ventilated by moderate hyperventilation ($\text{PaCO}_2 = 35 \text{ mmHg}$) with a mixture of air and oxygen ($\text{FiO}_2 = 0.35$).

In the operating room patients received routine monitoring including electrocardiography and urine bladder temperature monitoring.

The central venous catheter located within the right atrium so as to aspirate any invaded air during embolism. For early recognition of air embolism precordial Doppler ultrasonography (2.2 MHz) was initiated. A radial artery catheter was inserted to allow continuous invasive blood pressure measurement.

Anesthesiological Monitoring

Hemodynamic parameters (heart rate, systolic, diastolic and mean arterial pressure and right atrial pressure) were monitored continuously during surgery with their values being recorded. Electrocardiogram, pulse oximetry, capnography with end-tidal CO_2 , and transcutaneous electrical stimulation of the left ulnar nerve using the train-of-four method were routinely monitored in all patients. Arterial blood gas analyses were performed every 1-2 hours.

Intraoperative Management of the TCR

Upon the occurrence of the TCR, the anesthesiologist informed the surgeon immediately, who stopped dissection of the tumor and interrupted the eliciting

mechanism. Following cessation of surgical stimulation, normalization of the hemodynamic parameters was expected.

Statistical Analysis

The influence of the studied parameters on postoperative auditory function was analyzed with a SPSS statistical package using a stepwise logistic regression with a likelihood-ratio-test. The level of significance (p) was set at a probability value of less than 0,05.

4. Results

Of 100 vestibular schwannoma patients studied in this series, 11 presented evidence of TCR during tumor resection (11%).

Immediately following the occurrence of TCR, surgical manipulation was interrupted. Intravenous administration of vagolytics like atropine was not necessary to control the TCR in any of these cases. Surgery could be continued without any further occurrence of the TCR. Postoperatively, for at least 24 hours, continuous monitoring of the hemodynamic and respiratory parameters and repeated neurological examinations were performed in the intensive care unit.

The table 2 shows the characteristics of 100 cases of vestibular schwannoma surgery.

In the TCR group the mean age was 52.45 years (range 35-68) vs. 47 years (range 18-74) in the non-TCR group. There were three male (27.3%) and eight female patients (72.7%) vs. 52 male (58.4%) and 37 female patients (41.6%), and the tumor side was left in 8 cases (72.7%) and right in 3 cases (27.3%) vs. left in 50 cases (56%) and right 39 cases (44%) in the TCR and non-TCR groups, respectively.

The mean preoperative MABP was 96.9 mmHg (range 81-120 mmHg) in patients with a TCR and 102.6 mmHg (range 76-138 mmHg) in the non-TCR group. The TCR group showed a maximal intraoperative MABP of 91.7 mmHg (range 81-112 mmHg) and a minimal of 46.2 mm Hg (range 39-66 mmHg), while the non-TCR group presented a maximal intraoperative MABP of 94.6 mmHg (range 74-136 mmHg) and a minimal of 59.6 mmHg (range 46-79 mmHg).

There were no significant differences between the TCR and the non-TCR groups concerning gender, age, tumor side, tumor size, preoperative hearing status, MABP and preoperative medical diseases or medication.

Table 2 – Characteristics of 100 cases of vestibular schwannoma surgery

Characteristic	TCR Group (11 patients)	Non-TCR Group (89 patients)
Age	52.45 years	47 years
Range	35-68	18-74
Gender		
Male	3 patients	52 patients
Female	8 patients	37 patients
Antiarrhythmic Drugs		
Beta-blockers	1 patient	4 patients
Preoperative MABP	96.9 mmHg	102.6 mmHg
Range	81-120	76-138
Intraoperative MABP		
Maximal	91.7 mmHg	94.6 mmHg
Range	81-112	74-136
Minimal	46.2 mmHg	59.6 mmHg
Range	39-66	46-79

Within the TCR group 81.8% of the tumors were larger and occurred in the T3 and T4 classes.

Of the 11 patients with a TCR, 9 (81.8%) had large (T3-T4) tumors (3 cases of T3a; 1 case of T3b; 5 cases of T4a), and 2 (18.2%) had small (T1-T2) lesions (2 cases of T2;). Among these 11 patients, there were two preoperative deaf patients, which had large tumors (T4a).

Of the 89 patients without a TCR, there were 75 (84.3%) with large (T3-T4) (20 cases of T3a; 12 cases of T3b; 40 cases of T4a; 3 cases of T4b) and 14 (15.7%) with small tumors (T1-T2) (2 cases of T1; 12 cases of T2;). Of these 89 patients, 15 were preoperatively deaf (14 large tumors and 1 small

schwannoma). The distribution of the preoperative hearing status among the patients of both groups is summarized in tables 3, 4 and 5.

Table 3 – Group of patients with TCR – Distribution of the preoperative hearing function according to the tumor size.

Tumor Size	Preoperative Hearing				Preoperative	Total
	H1	H2	H3	H4	Deafness (H5)	
Small Tumors (T1-T2)	-	-	2	-	-	2
Large Tumors (T3-T4)	2	2	1	2	2	9
Total	2	2	3	2	2	11

Table 4 – Group of patients without TCR – Distribution of the preoperative hearing function according to the tumor size.

Tumor Size	Preoperative Hearing				Preoperative	Total
	H1	H2	H3	H4	Deafness (H5)	
Small Tumors (T1-T2)	4	5	2	2	1	14
Large Tumors (T3-T4)	6	17	22	16	14	75
Total	10	22	24	18	15	89

Table 5 – Distribution of the tumor size and hearing status in the TCR and non-TCR groups.

*The patients with preoperative deafness were excluded.

	Non-TCR	TCR
Tumor size		
Small	25%	18.2%
Large	75%	81.8%
Preoperative hearing		
H1-H2	36%	36.4%
H3-H4	47.1%	45.4%
Deafness	16.9%	18.2%

Eighty-three of the 100 patients had preoperatively functional hearing. Seventy-four of them had no TCR intraoperatively, 9 presented a TCR during surgery. With an overall hearing preservation of 47% (39 of 83 patients with preoperative classes H1-H4) (Table 6), 11.1% of the TCR group and 51.4% (38 of 74 patients) of the non-TCR group showed preserved hearing function postoperatively (Table 7,8,9 Figure 9).

Table 6 – Distribution of the postoperative hearing status according to the occurrence of TCR.

Postoperative Hearing Status	Group of operated patients with TCR	Group of operated patients without TCR	Total Rate
Preservation	1 (11%)	38 (51.4%)	39 (47%)
Deafness *	8 (88.9%)	36 (48.6%)	44 (53%)
Total	9 (100%)	74 (100%)	83 (100%)

Table 7 – Group of patients with TCR – Distribution of the postoperative hearing according to the tumor size.

*The cases of preoperative deafness were excluded.

Tumor Size	Postoperative Hearing				Postoperative	Total
	H1	H2	H3	H4	Deafness *	
Small Tumors (T1-T2)	-	-	1	-	1	2
Large Tumors (T3-T4)	-	-	-	-	7	7
Total	0	0	1	0	8	9

Comparing tumor sizes and postoperative hearing preservation there were some differences between the TCR and the non-TCR group:

Looking at all 61 patients with larger tumors in the non-TCR group (T3 - T4), 27 (44.3%) of them had their auditory function preserved, while in the TCR group, there were no patients with large tumors with postoperative hearing preservation (Table 10, Figure 10).

In the TCR group the overall preservation rate was 11.1% (1 out of 9 patients). The only case of preserved hearing was a class T2 tumor. As there were no class T1 tumors in this group at the same time, this lack of homogeneity in the group of small tumors between both groups makes it difficult to correlate these T1 and T2 tumors to hearing preservation.

In summary, the TCR and the tumor size influenced postoperative hearing function. Patients with an intraoperative TCR had significantly worse postoperative hearing function than those without a TCR during vestibular schwannoma surgery ($p = 0.005$, calculated by a stepwise logistic regression with a likelihood-ratio-test).

Table 8 – Group of patients without TCR – Distribution of the postoperative hearing evolution according to the tumor size.

*The cases of preoperative deafness were excluded

Tumor Size	Postoperative Hearing				Deafness	Total
	H1	H2	H3	H4	(H5)	
Small Tumors (T1-T2)	-	3	4	4	2	13
Large Tumors (T3-T4)	2	3	6	16	34	61
Total	2	6	10	20	36	74

Table 9 – Patients with TCR – Distribution of the tumor size and the pre- and postoperative hearing status.

Tumor Size	Preoperative Hearing					Postoperative Hearing					Total
	H1	H2	H3	H4	H5	H1	H2	H3	H4	H5	
T1	-	-	-	-	-	-	-	-	-	-	0
T2	-	-	2	-	-	-	-	1	-	1	2
T3a	2	1	-	-	-	-	-	-	-	3	3
T3b	-	-	-	1	-	-	-	-	-	1	1
T4a	-	1	1	1	2	-	-	-	-	5	5
T4b	-	-	-	-	-	-	-	-	-	-	0
Total	2	2	3	2	2	0	0	1	0	10	11

Table 10 – T3 and T4 tumors - Relation between the TCR and the postoperative hearing preservation. The postoperative hearing outcome was significantly worse in the patients with TCR ($p < 0.05$, calculated by a stepwise logistic regression with a likelihood-ratio-test)

Tumor size	Preoperative Hearing function	Postoperative Hearing Preservation
T3/T4 – TCR group	7	0 (0%)
T3/T4 – non-TCR group	61	27 (44.3%)

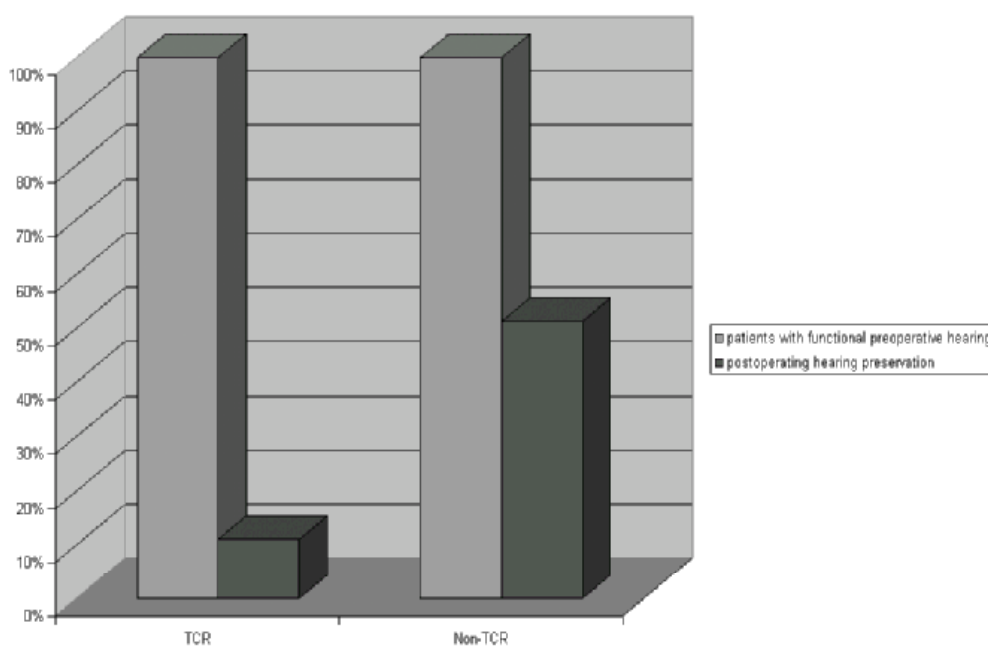


Figure 9 – Postoperative hearing preservation considering all tumor sizes. The difference between both groups was significant ($p < 0.05$, calculated by a stepwise logistic regression with a likelihood-ratio-test). The hearing outcome was worse in the TCR group.

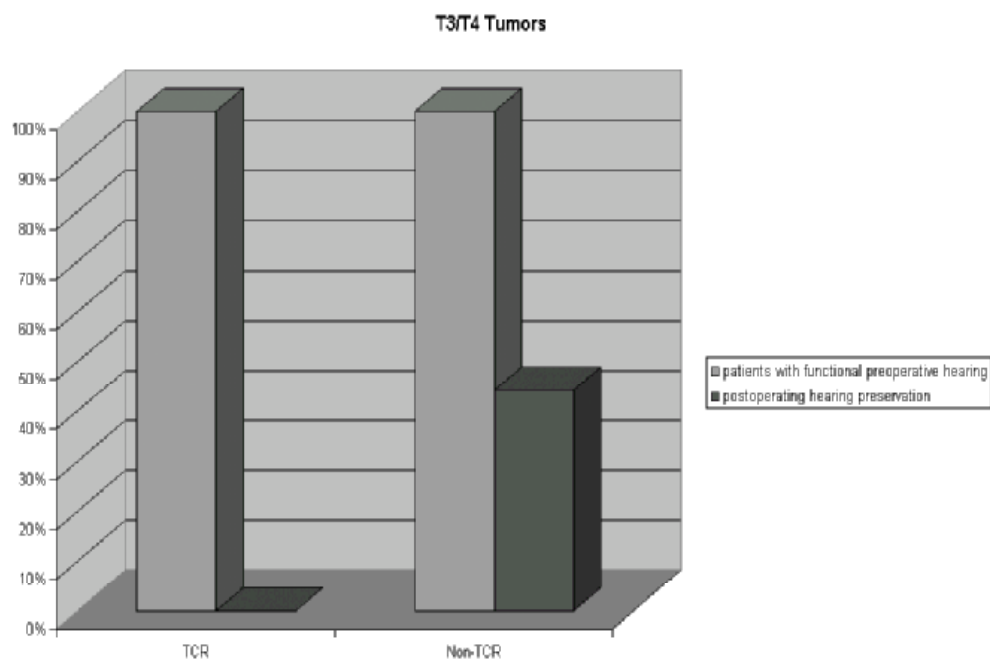


Figure 10 - Postoperative hearing preservation considering T3/T4 tumors. The patients with TCR had a significantly worse hearing outcome ($p < 0.05$, calculated by a stepwise logistic regression with a likelihood-ratio-test).

5. Discussion

The trigeminocardiac reflex is a phenomenon of hemodynamic instability due to cardiac output decrease that can be elicited by stimulating either the trigeminal nerve itself or any structure innervated by it (Barnard and Bainton 1990). After stimulation neuronal signals are sent to the sensory nucleus of the trigeminal nerve, constituting the afferent pathway of the reflex arc.

Through short internuclei fibers to the motor nucleus of the vagus nerve the efferent pathway is activated (Lang et al. 1991). Some of these efferent fibers terminate in the myocardium and act as cardioinhibitors leading to hypotension, bradycardia, asystolia, and also ventricular fibrillations through coronary vasospasm (Kariya et al. 1999). Other efferent fibers induce apnea or gastric hypermotility (Campbell et al. 1994) (Figure 11).

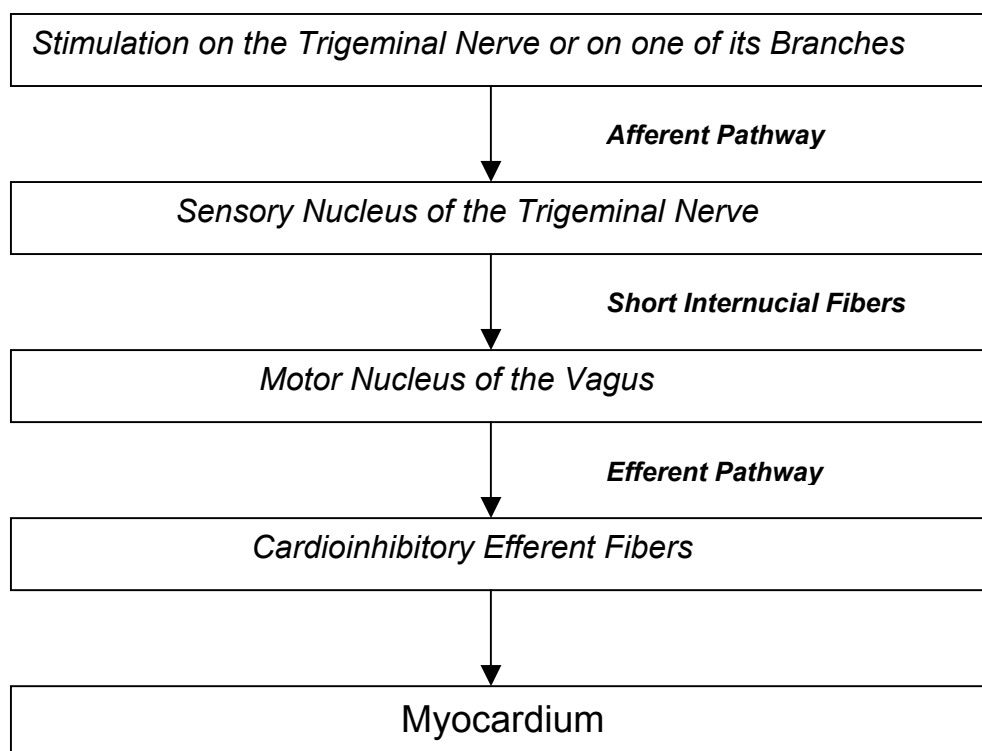


Figure 11 – Schematic diagram showing the mechanism of the TCR

Removing the triggering factor can cause the reflex to cease, raising the hemodynamic parameters to normal levels (Cha et al. 2002, Ragno et al. 1989) (Figure 12).

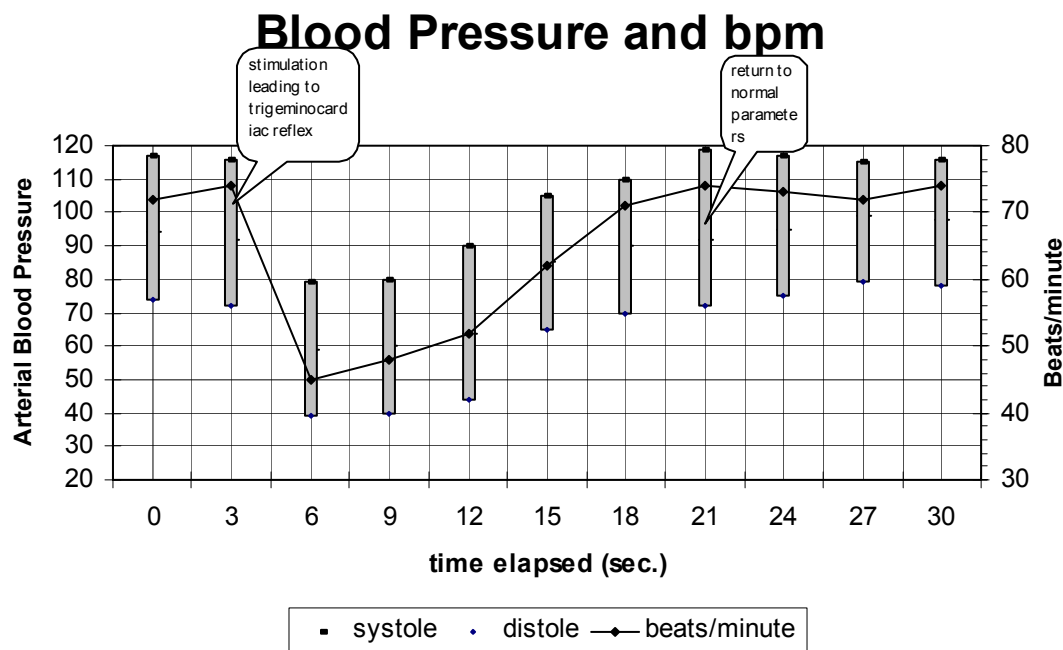


Figure 12 – Intraoperative monitoring of a patient in which a TCR was relapsed.

Kosaka et al. (Kosaka et al. 2000) reported a case of a patient who presented with bradycardia after a zygomatic fracture and was treated by an extra-corporal pacing which had to be performed for 20 days after the injury. Later the reduction of the zygomatic fracture improved the symptoms without any recurrence of the bradycardia. This example shows the direct cause-effect relationship, with the TCR reaction remaining as long as the stimulus is present. However, a decrease of the TCR is observed during repeated stimulation at short intervals (Chesley and Shapiro 1989, Lang et al. 1991).

Predicting the occurrence of TCR

The most important factor for the occurrence of the TCR is the intensity of the stimulation on the pathway. Traction is more likely to elicit the TCR when

performed rather abruptly and sustained than when it is smooth and gentle (Blanc et al. 1983, Lang et al. 1991, Schaller et al. 1999). Even intracranial manipulation of the trigeminal nerve is possible without inducing the reflex when performed gently (Cha et al. 2002).

The incidence of the OCR, elicited by stimulation of the ophthalmic division of the trigeminal nerve, is reported to be increased by the presence of hypoventilation, hypoxemia and acidosis (Yamashita 1986). Blanc et al. described hypoxia, hypercarbia and light anaesthesia as eliciting factors for the OCR (Blanc et al. 1983). Although the medial rectus muscle has been reported to be the most sensitive extraocular muscle in eliciting OCR, it may be due to its less accessible location, requiring more pulling for exposure (Miller 1994).

Arnold et al. (Arnold et al. 1994) found that patients having an OCR during eye surgery reacted in response to carotid sinus stimulation more severely with bradycardia than the control group. In strabismus surgery patients' gender, drugs used for narcosis (Sufentanil and Alfentanil) and preoperative medication (beta-blockers and calcium channel blockers) were found to be predictive factors for the occurrence of the OCR (Kim et al. 1999, Lang et al. 1991, Starr 1986).

An influence of preoperative medication with beta-blockers and calcium channel blockers on the occurrence of the TCR in cerebellopontine angle surgery was also reported by Schaller et al. (Schaller et al. 1999), a relationship that was not found in the present study.

In the present series more than 80% of the TCR occurred in larger tumors of classes T3 and T4. This can be explained by the close anatomical relationship of large vestibular schwannomas to the course of the trigeminal nerve in the cerebellopontine angle as well as by more traction and manipulation of the nerve during tumor preparation in these cases. The knowledge of the different ways to approach the CPA and the anatomy of the trigeminal nerve are

important to understand the relationship of the encountered neurovascular structures during vestibular schwannoma resection as well as during removal of other processes located in the CPA.

Methods Used in the Present Study

The present study aims to analyze the impact of intraoperative hypotension on the outcome of the auditory function in patients with vestibular schwannomas. As the trigeminocardiac reflex is a natural phenomenon, which occurs during the resection of some of these tumors, this was the mechanism selected for analysis. Since the incidence of TCR in vestibular schwannoma surgery is about 11% (as observed in this and past studies (Schaller et al. 1999)), a large number of patients was necessary to provide suitable statistical significance for the present research. Therefore, one hundred patients were prospectively analyzed in a center with standard monitoring and surgical techniques, thus providing a large number of patients and avoiding selection bias as well.

The influence of the studied parameters on postoperative auditory function was analyzed with a SPSS statistical package using a stepwise logistic regression with a likelihood-ratio-test in order to provide correct statistical analysis, since the TCR group had a lower number of patients than the non-TCR group. The statistical method used here allows adequate evaluation of the results, since it corrects potential distortions related to the different numbers of patients between both groups.

Choosing the Suboccipital Retrosigmoid Approach

The suboccipital retrosigmoid transmeatal via provides an ample approach to all size vestibular schwannomas, permitting facial nerve and hearing function preservation, and gives access to the brain stem and its vascular supply (Rhoton 1974).

Using the suboccipital via, an incidence of 93 to 99% anatomic preservation of the facial nerve has been achieved, with preservation rates of 100% in T1 class (intracanicular) and 96% in T2 class (intra-extrameatal) tumors (Samii and Matthies 1997 [1], Mazzoni et al. 1993).

The suboccipital and the middle fossa are the only approaches that permit hearing preservation.

Through the suboccipital route, anatomic cochlear nerve preservation is achieved in 79% to 96% of the patients with some preoperative hearing and functional hearing is preserved in 44 to 47% of the cases, with progressively increasing rates over years (Mazzoni et al. 1993, Samii and Matthies 1997 [1]).

In small tumors (class T1 and T2) with normal or good preoperative auditory function, rates of achieved hearing preservation range from 50 to 88% (Samii and Matthies 1997 [1], Rowed et al. 1997).

The auditory function preservation ranges from 13 to 64% in tumors class T3 and T4, with best results being found in patients with a good preoperative hearing (Samii and Matthies 1997 [1]).

Kumon et al compared tumors of 1 to 2 cm operated on by the retrosigmoid and middle fossa approaches, and demonstrated that the retrosigmoid via allowed higher rates of facial nerve and hearing preservation in these tumors, with hearing preservation rates of 47% for retrosigmoid and 0% for middle fossa routes (Kumon et al. 2000). The facial nerve was preserved in 87% of the cases in the first group and 50% in the second.

A higher incidence of postoperative headache has been related to the retrosigmoid via (Samii and Matthies 1997 [2]) when compared to the translabyrinthine and middle fossa approaches. However, it can be reduced with the use of cranioplasty or bone replacement routinely performed at the same surgical time of the tumor resection (Soumekh et al. 1996, Schaller and Baumann 2003, Koperer et al. Neurosurg 1999).

It is important to consider that the individual experience of the surgeon with each approach plays a fundamental role on the final surgical result; therefore

the surgical results among surgeons may vary enormously even when choosing the same approach.

Suboccipital Retrosigmoid Approach – Technical Considerations

The suboccipital approach is commonly used in the neurosurgical practice. It permits approaching the cerebellopontine angle, with the possibility of removal of different size tumors localized in the posterior cranial fossa. The cranial nerves on the posterior fossa may be visualized and preserved by this route. It is a simple and safe approach, with a minimum morbidity and mortality related to it when performed with meticulous surgical technique.

1. Semi-sitting Position

Three alternative surgical positions have been used to approach lesions of the cerebellopontine angle and further posterior cranial fossa by the suboccipital retrosigmoid via: The sitting or semisitting, the three-quarters prone and the supine position with the head turned.

The advantages of the semi-sitting position are favourable surgical approach, remarkable diminution in pooling of blood, improved drainage of liquor out of surgical site, better venous return, and diaphragm motility, endotracheal tube access and operator orientation (Samii et al 1988, Samii and Wild 1981, Fischler et al 1984, Papadopoulos et al 1994). Complete exposure and visualization of all structures in the posterior fossa and the possibility to perform the surgery continuously in a clean field, with the help of constant ring irrigation, provided by the assistant, are the most advantages for the surgeon and patient. With the use of irrigation, it is possible to maintain a clear surgical field and reduce the suction, which otherwise might traumatize the neurovascular structures of the posterior fossa (Samii et al 1988, Samii and Wild 1981). In the horizontal position, blood tends to accumulate in the operative field.

Conversely, the sitting position can present complication such as venous air embolism (VAE) and postural hypotension (Jellish et al 2002, Slbin et al. 1976), which can be reduced when operating the patient in the semi-sitting position (Gösseln and Suhr 1993).

VAE can occur in any operation with an open venous structure and a negative venous pressure gradient between the surgical site and the heart (Slbin et al 1978). Therefore, a higher incidence in the sitting or in the semisitting positioning is likely. However, any neurosurgical approach may lead to VAE, independent of the position. VAE has been reported to be associated with resection of convexity meningioma (Gómez-Perals et al. 2002, Frim DM et al. 1996), with cervical microdiscectomy (Wasnick et al. 1995), as well as with several procedures in the supine position (Gómez-Perals et al. 2002, Duke et al. 1998, Harris et al. 1987).

The incidence of VAE during posterior fossa surgery in the sitting/semisitting position varies in the literature, with reports ranging from 5 to 28% (Slbin et al. 1978, Duke 1998, Harris et al 1987, Kuo-Ning Shao et al. 1993). In an evaluation of 607 cases of posterior fossa lesions operated on with the patient in the semisitting position, the incidence of VAE was 6,5%. This incidence may range from 5% in patients with a normal jugular bulb, to 16% in patients with a high jugular one, when a retrosigmoid transmeatal approach is performed (Kuo-Ning Shao et al. 1993). The incidence of embolism in the supine position has been reported to range from 0-12% (Slbin 1978, Black 1988).

Duke et al. studied patients undergoing vestibular schwannoma resection, and demonstrated a 28% incidence of VAE when the patients were in the sitting position, compared to 5% in the supine position (Duke 1998). Nevertheless, the patients operated on in the supine position were monitored with less sensitive methods for detecting VAE than the other group, making the real difference probably lower. Despite of the higher incidence of VAE detection in the group of sitting position, the postoperative morbidity was similar between both groups.

Hypotension secondary to VAE was noted in 1,8% of the sitting patients and in 1,4% of the supine patients, also without significant difference. Concerning blood loss, it was greater in the supine group, despite the greater average tumor size in the group of sitting patients (Duke 1998).

These results were similar in other studies, which concluded that posterior fossa operations performed with the patients in the sitting position do not lead to serious hemodynamic changes and that venous air embolisms occur but are not associated with serious consequences (Zeilstra and Groen 1999).

Black et al. showed that hypotensive reactions of the blood pressure to be equally frequent in patients with horizontal positioning during operation (Black et al. 1988). The hypotensive reactions during positioning of the patient can be reduced with the following measures: semi-sitting instead sitting position, slow elevation, sufficient infusion of plasma expanders and electrolytic solutions, and compression stockings (Black et al. 1988, Samii, Draf 1989 [1]).

The morphological and pathological changes of the cervical cord associated with operations performed with patients in the sitting position have been described due to cases of quadriplegia following posterior fossa surgery (Buchheit and Delgado 1985, Hitzelberger and House 1980, Wilder 1982).

Flexion of the cervical spine occurring when the patient is positioned in the sitting position may stretch the spinal cord, altering the autoregulation of the spinal cord vasculature (Wilder 1982). Brieg demonstrated that when the neck moves from full extension to full flexion, the cervical spinal cord increases by a length up to 2,8 cm, and that it occurs principally at the C5 level (Brieg 1960).

Although extreme hyperflexion should be avoided in the sitting or semisitting position, quadriplegia may occur in patients operated in other positions, like in the prone one (Rau et al. 2002).

Potential venous bleeders may remain occult during operation in the sitting or semisitting position, may lead to a postoperative hematoma when the patient returns to a horizontal position (Greenberg 1997). It can be avoided with a

rigorous inspection of the operative site and of the bridging veins on the superior cerebellum during bilateral jugular compression, performed by the anesthetist, before closing the dura mater.

Kalfas and Little found no increased incidence of postoperative hemorrhage in the sitting position in their study with 4992 intracranial procedures (Kalfas and Little 1988).

Sciatic nerve compression has been reported as a complication of the sitting position (El-Rubaidi et al. 2003). The patient should be positioned over a soft and smooth surface to avoid pressure points on the nerve, and the knees should be flexed for reducing tension on the sciatic nerve due to piriformis syndrome (Brown et al. 1988).

Postoperative pneumocephalus is more commonly found after posterior fossa surgery in the semisitting or sitting position. However, in the majority of the cases, it resorbs spontaneously, without the need of additional interventions. Tension pneumocephalus may require drainage of the collected air.

The optimal exposure achieved by the retrosigmoid suboccipital approach in the semisitting position, associated with pre-, intra- and postoperative cares, which should be adopted by the surgeon, makes this approach the best, simplest and safest via to treat the majority of the affections of the CPA and of the remaining posterior cranial fossa, independent of the lesion size.

2. Preoperative Evaluation

Independent of the operated pathology, all patients should undergo a meticulous preoperative cervical spine investigation and a bone window CT study of the posterior fossa.

a. Cervical Spine Study

The preoperative anamnesis and neurological examination is directed to exclude signs and symptoms of cervical spine dysfunction, investigating the presence of radiculopathy or myelopathy.

Radiological functional examination of the cervical spine is carried out in all patients, verifying the presence of instability or deformities, which could be responsible for a postoperative deterioration of an incipient spinal pathology.

In the presence of cervical spine disorder demonstrated by the preoperative investigation, additional imaging studies, like myelotomography and/or MRI, should be performed. According to each case, treating the underlining spinal pathology before the posterior fossa affection should be considered.

b. Posterior Fossa Bone Window CT

Bone window CT is regarded as important before posterior fossa craniectomy to delineate the location of the sigmoid sinus related to pneumatization of the whole mastoid, as well as to identify the size of the lateral mastoid emissary vein, which drains into the sigmoid sinus. The patients undergo high-resolution CT using a 1,5-mm high-resolution slice technique by bone window.

The pneumatization of the mastoid is little in 12% of the male patients and 9% of the females, normal in 35% of the men and 50% of the women and extensive in 53% and 41% in the respective above cited gender groups (Matthies et al. 1997).

The identification of the grade of mastoid pneumatization orients for intraoperative location of the sigmoid sinus related to mastoid air cells, as well as provides data for the necessity of posterior closure with fibrin glue and muscle (Figures 13,14).

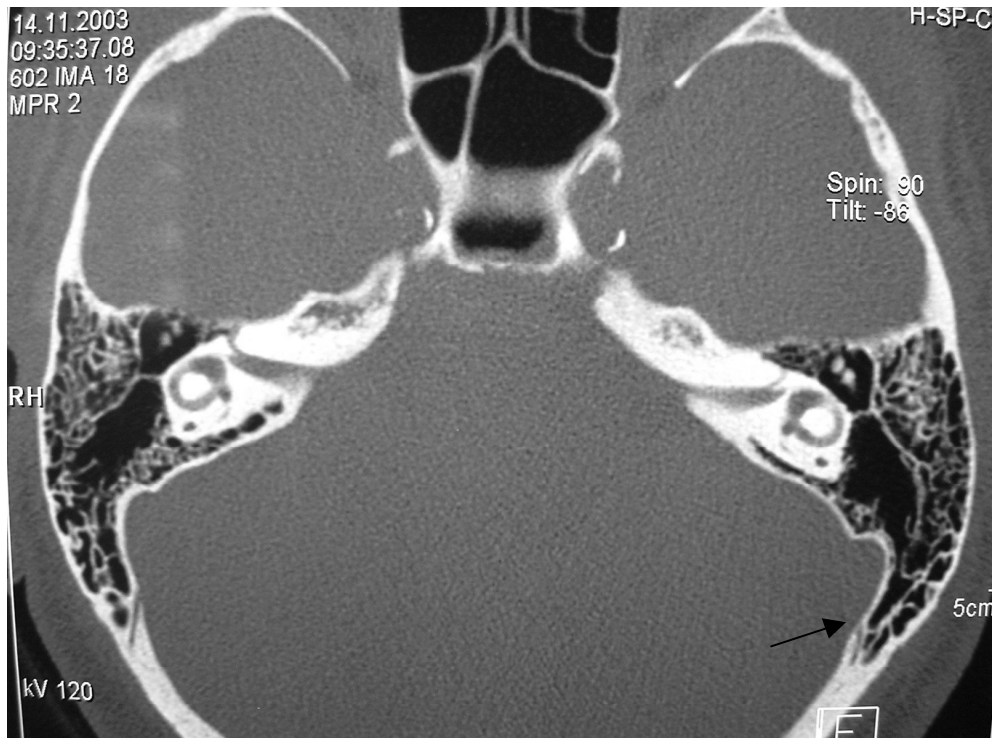


Figure 13 – Axial bone window CT showing the relation of the sigmoid sinus and the pneumatized mastoid cells. On the left side, the intraoperative identification of mastoid air cells corresponds to the proximity of the borders of the sinus (black arrow). Postoperative closing of the opened pneumatized bone with muscle and fibrin glue is indicated to avoid an internal fistula.

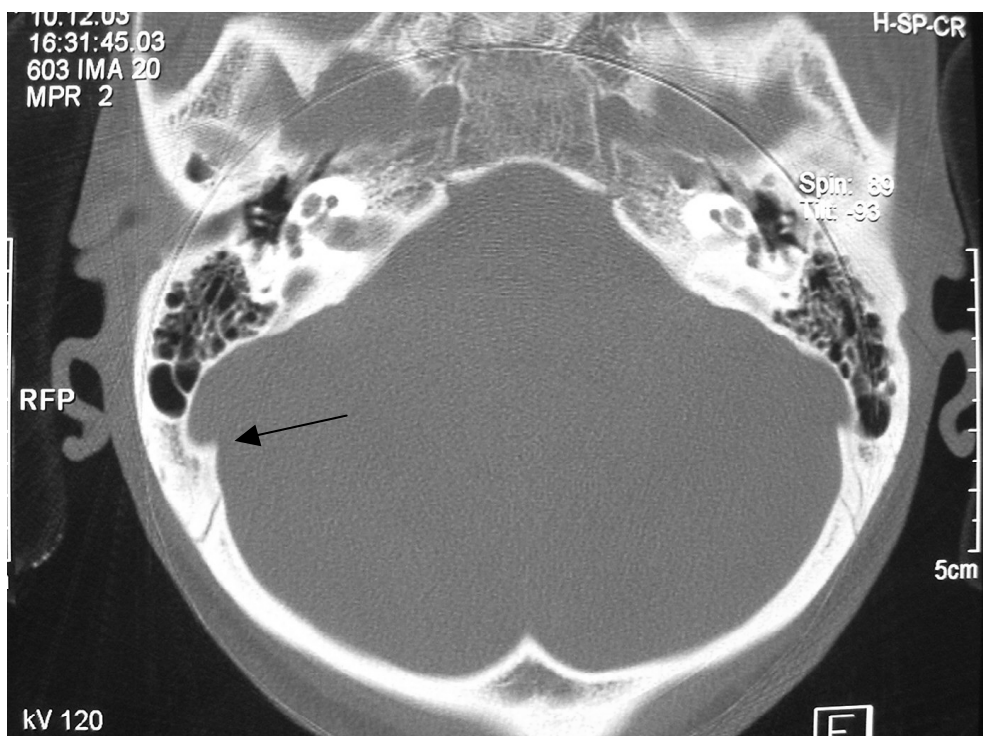


Figure 14 – Axial bone window CT - On the right side, no mastoid cells must be violated to expose the borders of the sigmoid sinus (black arrow).

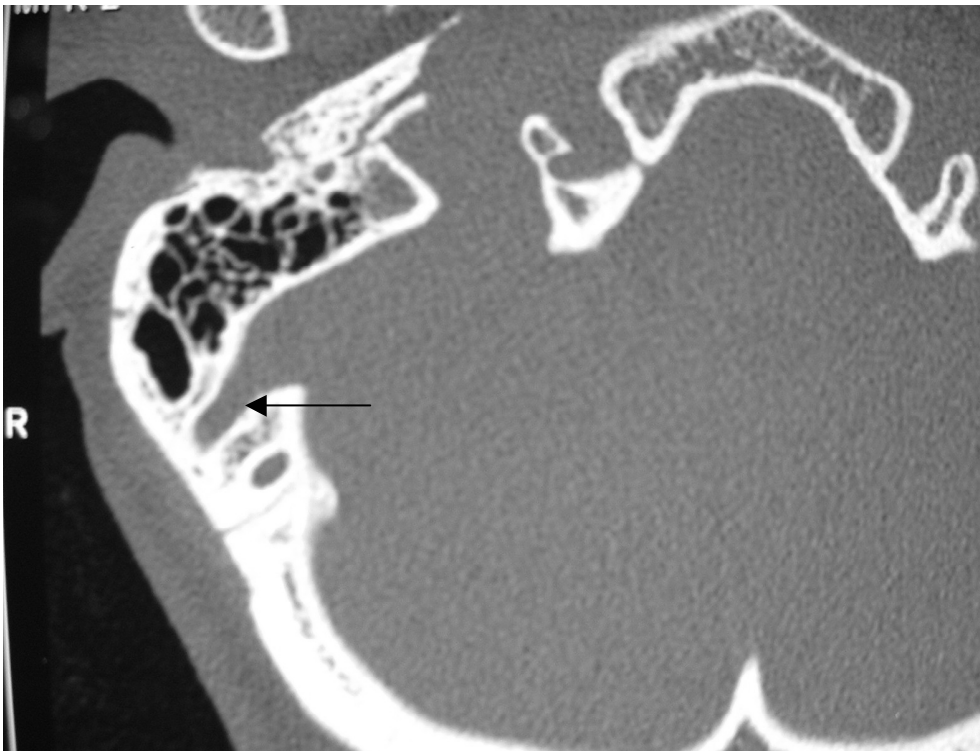


Figure 15– Axial bone window CT showing a large emissary vein (black arrow) draining into the right sigmoid sinus. Special intraoperative care should be taken in order to avoid a catastrophic laceration of the sinus during craniectomy.

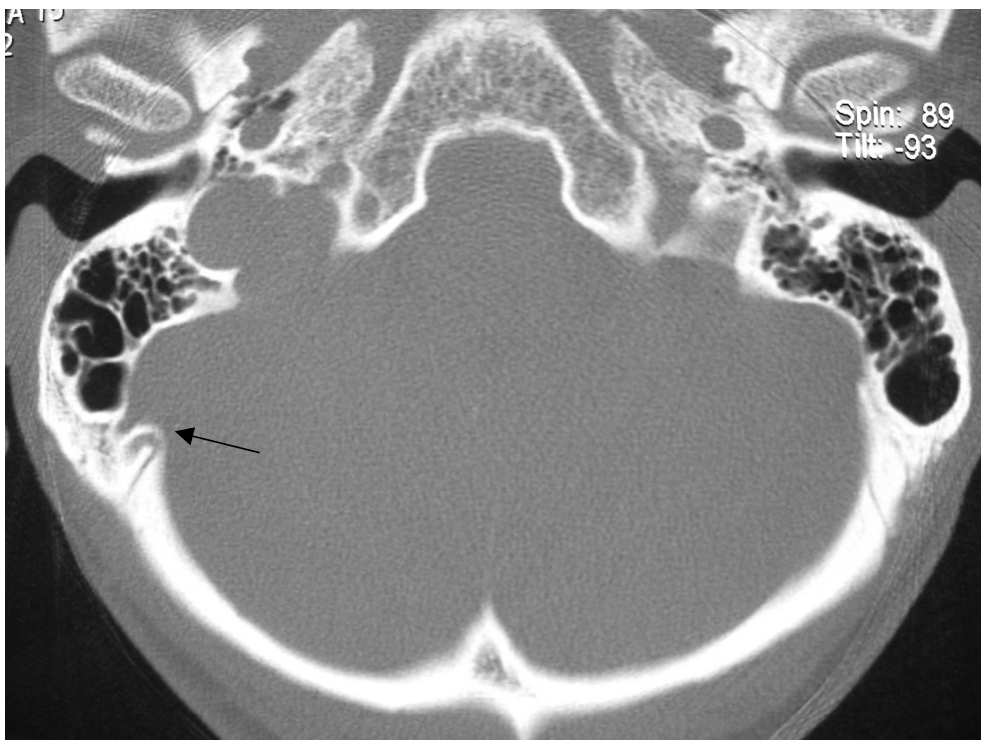


Figure 16 – Axial bone window CT demonstrating an emissary vein of medium caliber draining into the sigmoid sinus on the right side (black arrow).

The identification of the presence of a large emissary vein draining into the sigmoid sinus (Figures 15,16) in the preoperative bone window CT should alert to intraoperative care during the approach, concerning two important points:

- 1 - Special attention during the exposure concerning coagulating and dividing the vein, or waxing it at the bone, in order to avoid VAE.
- 2 – Special care during the craniectomy to avoid laceration of the sigmoid sinus due to unsuitable traction of the vein.

3. Intraoperative Monitoring

All patients that undergo a suboccipital retrosigmoid approach are rigorously monitored by constant SSEP, as well as monitored concerning detection and treatment of VAE. Additional cranial nerves monitoring are selected according to the respective pathology.

The SSEP alerts the occurrence of cervical myelopathy during positioning, and can help to reduce or avoid the occurrence of cervical spine injury secondary to hyperflexion. The SSEP electrodes are installed before the patient is placed in the semisitting position and his head become immobilized in a Mayfield frame. If during positioning of the patient, a dysfunction of the previous noticed SSEP waves is verified, the head must be repositioned. It should be stressed that the waves cannot become altered due to the position, without a corresponding repositioning. Otherwise, devastating neurological deficit may occur and be identified after the surgery.

VAE monitoring techniques and related ones, routinely used, comprise precordial Doppler echocardiography, end-tidal CO₂, electrocardiogram, right atrial pressure via a central venous catheter, and capnometry. A right atrial catheterisation is performed to aspirate air from the heart during VAE.

Paradoxical air embolism can occur in the presence of a patent foramen ovale, or pulmonary arterio-venous fistula, with the risk of producing a cerebral

ischemia. Therefore, manoeuvres of Valsalva, which may possibly increase right-to-left shunting phenomena, are contraindicated at the detection of VAE.

4. Positioning

After the institution of the general anesthesia, with continuous SSEP monitoring, a Mayfield head-holder three-point fixation is installed. On the operated side, a single pin is placed above the superior temporal line and anterior to the external acoustic meatus, avoiding the presence of a disturbing pin on the way of the operative site. On the contralateral side, two pins are installed, one on the frontal and other on the parietal region, above the superior temporal line and avoiding pins on the forehead.

The patient is placed in the semi-sitting position, with amply padding of the lower extremities and attention to potential points of compression on nerves and arteries of the patient. The legs are raised above of the cardiac level and both knees are slight flexed.

The head is positioned, turned toward the affected side and associated to a slight cervical flexion (Figure 17). This position is achieved following 3 steps described below:

- 1 – Lightly tilt forward
- 2 – Turn 30° toward the affected side
- 3 – Light tilt to the contralateral side

The surgeon should be able to place his hand between the chin and manubrium, thus allowing an unobstructed trachea, adequate venous return and free access for the anesthetist to perform jugular compression.



Figure 17 - The semisitting or lounging position: head turned to operative side associated to mild neck flexion; the legs are elevated above of the heard level.

5. Incision and Craniectomy

The vertical skin incision is placed 2 cm medial to the mastoid, beginning on the level of the top of the pinna, and extends inferiorly up to the mastoid tip (Figure 18). This length is sufficient to expose the transverse sinus superiorly and the inferior curve of the basal posterior cranial fossa inferiorly.

The musculature is incised vertically with a knife, following the skin incision. The veins should be promptly coagulated and divided. The lesser occipital nerve should be dissected and preserved if possible. Otherwise it should be coagulated before incised to avoid neuralgia of the respective nerve. The occipital artery, which originates from the posterior wall of the external carotid artery, runs from anterolateral to posteromedial, coursing in the medial part of the mastoid notch (medial to the posterior belly of the digastric muscle),

passing deep or superficial of the longissimus capitis muscle, to course between the semiespinalis capitis and the splenius capitis muscle. At this point, the artery is normally found during the muscular incision, and it is cauterised and divided.

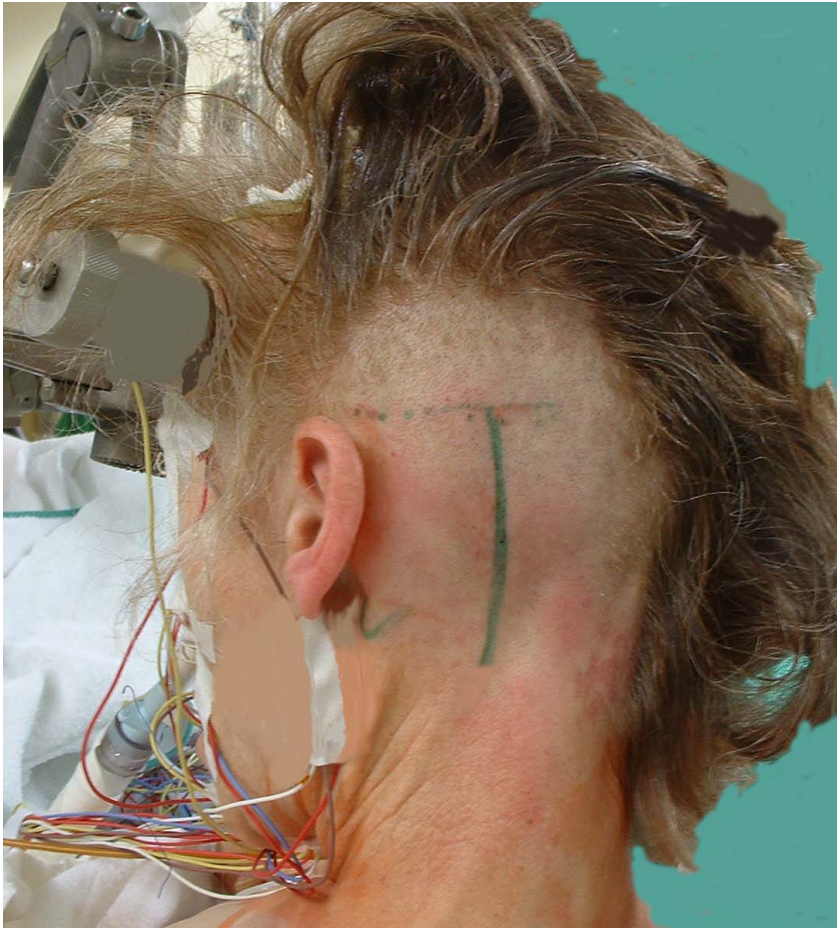


Figure 18 – Left-sided suboccipital retrosigmoid approach - The vertical skin incision is placed 2 cm medial to the mastoid, beginning on the level of the top of the pinna and extends inferiorly up to the mastoid tip.

The occipital bone and the mastoid are exposed, and the emissary vein, which has been studied previously by the bone window CT, is coagulated and divided or waxed at the bone. The exposition of the occipital bone is carried out caudally up to the inferior curve of the skull, without the need of further dissection, to avoid unnecessary risk of injuring the vertebral artery. At the superior limit of the exposure, the asterion, which consists of the junction of occipitomastoid, parietomastoid and lambdoid sutures, is identified (Figure 19).

It represents the landmark to localize the transition of the transverse and sigmoid sinus. One or more burr holes are performed with a drill inferiorly and medial to the asterion, and the craniectomy is amplified with rongeur until the borders of the sigmoid and transverse sinus become visible. Inferiorly, the curvature of the skull should be removed to provide an adequate exposure of the lower cranial nerves and of the basal cisterns, as well as to permit free access to the microinstruments and to the hands of the surgeon. The medial extension of the craniectomy is carried out up to 2,5 to 3 cm. In the surgical treatment of intrameatal processes, the medial extension can be increased to permit a better angle of visualization (Figure 20).

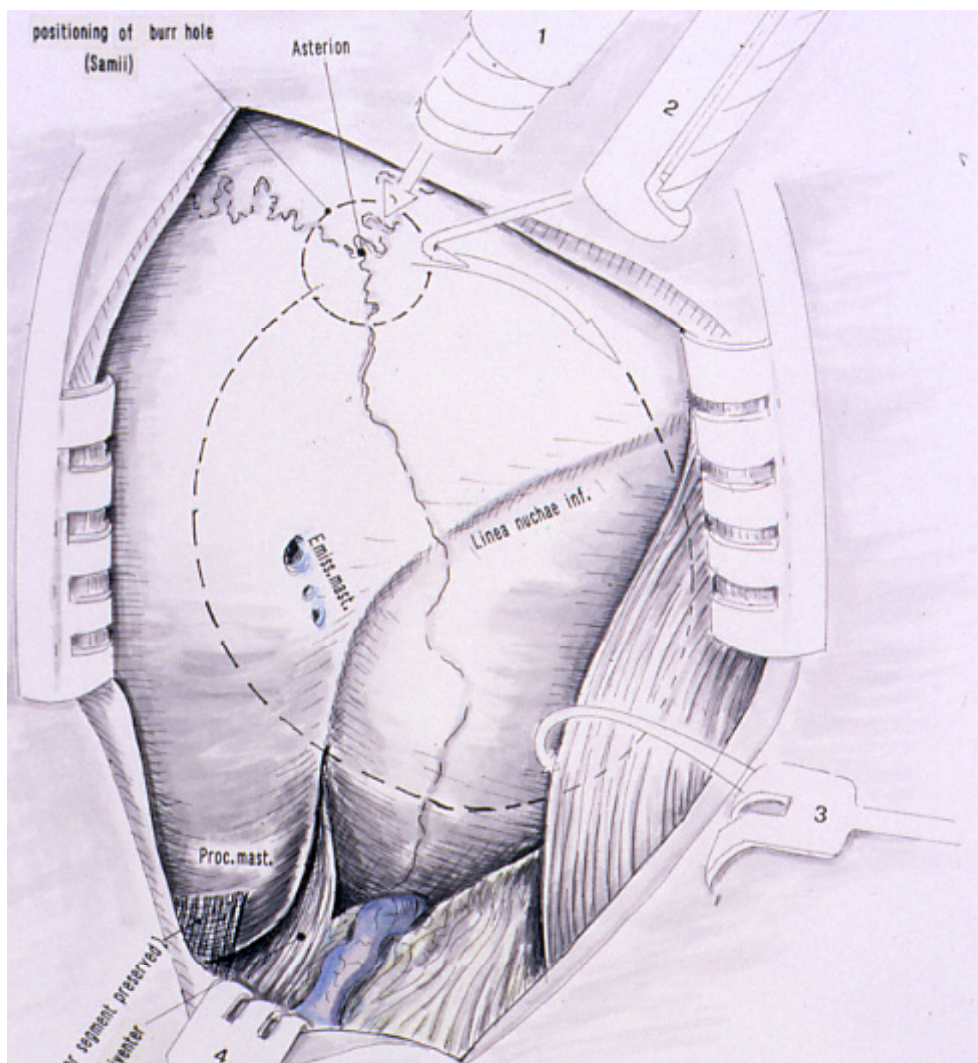


Figure 19 – Left side: Bone exposure after skin, subcutaneous tissue and musculature opening. The asterion is visualized (courtesy Prof. Dr. Seeger).

Craniotomies in the retrosigmoid approach are avoided due to the risk of injuring the sigmoid sinus. They are reserved for young patients, with lesser adhesion of the dura to the bone and with the presence of osseous growing due to age, without the evidence of a large emissary vein on CT.

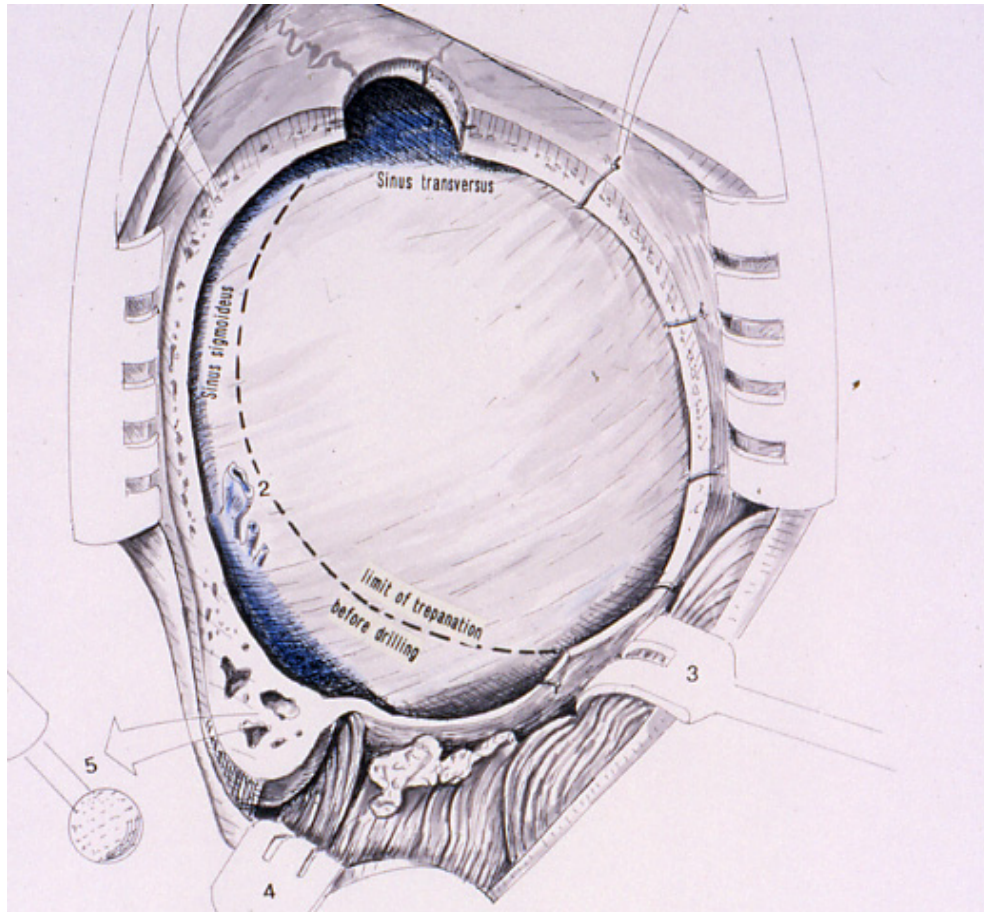


Figure 20 – Left Side: The sigmoid and transverse sinuses are the lateral and superior limits of the suboccipital retrosigmoid craniectomy, respectively (courtesy Prof. Dr. Seeger).

Before opening the dura, jugular compression is performed to identify precisely the limits of the sinuses and to detect eventual sinus wall lacerations. Points of potential sources of VAE, identified during the approach, should be managed with copious saline or Ringer irrigation, jugular compression by the anesthetist, and closing of the entry point.

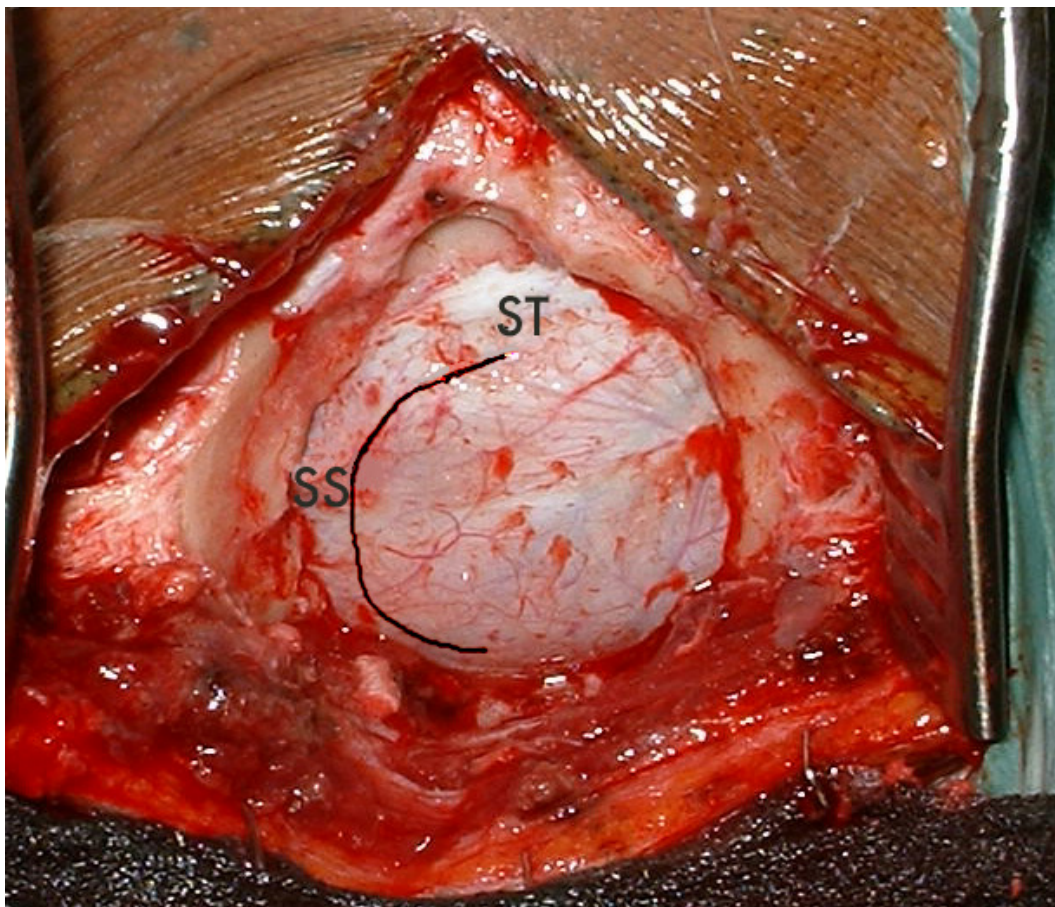


Figure 21 – A left-sided retrosigmoid suboccipital craniotomy – The borders of the transverse and sigmoid sinus are exposed. The dural incision, which is opened in a C-shaped fashion with a medially based flap, is indicated. The opening is performed near of the sinus borders, leaving a little dural flap laterally for posterior closing. ST – Transverse sinus; SS – Sigmoid sinus;

The dura is opened, under visualization of the operating microscope, in a C-shaped fashion, with a medially based flap. The opening is performed near of the sinus borders, leaving a little dural flap laterally for posterior closing (Figure 21). The cerebellomedullary cistern is opened, permitting withdraw of liquor and reducing the intracranial pressure (Figure 22). With the additional room gained by the surgeon with this measure, the cerebellum is then held by the retractor medially, and the pathology is exposed in the CPA. The lateral dural flap is retracted laterally with the dural sinus, using traction sutures. The technique for tumor removal is demonstrated in the figures 23 to 27.

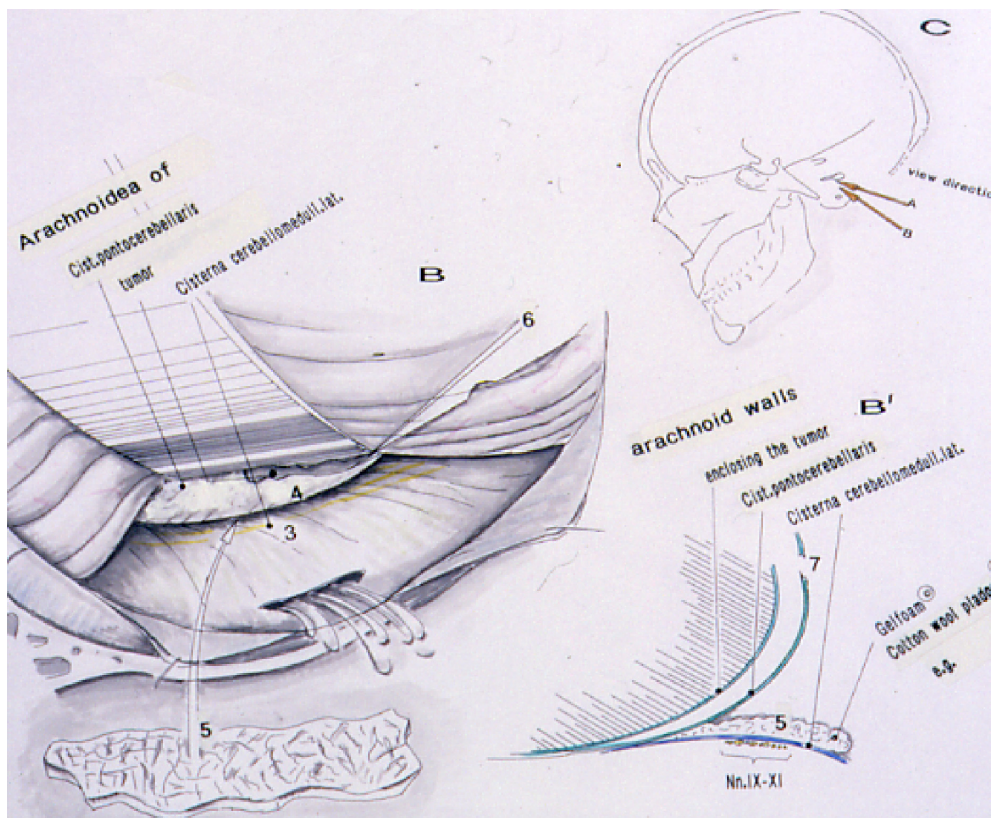


Figure 22 – Opening of the cisterns in order to provide liquor release and reduction of the cerebellar tension (courtesy Prof. Dr. Seeger).

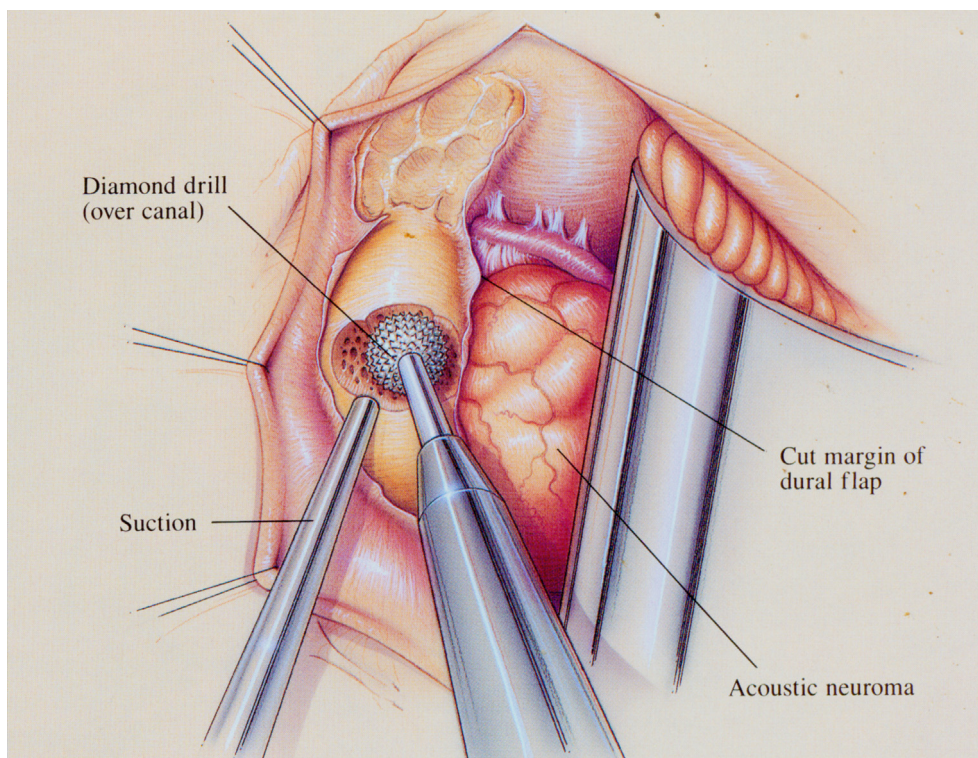


Figure 23 – After initial opening of the internal auditory canal, a diamond drill is used for further opening the canal (Samii and Tatagiba 1994 – with permission).

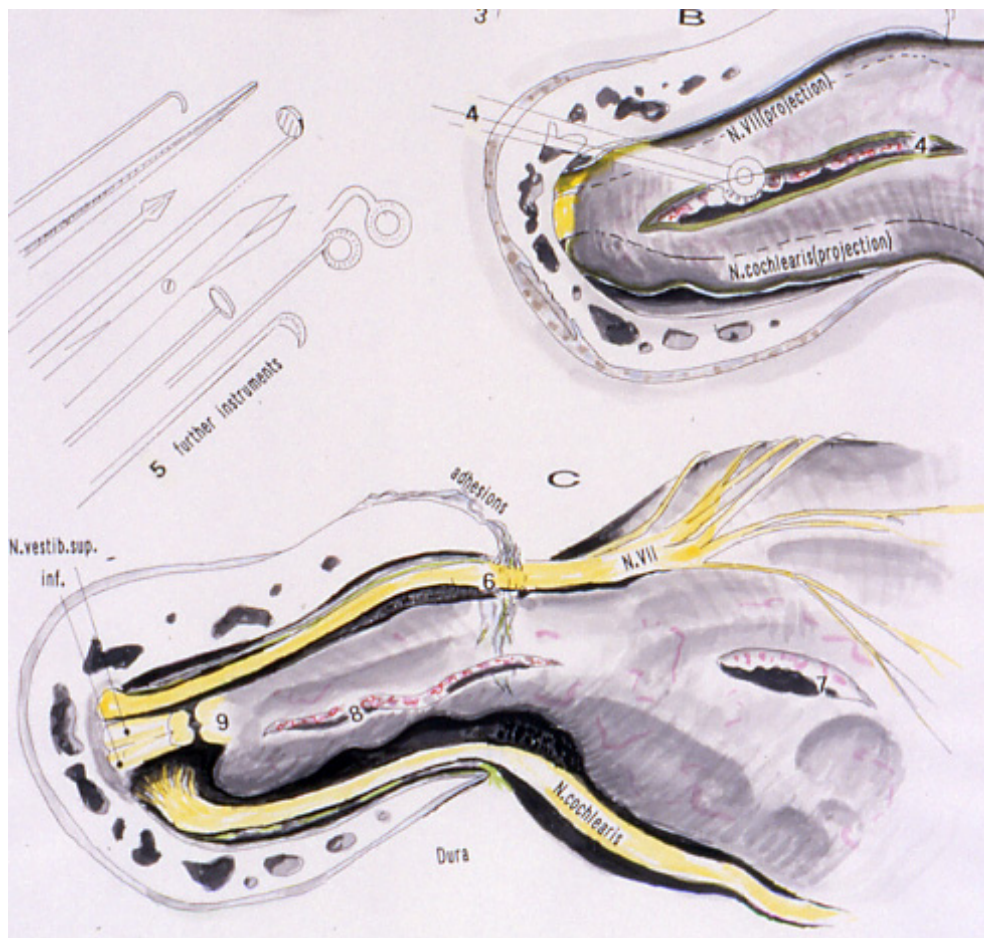


Figure 24 – The meatal dura is opened and the intrameatal tumor is decompressed in order to allow exposure of the intrameatal portion of the facial nerve (courtesy Prof. Dr. Seeger).

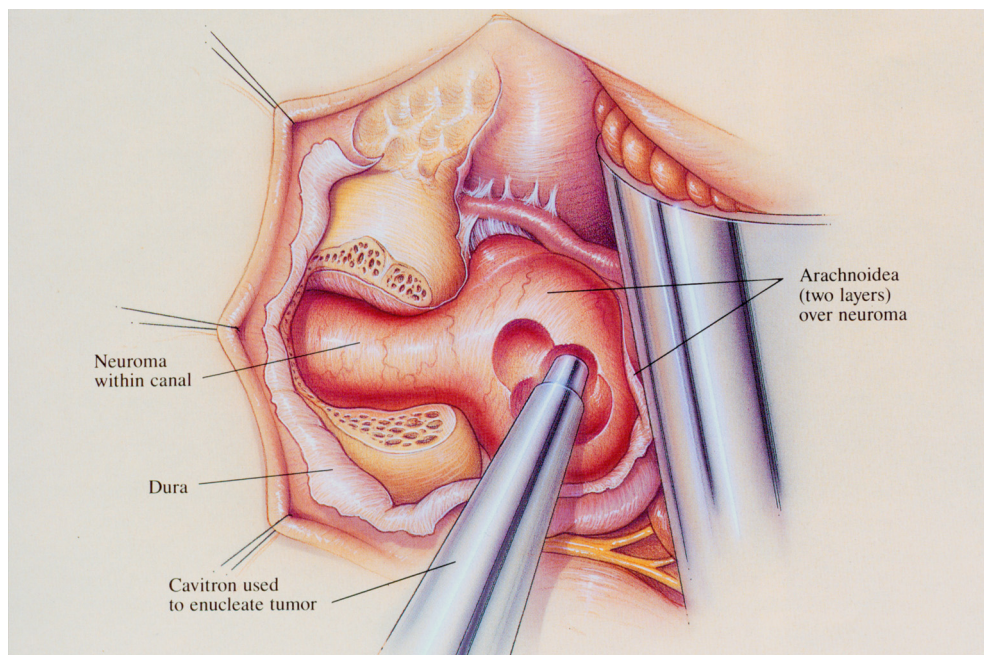


Figure 25 – The next step after opening the internal auditory canal and exposing the distal portion of the facial nerve, is to reduce the tumor volume (Samii and Tatagiba 1994 – with permission).

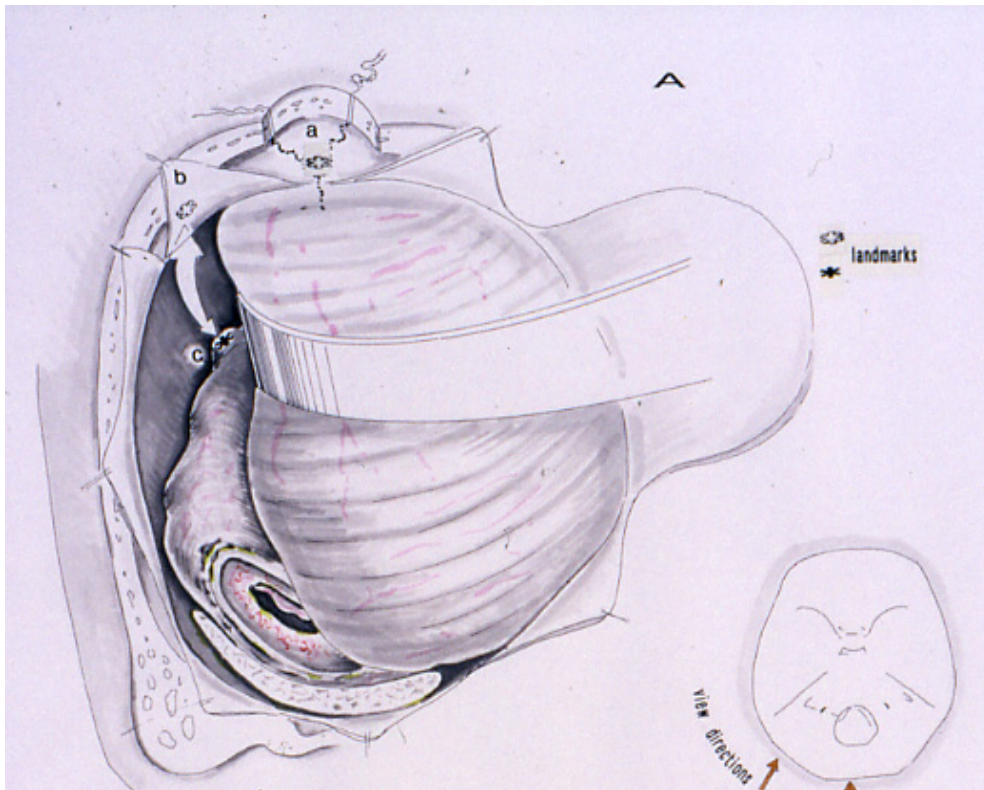


Figure 26 – The tumor is progressively debulked and reduced in size (courtesy Prof. Dr. Seeger).

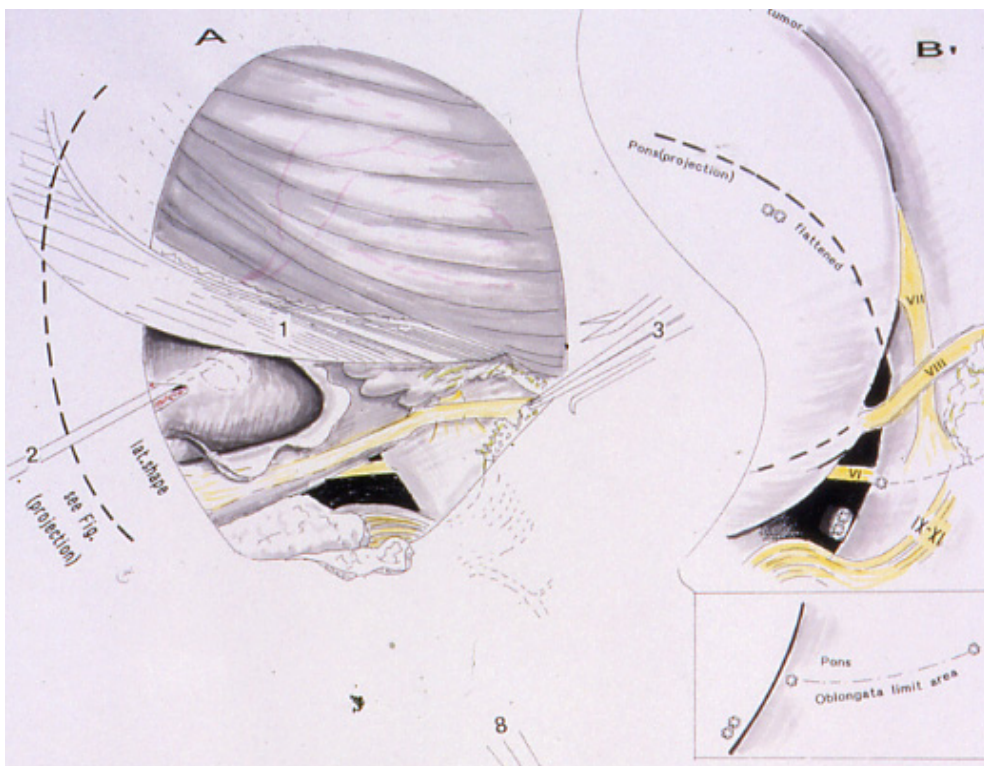


Figure 27 – The tumor is removed attempting to preserve the facial nerve, as well as the cochlear nerve when preoperative hearing function is present (courtesy Prof. Dr. Seeger).

6. Closure

The sitting or semisitting position creates a negative pressure in the venous system. Thus, collapsed veins may be ruptured during the surgery without correspondent bleeding. The ruptured vein may remain not recognized by the surgeon until the end of surgery, when the patient is brought to the horizontal position and a postoperative hemorrhage may occur, with potential catastrophic consequences.

Therefore, a meticulous hemostasis must be achieved before closing the dura. Jugular compression is performed by the anesthetist and the operative site is rigorously inspected, as well as the superior cerebellar veins, which may rupture due to intraoperative liquor release and consequent fall down of the cerebellum.

Intradural-drilled bones are closed with muscle and fibrin glue to avoid an internal fistula (Figure 28). The dura mater is closed in a watertight fashion with continuous suture and an additional muscle layer can be glued on the dural incision to reinforce the closure when necessary (Figure 29). The opened mastoid cells are sealed with a piece of muscle and fibrin glue.

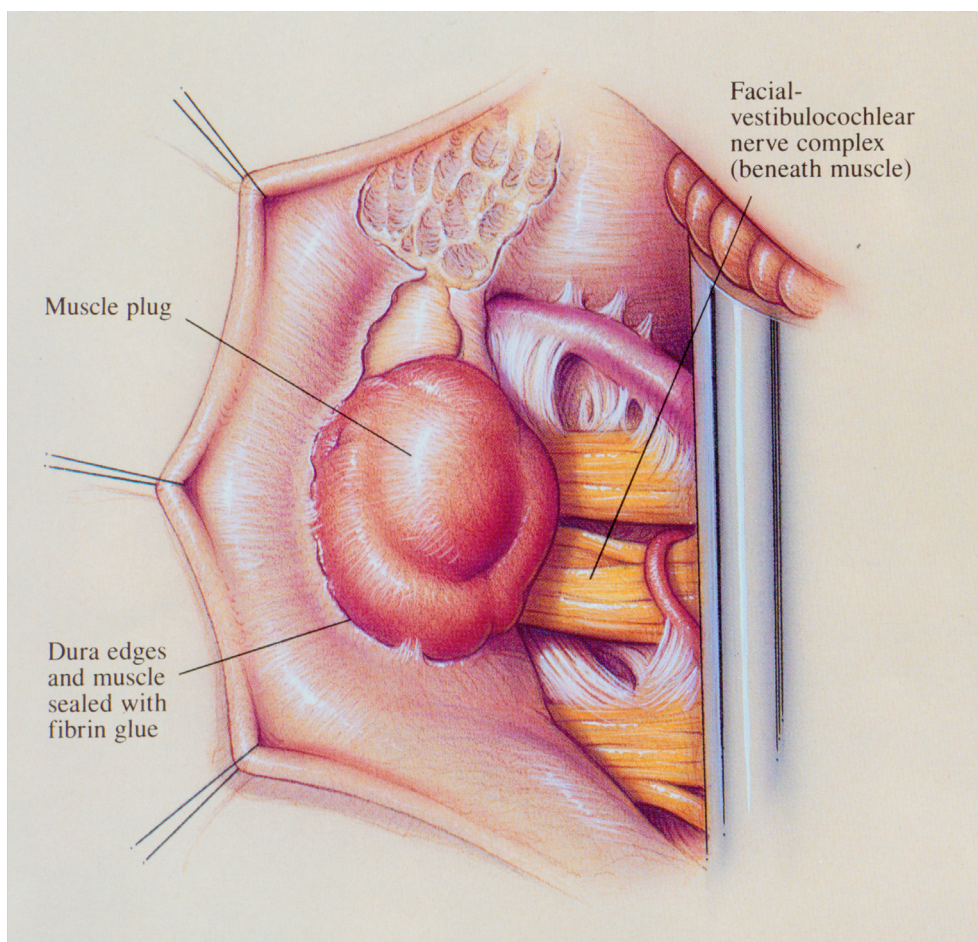


Figure 28 – After tumor resection by the suboccipital approach, the opened internal auditory canal is closed with muscle and fibrin glue (Samii and Tatagiba 1994 – with permission).

Cranioplasties reconstructing the normal shapes of the posterior skull base should be performed in all patients, using bone cement (methylmethacrylate). The prevalence of postoperative headache is significantly higher in patients who underwent suboccipital approach without osseous replacement (Soumekh et al. 1996, Schaller and Baumann 2003, Koperer et al. 1999). Dural adhesions to nuchal muscles or to subcutaneous tissues may be responsible to postoperative pain, due to traction of dural structures secondary to neck movement. Craniotomies with bone flap replacement or craniectomies with cranioplasty at the same operative procedure may prevent or reduce the incidence of postoperative headache in the retrosigmoid suboccipital approach. The muscles are closed in separately layers, and the subcutaneous and skin closures are completed. No drains are used. The wound is dressed in a standard fashion.

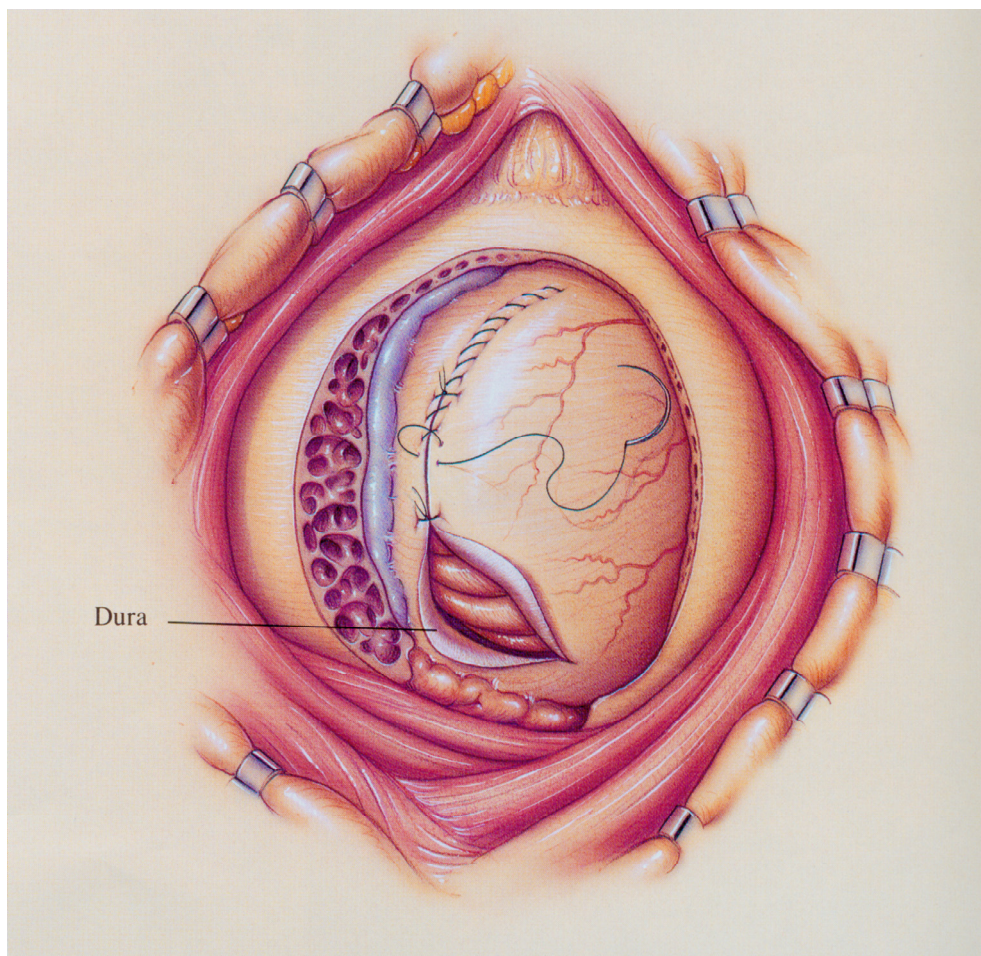


Figure 29 – Dural closure in a watertight fashion by the suboccipital retrosigmoid approach (Samii and Tatagiba 1994 – with permission).

Operating in the Semi-Sitting Position

The advantages of the semi-sitting position make it the favorable surgical approach due to a remarkable diminution in pooling of blood, improved venous return, and diaphragm motility. Complete exposure and visualization of all structures in the posterior fossa and the possibility of operating continuously in a clean field are most advantageous for the surgeon and patient. The use of irrigation with the help of “the third hand,” maintains a clear surgical field and reduces the necessity for suction, which might traumatize the neurovascular structures of the posterior fossa (Samii et al. 1988, Samii and Wild 1981).

On the other hand, the sitting position may present complications such as venous air embolism and postural hypotension (Jellish et al. 2002, Sibin et al

1976), which can be reduced when operating the patient in the semi-sitting position, instead the sitting one (Gössenl and Suhr 1993).

Black et al. (Black et al. 1988) described hypotensive reactions of the blood pressure to occur as often in patients operated in horizontal position as in semi-sitting position. The hypotensive reactions during positioning of the patient can be reduced with the following measures: semi-sitting instead of sitting position, slow elevation, sufficient infusion of plasma expanders and electrolytic solutions, and application of compression stockings (Gössenl and Suhr 1993).

Based on the same definition of TCR used in the present study, Schaller et al. (Schaller et al. 1999) observed this phenomenon in 14 of their 125 patients (11%) who underwent cerebellopontine angle tumor surgery in the supine position. Beside the same incidence of the TCR, with 11 of 100 patients (11%) in the present study, the minimal MABP found in both groups was also similar (44 mmHg in Schaller's series vs. 46.2 mmHg in our series). Thus, patient's intraoperative positioning seems not to be a relevant factor for the occurrence of the TCR.

Surgical Results of the Different Approaches to the CPA

Using the suboccipital approach, an incidence of 93 to 99% anatomic preservation of the facial nerve has been achieved, with preservation rates of 100% in T1 tumor class (intra-canalicular) and 96% in T2 tumor class (intra-extrameatal) tumors (Samii and Matthies 1997 [3], Mazzoni et al. 1993).

Anatomic facial nerve preservation rates of 94-95% are reported using the translabyrinthine-transotic approach, with the necessity for facial reanimation in 10% of the cases (Pellet et al. 1993, Braam and Nicolai 1993, Chen and Fisch 1993).

In the treatment of small lesions through the middle fossa approach a normal facial function is found in 70-80% of the cases (Haid and Wigand 1992). A

lower incidence of transient facial nerve dysfunction is reported in the suboccipital approach compared to the middle fossa route (Glasscock et al. 1993). Satar et al showed that the rates of facial preservation by this route depends on the size of the tumor, ranging from 98.9% for intracanicular tumors, 93,9% for 10-19mm tumors, to 85,6% for 10-19mm (Satar et al. 2003). Satar et al also compared the results of removal of vestibular schwannomas operated on by the translabyrinthine and middle fossa approach, demonstrating that although there is the possibility of hearing preservation by the middle fossa route, it implies in a higher risk of facial nerve injury in tumors larger than 10 mm (Satar et al. 2003). Arriaga et al analyzed patients that underwent translabyrinthine and middle fossa approach and found similar results regarding facial nerve preservation in tumors measuring 1,5 cm or less (Arriaga et al. 1994). In the resection of large tumors by the middle fossa via, excellent facial function was obtained in 78% of the cases, persistent paralysis was found in 6% and radicality was achieved in 96% of the patients (Haid and Wigand 1992).

Through the suboccipital route, anatomic cochlear nerve preservation is achieved in 79% to 96% of patients with some preoperative hearing and functional hearing is preserved in 44 to 47% of the cases, with progressive increasing rates (Mazzoni et al. 1993, Samii and Matthies 1997 [1]).

In small tumors (class T1 and T2) with normal or good preoperative auditory function, rates of achieved hearing preservation range of 50 to 88% (Samii and Matthies 1997 [1], Rowed et al. 1997).

Using the middle fossa approach, hearing preservation rates have been reported from 31 to 59% in long term studies (Wade and House 1984, Shelton et al. 1989, Shelton et al. 1989). Sanna et al obtained better results by using the middle fossa route than by using the suboccipital via (50 versus 29% preservation), although they apparently had more experience with the first approach (Sanna et al. 1987). Other study reported compared intracanicular tumors operated on by these two routes, demonstrating a hearing preservation rate of 57% for middle fossa and 47% for suboccipital approaches (Sanna et al. 1987).

Wigand et al demonstrated the removal of large vestibular schwannomas (up to a size of 30 mm) by an extended middle fossa approach in a study of 190 patients (Wigand 1989). The auditory function preservation rates by the enlarged middle fossa route are reported up to 59% (Kanzaki et al. 1989, Stidham et al. 2001). Others authors, which removed tumors up to 20 mm by the enlarged middle fossa via, described that hearing preservation in large tumors (larger than 15-20mm) is best achieved by the suboccipital via (Cohen et al. 1986, Gardner and Robertson 1988). Many authors report that by the extended via, the hearing preservation drop to almost 0% when tumors larger than 20 to 30mm are operated. Using the suboccipital via, the auditory function preservation ranged from 13 to 64% in tumors class T3 and T4, with best results being found in patients with a good preoperative hearing (Samii and Matthies 1997 [1]).

Kumon et al compared tumors of 1 to 2 cm operated on by the retrosigmoid and middle fossa approaches, and demonstrated that the retrosigmoid via allowed higher rates of facial nerve and hearing preservation in these tumors, with hearing preservation rates of 47% for retrosigmoid and 0% for middle fossa routes (Kumon et al. 2000). The facial nerve was preserved in 87% of the cases in the first group and in 50% of the cases in the second.

Regarding the occurrence of cerebrospinal fluid leaks, Hoffman compared patients with vestibular schwannomas that were treated by the retrosigmoid transmeatal approach and by the translabyrinthine via, and did not find significant differences between both groups (16% versus 21%) (Hoffman 1994). In the translabyrinthine approach, the incidence of cerebrospinal fluid leaks has been reported to be from 6,8 to 17% of the cases, with 1,5 to 2,9% incidence of meningitis (Ramsay and Luxford 1993, Rodgers and Luxford 1993). Celikkanat et al related that 75% of the patients with a cerebrospinal fluid leakage operated on by the translabyrinthine via underwent another surgery to control the fistula (Celikkanat et al. 1995). The incidence of a fistula using the suboccipital approach has been reported to be from 6 to 9,2 % of the patients,

while meningitis occurred in 1,2 to 2,2 % of the cases (Mazzoni et al. 1993, Celikkanat et al. 1995, Samii and Matthies 1997 [2]). Bani and Gilsbach reported that 3 of 14 cases of patients with fistulas operated on by the suboccipital via required a second surgery for closing the cerebrospinal fluid leak (Bani and Gilsbach 2002).

By the extended translabyrinthine-transotic approach, the reported mortality was 1 of 147 patients (Chen and Fisch 1993), while the mortality by the suboccipital approach was reported to be 11 deaths among 1000 patients (Samii and Matthies 1997 [2]). Pellet et al described 228 patients operated on using the translabyrinthine (85% of the cases) and the middle fossa approach (15%) (Pellet et al. 1993). The mortality was 1,75%. Kanzaki et al reported a 1,9% (3 of 160 cases) mortality rate in the treatment of vestibular schwannomas by the extended middle fossa approach, two of them related to very large tumors (Kanzaki et al. Acta Otolaryngol Suppl 1991).

In an analysis of the results of the surgical treatment of 120 large vestibular schwannomas by using the combined translabyrinthine-transtentorial approach a total tumor removal was achieved in 92% of the cases, with 20% of facial nerve injury, 10% meningitis, 20% aphasia, with cases of hemiparesis and permanent seizures (Sluyter et al. 2001). Regarding the facial function, 56% of the cases had a House-Brackmann Grade I or II in the long-term follow-up. Hearing in this series of patients occurred due to the nature of the translabyrinthine approach.

Anatomy of the Trigeminal Nerve and TCR in Skull Base Surgery

The occurrence of the TCR during surgical procedures in the anterior, middle and posterior skull base is directly related to the intra- and extracranial course of the trigeminal nerve. Being aware of the anatomical relationships may reduce manipulations of this nerve when performing the approach or during tumour dissection.

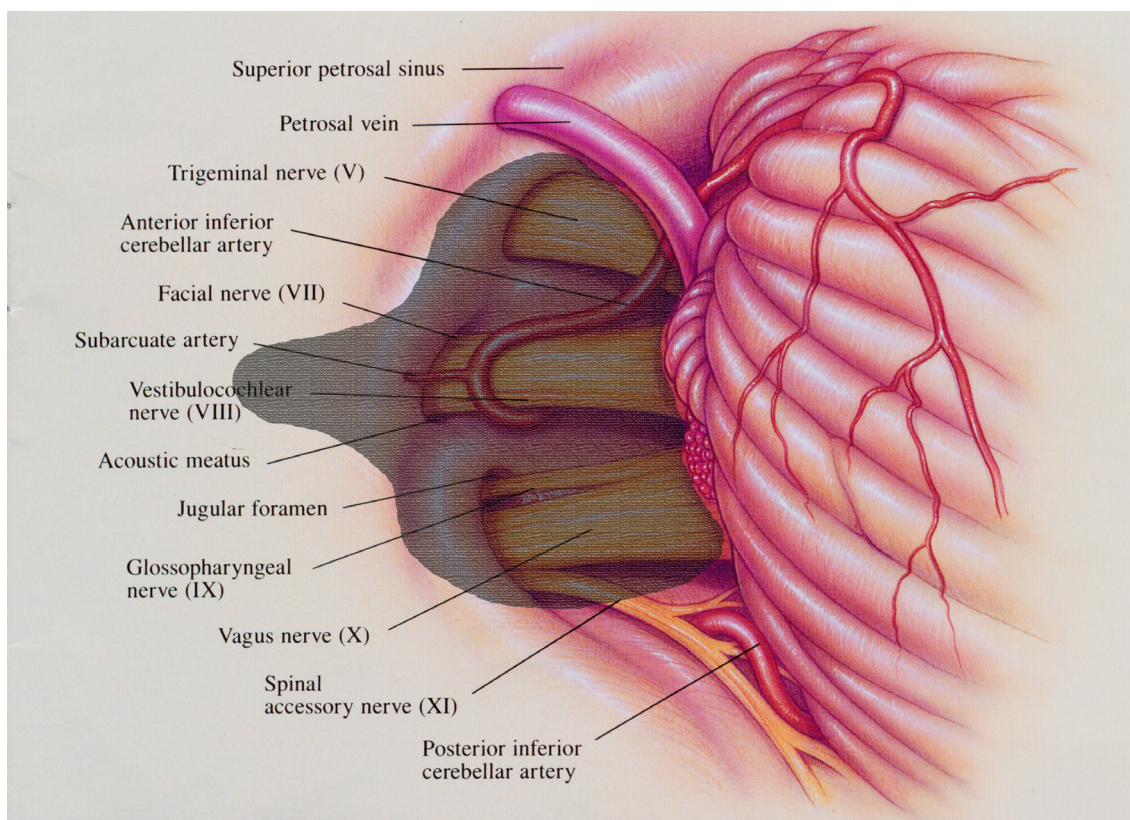


Figure 30 – Location of large vestibular schwannomas: They arise from the vestibulocochlear nerve (VIII) (vestibular portion) and may have close relationship to the trigeminal nerve (V).

The trigeminal nerve joins the brainstem about halfway between the upper and lower borders of the pons. In the posterior fossa the nerve runs towards the petrous apex. (Rhoton 2000 [2]). Irritations of the nerve at this level can be elicited by tumour surgery in the cerebellopontine angle (Figure 30).

At the petrous apex, the nerve enters the middle fossa in Meckel's cave, which is located on the petrous part of the temporal bone (Rhoton 2000 [2]). At this

location, preparations and manipulations during petroclival meningioma resection may stimulate the trigeminal nerve as well. The ophthalmic, maxillary and mandibular branches of the trigeminal nerve start from the trigeminal ganglion.

The ophthalmic division passes forward near the medial surface of the dura forming the lower part of the lateral wall of the cavernous sinus to reach the superior orbital fissure (Rhoton 2002 [1], Rhoton 2002 [2]). As the nerve approaches the superior orbital fissure, it splits into the lacrimal, frontal and nasociliary nerves (Rhoton 2002 [1]). All these branches may be exposed during different surgical procedures of the anterior skull base and the orbit.

The maxillary nerve passes through the foramen rotundum to enter the pterygopalatine fossa, where it divides into infraorbital and zygomatic branches and communicating rami to the sphenopalatine ganglion (Rhoton 2002 [1]).

The mandibular nerve passes through the foramen ovale reaching the infratemporal fossa, where it gives rise to the pterygoid, buccal, masseteric, and temporal branches, as well as to the lingual, inferior alveolar and auriculotemporal branches (Rhoton 2002 [3]). Both the maxillary and mandibular branches can be directly accessed during several maxillofacial procedures.

Neurophysiology and Monitoring

Continuous monitoring of AEP is designed to control and predict auditory function during tumor removal at the cerebellopontine angle. The disappearance or changes of certain AEP components in relation to surgical actions may orient the surgeon to adopt certain intraoperative maneuvers in order to preserve auditory function.

a. Indication for AEP

It serves as an important diagnostic modality in cases where a retrocochlear pathological lesion is suspected. Intraoperatively, it should be used in all vestibular schwannoma cases with preoperative functional hearing, in order to attempt hearing preservation during the tumor resection.

b. Importance of Waves I, III and V

The methodology includes intrameatal earphones and emphasizes the analysis of Wave III as well as V and I through the V interpeak latency.

The waves I, III and V are functional representatives of the cochlea, the nucleus cochlearis, and the colliculus inferior, respectively (Matthies and Samii 1997 [2]). The intraoperative loss of Wave V is the most definite sign associated with postoperative deafness in most of the cases. Although it is fairly reliable in indicating definite hearing loss, this sign is the least helpful because it is the consequence of earlier warning signs, e.g., the disappearance of Wave I and III. The Wave III is the most sensitive warning sign and it has the highest incidence of actions associated with hearing loss (Matthies and Samii 1997 [2]). In cases with hearing preservation, AEPs without Wave III indicate generally poor-quality hearing, as shown by correlation of AEP quality and speech discrimination (Matthies and Samii 1997 [3]).

c. Anatomic and Physiologic Correlations

The evaluation of manipulations, which cause specific waves, supports certain anatomic and physiological considerations. Pulling the acoustic neuroma in the medial direction, toward the brain stem and away from the cochlea, is related to reduction of the amplitude or to a loss of Wave I (Matthies and Samii 1997 [1]). Pulling the tumor in the other direction, is associated with Wave III reduction or disappearance, while in this case the Wave I remains stable. Moreover, the

disappearance of the Wave I is also associated with Wave III disturbances, since the function of the cochlear nucleus depends primarily on the cochlea.

Analysis of the Results

TCR and non-TCR groups presented no significant preoperative differences concerning patients' age and gender, side and size of the tumors, quality of the preoperative hearing function, or other parameters that could have influenced the postoperative hearing function.

Patients presented with a significantly poorer postoperative auditory function when having the TCR during surgery in comparison to the non-TCR group ($p=0.005$).

When the small tumors in the TCR group are separately analyzed, there was one case of hearing preservation (50%) and one case of deafness (50%) after the surgery. A small number of patients with small tumors and TCR is naturally encountered, since the TCR follows trigeminal manipulation, which occurs usually during the resection of large tumors. Thus, one cannot observe a statistically significant difference in the postoperative hearing function between TCR and non-TCR groups in small vestibular schwannomas.

However, none of the patients with larger tumors (T3 and T4) and an intraoperative TCR had functional hearing postoperatively, while hearing preservation was achieved in 44.3% of the cases in the non-TCR group of these tumors. Thus, a clear correlation between TCR and postoperative hearing loss can be observed in large vestibular schwannomas.

Perspectives

Treatment and Morbidity of TCR

Interrupting the eliciting mechanism is the principal treatment modality for the TCR. The cessation of trigeminal nerve manipulations is followed by a normalization of the hemodynamic parameters.

Some authors recommend the use of atropine to treat the TCR and to prevent new episodes (Alexander 1975, Campbell et al. 1994, Kim et al. 2000, Locke et al. 1999). However, the symptoms disappear within 20 s after ceasing of the manipulation (Kosaka et al. 2000), without any medication necessary. In all cases the surgery could be continued without further problems while modifying the surgical maneuvers in terms of traction intensity and/or area of manipulation.

Moreover, as the TCR response includes the inhibition of adrenergic vasoconstriction and the activation of vagal cardioinhibitory fibers, cholinergic blockage with atropine, alone, does not completely prevent these symptoms (Kumada et al. 1977). Although intravenous administration of atropine sulfate may reduce bradycardia due to trigeminal stimulation, it can cause or contribute to more serious arrhythmias (Oppenheimer 1982, Signore et al. 1993), which have been reported with episodes of bradycardia during vestibular schwannoma surgery via the translabyrinthine approach that did not respond to atropine administration, but ceased after modulation of surgical maneuvers.

It has been reported that transient cardiac arrest may occur as frequently as one in 2.200 cases of strabismus surgery (Miller 1994).

Although even intraoperative death has been reported in association with the TCR (Fayon et al. 1995), the postoperative course is usually favorable and uneventful, as long as the TCR is recognized early and managed adequately during surgery (Schaller et al. 1999).

Auditory Function

As vestibular schwannomas have a vestibular origin, the cause of hearing loss in these tumors is not always obvious. Moreover, intrameatal processes sometimes present with deafness or very poor hearing while large tumors occasionally present with nearly normal hearing (Samii and Matthies 1997 [2]). Possible mechanisms of hearing loss are mechanical injury to the cochlear nerve, elevation of the IAC pressure and/or vascular compromise of the auditory apparatus (Lapsiwasa et al. 2002).

Recordings in the IAC have shown the pressure to be significantly elevated in most patients with vestibular schwannomas corresponding to the tumor extension into the IAC (Badie et al. 2001, Lapsiwasa et al. 2002). Possible underlying mechanisms for the decrease of auditory function are mechanical compression on the cochlear nerve or reduced vascular supply of the nerve and the auditory apparatus.

Twenty-seven percent of all vestibular schwannoma patients present with deafness preoperatively, and another 44% are deaf postoperatively (Matthies and Samii 1997 [3]).

Several prognostic factors have already been described for good postoperative hearing function in vestibular schwannomas. Male gender, small to medium tumor size (Matthies and Samii 2002, Samii and Matthies 1997[1]), good or moderate preoperative hearing (up to 40 dB loss), short preoperative duration of hypoacusis (<1,5 yr) or of vestibular disturbances (<0,7 yr) (Samii and Matthies 1997 [1]), short wave V AEP-latency and tumor origin from the superior part of vestibular nerve (Brackmann et al. 2000) have been reported as favorable preoperative factors.

Severe changes of the IAC verified in preoperative bone-window computed tomography are also described to be associated with poor preoperative hearing function as well as with an unfavorable postoperative outcome in terms of

hearing preservation (Yamakami et al. 2002). Also, the extent of the IAC widening and the tumor growth in anterior and caudal direction to the IAC are significant predictors for postoperative auditory function in large tumors (Matthies et al. 1997). Somers et al. (Somers et al. 2001) evaluated magnetic resonance imaging findings and found low intralabyrinthine signal intensity on gradient echo images to be followed by a lower rate of hearing preservation. The authors hypothesized that vascular compression in the IAC by the tumor was responsible for the decrease of intralabyrinthine signal intensity.

Intraoperative electrophysiological monitoring of brainstem auditory evoked potentials and near-field cochlear nerve action potentials proved to be most useful predictors for hearing preservation as described by our group in detail elsewhere (Matthies and Samii 1997 [2]).

The influence of the TCR on postoperative hearing preservation had not been reported so far. Patients with class T3 and T4 tumors presented with a significantly poorer postoperative auditory function when having the TCR during surgery in comparison to the non-TCR group. While none of the patients with larger tumors (T3 and T4) and an intraoperative TCR had functional hearing postoperatively, there was a hearing preservation of 44.3% in the non-TCR group of these tumors.

The cochlear nerve is supplied by small branches of the anterior-inferior cerebellar artery, while the cochlea is supplied by the labyrinthine artery, which is a branch of the anterior-inferior cerebellar artery.

An already compromised vascular supply in the internal auditory canal due to tumor compression can be further decreased in cases of sudden intraoperative hypotension occurring along with the TCR. This mechanism may lead to decreased auditory function or even deafness, despite morphological preservation of the cochlear nerve during surgery.

Additionally, larger tumors may increase pressure within the IAC thereby enhancing subsequent ischemia of the auditory apparatus. This mechanism would explain the major impact of the TCR on auditory function in larger vestibular schwannomas, which in addition are often subject to more intraoperative manipulations due to their size.

Gentle and smooth manipulations in the region of the trigeminal nerve while avoiding traction have proven to be the most important surgical maneuvers so as to decrease the occurrence of the TCR. As soon as this phenomenon has occurred immediate feedback to the surgeon is essential in order to stop the eliciting surgical maneuver immediately.

6. Conclusion

The trigeminocardiac reflex is a common intraoperative phenomenon that occurred in 11% of the patients in the present study.

The overall hearing preservation was 47% among all tumor sizes. In the group of patients who experienced the trigeminocardiac reflex during the surgical procedures, the rate of hearing preservation was 11%, while in the non-TCR group the hearing preservation rate was 51.4%. This difference was statically significant ($p=0.005$).

In patients with large tumors (T3/T4), intraoperative occurrence of TCR resulted in deafness in all cases, while in the remaining cases (without TCR) the hearing preservation rate was 44% ($p<0.005$).

The present study demonstrates therefore a clear correlation between occurrence of TCR and postoperative risk of hearing loss, particularly in large tumors.

Regarding the pathophysiological mechanisms, an already compromised vascular supply to the nerve and the cochlea due to tumor compression will become worse due to a sudden intraoperative hypotension occurring along with the TCR. In large tumors, this phenomenon may be even more evident.

The prophylactic use of atropine, as used for ocular surgery, might reduce the severity and frequency of the episodes of TCR. Therefore, its use during large vestibular schwannoma resection in patients with preoperative functional hearing function should be considered in selected cases.

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Abstract

Objective. To study the impact of the trigeminocardiac reflex (TCR) on postoperative auditory function in vestibular schwannoma surgery.

Surgery for vestibular schwannomas (acoustic neuromas) and other procedures close to the fifth cranial nerve at its intra- or extracranial course may lead to patient's bradycardia or even asystolia along with arterial hypotension. This phenomenon is described as the TCR.

Clinical Material and Methods. One hundred subsequent patients scheduled for vestibular schwannoma surgery were studied prospectively for parameters that might influence the postoperative auditory function. The evaluation included gender, age, pre- and postoperative auditory function, preoperative mean arterial blood pressure, preoperative medical diseases or medication (e.g. antiarrhythmic drugs), tumor size and localization, and the intraoperative occurrence of the TCR.

Results. The overall hearing preservation was 47% among all tumor sizes. TCR occurred in 11% of the patients. In the TCR group the rate of hearing preservation was 11%, while in the non-TCR group the hearing preservation rate was 51.4%, considering all tumor sizes ($p=0.005$).

In larger tumors (T3 and T4), patients with intraoperative TCR had a significantly worse postoperative hearing function than those without a TCR ($p<0.005$).

Conclusion. The hypotension following TCR is a negative prognostic factor for hearing preservation in vestibular schwannoma surgery. Referring to this knowledge patients' information can be increased pre- and postoperatively. Further study of this phenomenon will advance the understanding of the underlying mechanisms and may help to improve hearing preservation by controlling the occurrence of the TCR.

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BIOGRAPHY

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EDUCATION

Medical School of Graduation

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Internships

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Medical Licensure

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Neurosurgical Training

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Fellowship Skull Base Surgery

International Neuroscience Institute, Hannover, Germany - 2003.

Fellowship Skull Base Surgery

Tübingen University, Tübingen, Germany – 2004 to Mai 2005.