Accepted Manuscript online: 2022-03-10 Article published online: 2022-06-06

THIEME OPEN ACCESS

The Combined TL-RS Approach: Advantages and Disadvantages of Working 360 Degrees around the Sigmoid Sinus

Maarten C. Kleijwegt[1] Radboud W. Koot[2] Andel G.L. van der Mey[1] Erik F. Hensen[1] Martijn J.A. Malessy[2]

[1] Department of ENT, Leiden University Medical Center, RC Leiden, The Netherlands
[2] Department of Neurosurgery, Leiden University Medical Center, RC Leiden, The Netherlands

Address for correspondence Maarten C. Kleijwegt, MD, Leiden University Medical Center, P.O. Box 9600, 2300 RC Leiden, The Netherlands (e-mail: m.c.kleijwegt@lumc.nl).

J Neurol Surg B Skull Base 2023;84:288–295.

Abstract

Objective To highlight the advantages and disadvantages of the combined translabyrinthine (TL) and classic retrosigmoid (RS) approaches.

Design Retrospective chart review.

Setting National tertiary referral center for skull base pathology.

Participants Twenty-two patients with large cerebellopontine angle tumors were resected using the combined TL-RS approach.

Main Outcome Measures Preoperative patient characteristics including age, sex, and hearing loss. Tumor characteristics, pathology, and size. Intraoperative outcome: tumor removal. Postoperative outcomes included facial nerve function, residual tumor growth, and neurological deficits.

Results Thirteen patients had schwannoma, eight had meningioma, and one had both. The mean age was 47 years, mean tumor size was 39 × 32 × 35 mm (anterior–posterior, medial–lateral, craniocaudal), and mean follow-up period was 80 months. Tumor control was achieved in 13 patients (59%), and 9 (41%) had residual tumor growth that required additional treatment. Seventeen patients (77%) had postoperative House–Brackmann (H-B) facial nerve function grades I to II, one had H-B grade III, one H-B grade V, and three H-B grade VI.

Conclusion Combining TL and RS approaches may be helpful in safely removing large meningiomas and schwannomas in selected cases. This valuable technique should be considered when sufficient exposure cannot be achieved with the TL or RS approach alone.

Keywords

- ► cerebellopontine angle
- ► petroclival
- ► retrosigmoid
- ► sigmoid sinus
- ► translabyrinthine

received
December 29, 2021
accepted after revision
March 6, 2022
article published online
June 6, 2022

DOI https://doi.org/10.1055/a-1793-7925.
ISSN 2193-6331.

Georg Thieme Verlag KG, Rüdigerstraße 14, 70469 Stuttgart, Germany

Introduction

The objective of treating large posterior fossa meningiomas and schwannomas with progressive growth and brain stem compression is to safely resect as much of the tumor as possible. Many surgical approaches have been developed to achieve these goals.[1] The choice of surgical route is determined by anatomical factors related to the lateral skull base, shape, and extent of the tumor. Occasionally, approaches are combined to reduce the need for brain retraction, decrease the operative distance to the tumor and neurovascular structures, improve visualization, and access for safe microsurgical dissection of the brain stem.[2–4] A major challenge has always been how to work around the transverse and sigmoid sinus (SS) to gain wider and safer access (►**Fig. 1**).[5] In 1966, Hitselberger and House introduced the wide exposure of the cerebellopontine angle (CPA) through a combined translabyrinthine (TL) and classic retrosigmoid (RS) approaches. Technical developments, such as a pneumatic drill and operating microscope, allowed them to avoid excessive blood loss from damaged emissary veins and sinuses, which until then were difficult to overcome.[6] Initially, the SS was divided and ligated[6–10] or reanastomosed.[11] Preoperative angiography, temporary clipping, and sinus pressure recordings before and after occlusion were used to assess whether the sinus could be safely sacrificed.[3,6] In subsequent surgical modifications, the SS was kept intact and mobilized.[3,5,12,13] Widening of the approach to gain further access was then obtained by anterior retraction of the SS to create a larger posterior passage or posterior retraction to increase anterior access.[3,5,13] The retraction of the SS has its limitations due to the limited elastic properties and drawbacks of tearing and occlusion due to long-standing compression. The limitations of manipulation can be overcome by combining the TL and RS approaches.[14] The combination of these two approaches is not widely used for unknown reasons. A potential explanation is that it entails working 360 degrees around a skeletonized SS that harbors risks of tearing or occlusion due to thrombosis.[3,15,16] Here, we present a series of 22 patients with a large CPA meningioma or schwannoma. We chose the combined TL-RS surgical route to widen access to resect as much tumor as was safely possible or to reduce tumor volume so that radiotherapy could be provided. These patients had a combination of one or more of the following factors: a substantial amount of tumor in the internal auditory canal (IAC), tumor extension anterolateral to the brain stem and foramen magnum, narrow mastoid, and/or high-riding jugular bulb. We assessed the extent of tumor resection, whether tumor control was achieved, and if facial nerve function remained intact.

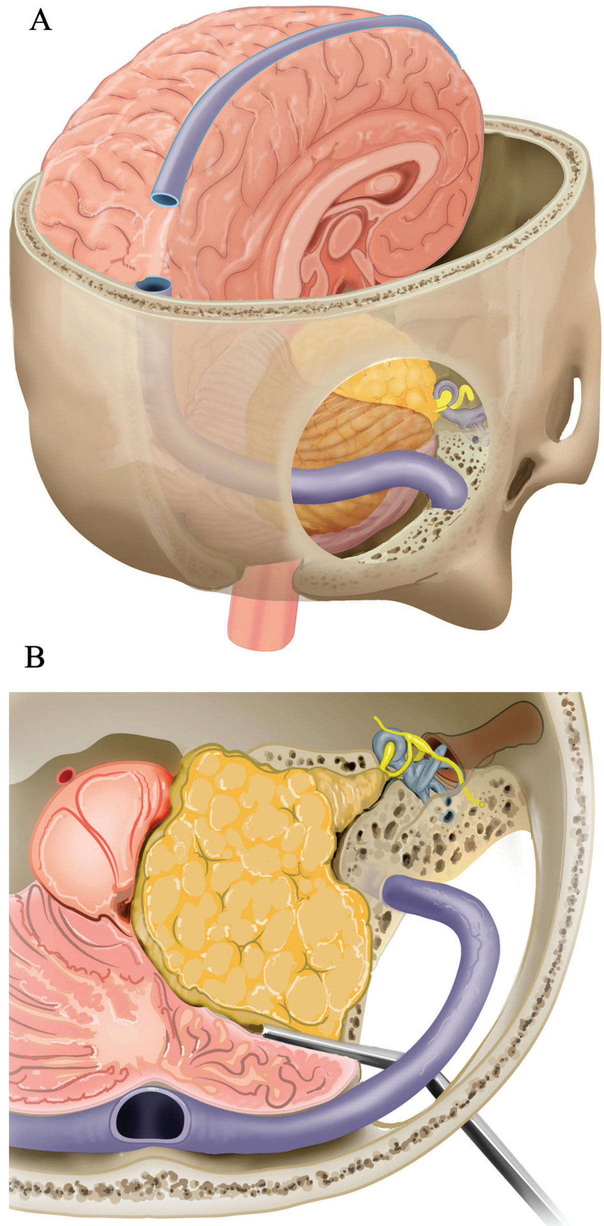

Fig. 1 The combined translabyrinthine (TL) and retrosigmoid (RS) approach. A. Oblique posterior view. B. Axial view. To obtain a 360 degrees skeletonized sigmoid sinus (in blue) a diamond drill with constant irrigation for cooling was used. Emissary veins were carefully addressed. Firmly attached thin bone shells were purposely left in situ. Direct cauterization of the sigmoid sinus was avoided. During resection it was draped with a moist spongy material and protected by a retractor blade while avoiding direct pressure or mobilization.

Materials and Methods

Patient Population

We performed a retrospective chart review of consecutive series of patients using the combined TL-RS approach. Patients were identified in a database containing more than 900 patients with CPA schwannoma or meningioma who were surgically treated between 2000 and 2020. This study was approved by the Medical Ethics Committee of the Leiden University Medical Center.

The TL-RS approach was chosen for both schwannoma and meningioma surgeries but from a different perspective. For schwannomas (most often vestibular schwannomas), we prefer tumor removal through the TL approach to dissect the IAC portion of the tumor, allowing early identification of the course of the facial nerve. We considered the extension of the TL approach by adding an additional RS route depending on tumor size (large, >30 mm), shape, and location in relation to the bony anatomy of the lateral skull base. We specifically examined the dimensions and shape of the mastoid process (capacious or contracted), the presence of a high-rise jugular bulb or anteriorly placed SS, and extension of the tumor to the foramen magnum and/or anterolaterally to the brain stem.[17,18] For meningiomas, we preferred the RS approach and considered extension with TL if the IAC was substantially filled with tumor, and/or hearing was impaired, four-handed surgery was beneficial for optimal resection, and/or subtemporal transtentorial (STT) extension was required. For resection of both types of tumors, the dominance of the SS on the tumor side was a contraindication for this combined approach. Tumor size was measured using the maximal extrameatal diameter on a T1 gadolinium-enhanced sequence (axial and coronal planes). Extrameatal diameters were measured in three dimensions: anterior–posterior, medial–lateral (axial plane), and craniocaudal (coronal plane).[19] Classes A and B were defined as useful hearing, using the American Academy of Otolaryngology-Head and Neck Surgery guidelines.[19] The surgical technique we used is described later. Six-channel intraoperative nerve monitoring (Medtronic NIM-Neuro 3.0) of the facial, accessory, and vagal nerves was performed.

The extent of tumor resection was documented intraoperatively as total, near total (up to 2% of the initial tumor was left in situ), or subtotal (more than 5% of the initial tumor was left in situ).[19,20]

Tumors were histologically classified according to the World Health Organization (WHO) criteria.[21] House–Brackmann (H-B) classification was used to evaluate postoperative facial nerve function and was scored by an ENT specialist and/or neurosurgeon.[22] Residual tumor growth over time was documented with magnetic resonance imaging (MRI), and in one patient with contrast-enhanced computed tomography.[19] Growth was defined as the expansion of more than 2 mm per year in at least one plane. The follow-up interval was defined as the number of months between surgery and the most recent MRI. Tumor regrowth was defined as the growth of a residual tumor that required additional treatment, surgical reintervention, and/or radiotherapy. Tumor control was defined as the absence of residual tumor growth on postoperative MRI, and no additional treatment was required.

Surgical Technique of the Combined TL-RS Approach

A retroauricular U-shaped skin incision was made ~2 cm posterior to the course of the SS. The exposure started with a mastoidectomy, which resulted in exposure of the middle and posterior fossa dura. The bone overlying the SS was drilled using a diamond burr with constant irrigation for cooling. Bipolar cauterization of the SS was avoided at all times. The dura posterior to the SS (1–2 mm) was exposed by further drilling to facilitate the creation of the RS bone flap with the craniotome. The bone flap was ~2.5 cm anteroposteriorly and 3 cm craniocaudally, adjacent to the transverse sinus. Subsequently, a labyrinthectomy was performed, followed by exposure to the IAC. The superior petrosal sinus is preserved. Subsequently, a RS bone flap was created. The dura anterior or posterior to the SS was opened to reduce posterior fossa pressure by releasing cerebrospinal fluid (CSF). The SS was covered with a wet Merocel sponge (Medtronic Inc., Minneapolis, Minnesota, United States). The bulk of the tumor was first reduced anterior to the SS through the TL approach. A manually curved retractor blade was positioned over the SS for protection. Once limitations of the TL route were encountered, that is, when excessive traction to the tumor or mobilization of the SS (which is limited) is required to allow safe mobilization and resection of the tumor or to identify the planes of the brain stem, the exposed dura posterior to the SS was opened (if not yet performed). At this stage, the SS is 360 degrees exposed and forms a vascular bridge between the TL and RS approaches (►**Fig. 2**). The SS was not mobilized. Tumor resection was continued alternately anterior and posterior to the SS, with minimal retraction to the SS and cerebellum. A STT approach was used if the tumor extended through the tentorial hiatus. At closure, the antrum of the middle ear was plugged with bone wax (to prevent CSF leakage through the Eustachian tube), the RS dura was closed, and the abdominal adipose tissue was fixed with glue to obliterate the mastoidectomy cavity. The RS bone flap was then fixed using sutures. The muscle, subcutis, and skin were sutured in the original position.

Results

We used the combined TL-RS approach in 22 patients with large CPA schwannomas or meningiomas (►**Table 1**). The mean age of the patients at surgery was 45 years (standard deviation [SD] ± 14.9; range, 18–67; median, 47 years). Eight patients had meningioma (WHO grade I), 11 had vestibular schwannoma, 1 had jugular foramen schwannoma, 1 had trigeminal schwannoma (with extension to the IAC), and 1 had both schwannoma and meningioma (neurofibromatosis type 2). The mean anteroposterior diameter was 39 mm (SD ± 12; range, 17–79; median, 38). The mean extrameatal mediolateral diameter was 32 mm (SD ± 8, range, 20–50, median, 30). The mean craniocaudal diameter was 35 mm (SD ± 5.7; range, 25–47, median, 34). An STT approach was also used in 7 of the 22 patients; in 4 of these patients, the superior petrosal sinus was coagulated (►**Table 2**).

The extent of resection was classified as total in 4 patients, near total in 8 patients, and subtotal in 10 patients (►**Table 2**). Examples of preoperative and postoperative imaging are shown in ►**Figs. 3** and **4**. The mean follow-up period was 80 months (SD ± 33.4; range, 16–153; median, 80). Tumor control was obtained in 13 (59%) patients. Nine patients (41%) had residual tumors, of which six had a schwannoma and three had a meningioma (►**Tables 1** and **2**). Stereotactic radiotherapy was administered to six of these patients, and tumor control was achieved. The average interval between surgery and radiotherapy was 36 months (SD ± 26; range 5–67: median, 36 months). Among the other three patients with residual growth, one patient underwent revision surgery (TL approach) after 77 months, and two underwent surgery and radiotherapy. This was performed sequentially in one patient (no. 9) (TL approach) after a 27-month interval, and in the other patient

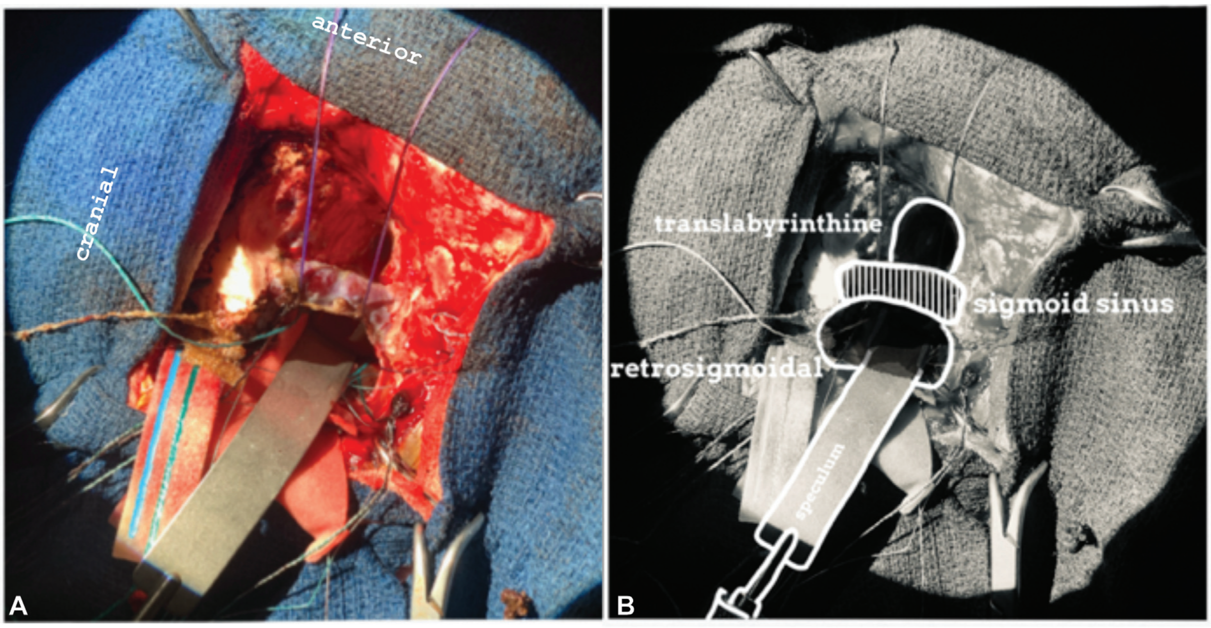

Fig. 2 (A) Intraoperative photograph of a combined right-sided TL-RS approach. The SS was 360 degrees exposed and formed a vascular bridge demarcating the anatomic boundary between the RS and TL routes. Suspension sutures attached to the dural rim and cerebellar retractor in situ. (B) Schematic outline of the TL-RS approach, with a completely exposed SS in between. RS, retrosigmoid; SS, sigmoid sinus; TL, translabyrinthine.

Table 1 Characteristics of the patient with large petroclival meningiomas and cerebellopontine angle schwannomas in which the combined retrosigmoid and translabyrinthine approaches is used for tumor resection

Patient no.	Tumor size (mm)	Side	Gender	Age	Hearing	Hydrocephalus	Histology
1	36 × 38 × 30	L	M	51	D	–	S
2	38 × 37 × 33	R	F	55	B	–	M
3	35 × 50 × 32	R	M	44	D	Yes (shunt)	S
4	46 × 28 × 42	L	M	31	A	–	S
5	37 × 38 × 47	L	M	48	A	Yes (shunt)	M
6	49 × 28 × 41	L	F	55	D	Yes (shunt)	S
7	17 × 30 × 40	R	F	67	D	–	M
8	38 × 28 × 37	L	F	59	B	Yes[a]	S
9	31 × 21 × 28	R	F	31	D	Yes[a]	M
10	36 × 35 × 38	L	F	57	A	–	M
11	79 × 35 × 41	L	F	47	D	Third ventriculostomy	M
12	26 × 33 × 36	R	F	43	D	–	S
13	37 × 29 × 33	L	M	26	D	–	S
14	50 × 37 × 38	R	F	20	D	Yes (shunt)	S
15	41 × 30 × 32	R	M	38	A	–	S
16	31 × 27 × 29	R	M	58	B	–	S
17	29 × 27 × 32	R	M	65	D	–	S
18	38 × 23 × 25	R	M	46	B	–	S
19	29 × 21 × 27	L	M	46	D	–	M
20	50 × 20 × 35	R	F	64	D	–	M
21	40 × 49 × 41	R	F	18	D	Yes[a]	S
22	38 × 28 × 31	L	F	22	D	–	S/M

Abbreviations: Hearing classification A & B; useful hearing; F, female; L, left; M, male; M (histology), meningioma; R, right; S (histology), schwannoma.
Notes: At presentation, 8 of 22 (36%) patients had enlarged lateral and third ventricles indicative of hydrocephalus, 7 of which had papilledema. One has a third ventriculostomy elsewhere before being referred to our center. Four patients underwent ventriculoperitoneal shunt placement before tumor removal, and the other three underwent tumor resection within 1 week without prior shunt. Eight of the 22 patients had a serviceable hearing.
[a]Tumor resection within 1 week after presentation.

Table 2 Surgical results

Patient no.	STT extension	Extent of resection	SS obstruction	Postoperative facial nerve outcome (H-B)	Follow-up (mo)	Recurrence	Treatment of recurrence	Long-term impairment
1	–	ST	No	V	134	Yes	R	None
2[a]	Yes	T	No	I	53	–	–	None
3	–	NT	No	I	51	–	–	CN VI, mild ataxia
4	–	ST	No	I	119	–	–	Compensated CN X
5	Yes[b]	ST	No	I	122	Yes	R	Ataxia
6	Yes	ST	No	II	105	Yes	R + S	CN V[c]
7	Yes	ST	No	I	102	Yes	R	CN V, ataxia[d]
8	–	NT	Yes	I	60	–	–	Ataxia[e]
9	Yes	ST	No	III	94	Yes	R + S	CN V[f]
10	–	T	No	I	104	–	–	None
11	Yes[g]	ST	No	I	10	–	–	Dysphagia, mild hemiparesis right sided
12	–	T	No	VI	63	–	–	None
13	–	ST	No	I	98	Yes	S	None
14	–	T	Yes	III (XII-VII)	87	–	–	None
15	–	ST	No	II	78	Yes	R	None
16	–	NT	No	II	70	–	–	None
17	–	NT	No	I	37	–	–	None
18	–	NT	No	I	71	–	–	None
19	–	NT	No	II	82	–	–	None
20	Yes	ST	No	I	103	Yes	R	None
21	–	NT	No	II	55	Yes	R	None
22	–	NT	No	III (facial reanimation)	31	–	–	Dysphagia

Abbreviations: CN, cranial nerve; H-B, House–Brackmann grade; NT, near total; R, radiotherapy; S, surgery; SS, sigmoid sinus; ST, subtotal; STT, subtemporal transtentorial; T, total. Recurrence is defined as progressive residual tumor growth requiring additional treatment. Six patients (26%) suffered postoperative impairment of other cranial nerves.

[a]Deceased due to nonrelated cancer.

[b]Additional surgery by posterolateral approach to debulk the residual retroclival mass 6 months after the initial procedure.

[c]Trigeminus schwannoma.

[d]Speech disturbances, 5 days postoperative.

[e]Eye movement disorder, speech disturbance, and coercion of the head to the right, 2 days postoperative.

[f]longterm hypoesthesia

[g]Speech and swallowing disturbances, hydrocephalus requiring shunting, 11 weeks postoperative;.

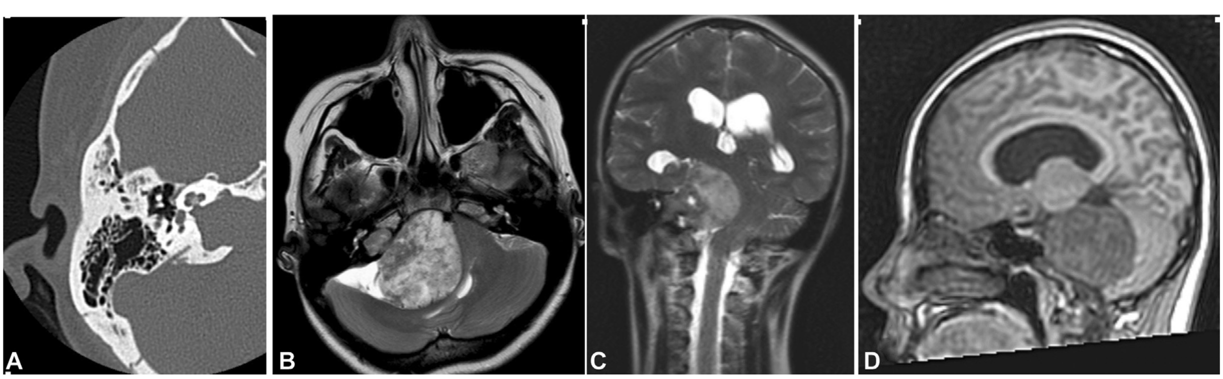

Fig. 3 Preoperative imaging of patient 21 with a large vestibular schwannoma and a contracted mastoid process. (A) Axial CT scan of the right mastoid. (B) Axial T2 MRI. (C) Coronal T2 MRI. (D) Sagittal T1 MRI, no contrast. CT, computed tomography; MRI, magnetic resonance imaging.

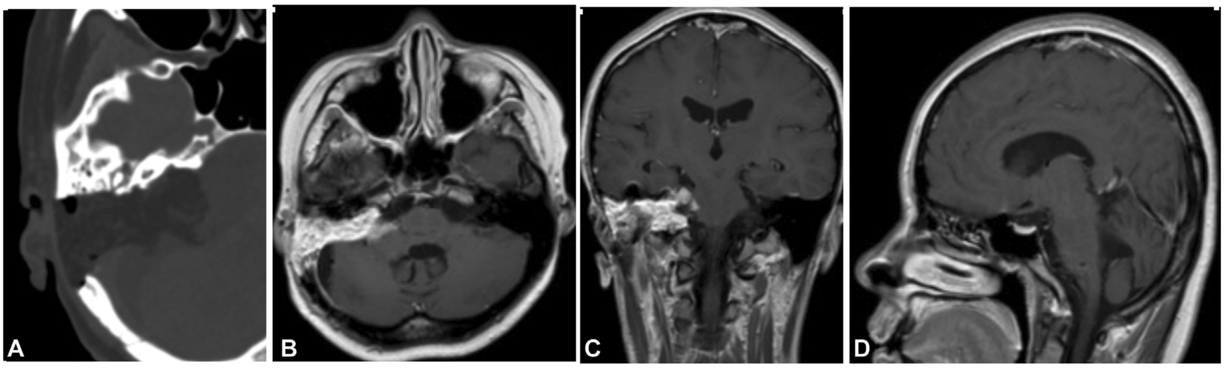

Fig. 4 Postoperative imaging after TL-RS resection of patient 21. (A) Postoperative CT scan of the right mastoid. (B) Axial T1-weighted gadolinium-enhanced MRI. (C) Coronal T1-weighted gadolinium-enhanced MRI. (D) Sagittal T1-weighted gadolinium-enhanced MRI. CT, computed tomography; MRI, magnetic resonance imaging; RS, retrosigmoid; TL, translabyrinthine.

(no. 6), radiotherapy was administered after 43 months, and surgery (endoscopic transsphenoidal approach) was performed after 58 months. Seventeen patients (77%) had good postoperative facial nerve function (H-B grades I–II), three patients (14%) had moderate function (H-B grade III), and two patients (9%) had poor facial nerve outcomes (H-B grades V–VI). The average follow-up period for facial nerve function was 47 months (SD $\pm$ 34.5; range, 4–116: median, 43). Two patients with H-B grade VI underwent hypoglossal–facial nerve transfer and recovered to H-B grade III. The structural anatomy of the SS remained intact in all cases. One of the 22 patients (4.5%) had clinically relevant symptoms (headache, torticollis, and eye movement disorder) and radiologically proven SS outflow obstruction occurred, which did not require additional treatment. One other patient had a pulmonary embolism, and imaging was performed during the work-up to start anticoagulant therapy, revealing SS thrombosis. The patient had no neurological symptoms. No CSF leakage was observed in this series.

Discussion

Several combined approaches have been described for resecting large CPA meningiomas and schwannomas. In these approaches, the SS is sacrificed or mobilized to increase the anterior or posterior passage.[3,5,6,12,13] Our objective of treatment is to obtain long-term tumor control in a single surgical treatment. Therefore, we strive to resect as much of the tumor as safely as possible while preserving facial nerve function. For this purpose, we used a combined TL and RS approaches in a selected group of patients. The use of this combined approach has been reported previously. It has been suggested that RS exposure alone or in combination with a TL approach offers the best chance of preserving the facial nerve, but further details were not provided.[14] In our experience, the combined approach offers a wide exposure that facilitates maximal resection with the added advantage of early identification of the facial nerve without introducing an increase in SS-related morbidity. No additional tumor treatment was required in most of our patients and they had good facial nerve function after a mean follow-up of almost 7 years. Combining TL and RS makes four-handed surgery possible, which cannot be performed if only RS is used. The tumor can be handled pre- and post-SS simultaneously, facilitating removal in difficult cases. A wider surgical exposure, compared with only RS or TL, creates a broader field of view with more light on the target area. Additionally, the assisting surgeon can operate in a relaxed ergonomic posture.

The balance between tumor resection and facial nerve preservation is a dynamic process and cannot be attributed solely to the combined TL-RS approach. The overall outcome of surgery ultimately depends on many factors.[23,24] The number of tumors that can be safely resected, for example, depends not only on the approach but also on factors such as tumor adherence to the brain stem or associated vessels.[25–27] The outcome of the facial nerve decreases with increasing tumor size, especially when exceeding 4 cm. The percentage of H-B grades I to II drops to 50% using TL or RS approach separately.[26,28,29] In this study, 77% of the patients had H-B grades I to II after surgery. Gross total resections in patients with tumors larger than 2.5 cm are associated with a higher risk of facial nerve injury.[30] Less than total resection results in regrowth in nearly half of the patients.[31] Subtotal resection has a ninefold higher recurrence rate than total or near total.[32] Of our population, we had nine patients with regrowth, eight tumors were subtotally removed, and one near totally removed.

The potential downsides of the TL-RS approach compared with just an RS or TL approach include the greater time spent on the approach (especially compared with only RS) and SS thrombosis. In experienced hands, combining the TL approach with an RS adds ~2 hours. This time, the investment is nullified because it is gained back during resection due to better access. SS thrombosis can occur following both TL and RS approaches, and the reported proportion of patients ranges from 1.3 to 19%.[25,33–35] The proportion of SS thrombosis increases with increasing tumor size.[36] However, underreporting of SS thrombosis is known to occur. SS thrombosis was documented in 14.2% of the patients, which was initially not detected on postoperative imaging.[34] In the current series, one patient (4.5%) had a clinical manifestation of SS thrombosis, which was not more than when only TL or RS was used.

We routinely begin tumor resection through the TL route anterior to the SS. This opportunity is created by early identification and assessment of the course of the facial nerve in the lateral IAC, thereby facilitating resection of the lateral part of the tumor. We switch from anterior to posterior SS when the tumor needs to be removed in the central direction toward the brain stem, the inferior part toward the foramen magnum, and anterior to the petroclival area. Working posteriorly with the SS at this stage requires little cerebellar retraction because the posterior fossa tension is already reduced by the lateral decompression obtained via the TL route. Furthermore, the tumor can be mobilized in the cavity created via the TL route, facilitating the identification of the facial nerve root exit from the brain stem. We ended the resection via the TL route to remove the last part of the tumor from the vulnerable facial nerve.

In addition, we used the STT approach to expose the part of the tumor that extended into the middle fossa. The superior petrosal sinus was then preferentially preserved, as it is difficult to estimate how essential its patency is to preserve sufficient venous drainage.[37] None of our patients in whom scarification was necessary developed signs of venous obstruction of the SS. This additional procedure does not contain specific risks for SS patency and cannot be seen as a disadvantage.

Considering the morbidity related to tumor removal, more than one-third of our patients had useful hearing before surgery. In patients with meningioma and useful hearing, the tumor extended deep into the IAC. Therefore, by exclusively using the RS approach, the chance of obtaining adequate tumor resection with hearing preservation and, at the same time, not jeopardizing facial nerve function was limited. In schwannoma resection, the a priori chance of losing useful hearing when tumors are larger than 25 mm is high.[38] The only way to preserve hearing in these large schwannomas is to intentionally perform partial debulking only. However, the likelihood of tumor regrowth is higher in subtotal resections than in gross and near-total resections.[24] The inherent consequence of partial debulking is that it increases the likelihood that additional radiotherapy is required to obtain tumor control. Evidence from modern, highly conformal, low-dose radiation techniques demonstrates that long-term hearing preservation rates are poor, that is, ~23% at 10 years.[39] Based on this observation, we deliberately opted for TL, which inherently causes the disadvantage of hearing loss but provides the advantage of early facial nerve identification. Moreover, in these large tumors, we did not use retrolabyrinthine variation to save hearing because it provides inferior visualization of the tumor and does not expose the IAC, excluding early facial nerve identification.

This study represents results based on a relatively small series of 22 patients treated over a long period. Twenty-two patients were a fraction of the total number of ~900 patients we operated on in the past 20 years. The low number of cases reflects the fact that, in rare cases, anatomical factors related to the skull base and tumor size and shape were such that the combined TL-RS approach was considered optimal to reach our goals. However, we believe that the number of patients has little influence on our conclusions.

Conclusion

Different surgical approaches have been used to resect large CPA schwannomas and meningiomas. However, the combined TL-RS approach is relatively unknown and has not been widely used. In our experience, this approach facilitates tumor resection in selected cases by providing substantial exposure. It should be considered when maximal resection is pursued in patients with a high-riding jugular bulb or anteriorly placed SS, a substantial presence of tumor in the IAC, tumor extension anterolateral to the brain stem, and foramen magnum in which sufficient exposure cannot be achieved with the TL or RS approach alone. In selected cases, the combined TL-RS approach is a valuable addition to the widely used surgical approaches.

Conflict of Interest
None declared.

References

1 Maurer AJ, Safavi-Abbasi S, Cheema AA, Glenn CA, Sughrue ME. Management of petroclival meningiomas: a review of the development of current therapy. J Neurol Surg B Skull Base 2014;75 (05):358–367
2 Chamoun R, MacDonald J, Shelton C, Couldwell WT. Surgical approaches for resection of vestibular schwannomas: translabyrinthine, retrosigmoid, and middle fossa approaches. Neurosurg Focus 2012;33(03):E9
3 Spetzler RF, Daspit CP, Pappas CT. The combined supra- and infratentorial approach for lesions of the petrous and clival regions: experience with 46 cases. J Neurosurg 1992;76(04):588–599
4 Erkmen K, Pravdenkova S, Al-Mefty O. Surgical management of petroclival meningiomas: factors determining the choice of approach. Neurosurg Focus 2005;19(02):E7
5 Grossi PM, Nonaka Y, Watanabe K, Fukushima T. The history of the combined supra- and infratentorial approach to the petroclival region. Neurosurg Focus 2012;33(02):E8
6 Hitselberger WE, House WF. A combined approach to the cerebellopontine angle. A suboccipital-petrosal approach. Arch Otolaryngol 1966;84(03):267–285
7 Borchardt M. Zur Operation der Tumoren des Kleinhirn-Brückenwinkels. Klin Wochenschr 1905;42:1033–1035
8 Malis LI. Surgical resection of tumors of the skull base. In: Wilkins RH, Rengachary SS, ed. Neurosurgery. New York: McGraw-Hill; 1985:1011–1021
9 Marx H. Zur chirurgie der leinhirnbrückenwinkeltumoren. Mitt Grenzgeb Med Chir 1913;26:117–134
10 Naffziger HC. Brain surgery with special reference to exposure of the brain stem and posterior fossa; the principal of intracranial decompression, and the relief of impactions in the posterior fossa. Surg Gynecol Obstet 1928;(46):241–248
11 Bailey P. Concerning the technique of operation for acoustic neurinoma. Zentralbl Neurochir 1939;(04):1–5
12 Abolfotoh M, Dunn IF, Al-Mefty O. Transmastoid retrosigmoid approach to the cerebellopontine angle: surgical technique. Neurosurgery 2013;73(1, Suppl Operative):ons16–ons23
13 Samii M, Ammirati M, Mahran A, Bini W, Sepehrnia A. Surgery of petroclival meningiomas: report of 24 cases. Neurosurgery 1989; 24(01):12–17
14 Anderson DE, Leonetti J, Wind JJ, Cribari D, Fahey K. Resection of large vestibular schwannomas: facial nerve preservation in the context of surgical approach and patient-assessed outcome. J Neurosurg 2005;102(04):643–649

15 Darrouzet V, Guerin J, Aouad N, Dutkiewicz J, Blayney AW, Bebear JP. The widened retrolabyrinthine approach: a new concept in acoustic neuroma surgery. J Neurosurg 1997;86(05):812–821
16 Raza SM, Quinones-Hinojosa A. The extended retrosigmoid approach for neoplastic lesions in the posterior fossa: technique modification. Neurosurg Rev 2011;34(01):123–129
17 Singh A, Irugu DVK, Sikka K, Verma H, Thakar A. Study of sigmoid sinus variations in the temporal bone by micro dissection and its classification - a cadaveric study. Int Arch Otorhinolaryngol 2019;23(03):e311–e316
18 Alonso F, Dekker SE, Wright J, et al. The retrolabyrinthine presigmoid approach to the anterior cerebellopontine region: expanding the limits of Trautmann triangle. World Neurosurg 2017;104:180–185
19 Kanzaki J, Tos M, Sanna M, Moffat DA, Monsell EM, Berliner KI. New and modified reporting systems from the consensus meeting on systems for reporting results in vestibular schwannoma. Otol Neurotol 2003;24(04):642–648, discussion 648–649
20 Godefroy WP, van der Mey AG, de Bruine FT, Hoekstra ER, Malessy MJ. Surgery for large vestibular schwannoma: residual tumor and outcome. Otol Neurotol 2009;30(05):629–634
21 Louis DN, Perry A, Reifenberger G, et al. The 2016 World Health Organization Classification of Tumors of the Central Nervous System: a summary. Acta Neuropathol 2016;131(06):803–820
22 House JW, Brackmann DE. Facial nerve grading system. Otolaryngol Head Neck Surg 1985;93(02):146–147
23 Leonetti JP, Anderson DE, Marzo SJ, Origitano TC, Schuman R. Combined transtemporal access for large (>3 cm) meningiomas of the cerebellopontine angle. Otolaryngol Head Neck Surg 2006;134(06):949–952
24 Monfared A, Corrales CE, Theodosopoulos PV, et al. Facial nerve outcome and tumor control rate as a function of degree of resection in treatment of large acoustic neuromas: preliminary report of the acoustic neuroma subtotal resection study (ANSRS). Neurosurgery 2016;79(02):194–203
25 Sade B, Mohr G, Dufour JJ. Vascular complications of vestibular schwannoma surgery: a comparison of the suboccipital retrosigmoid and translabyrinthine approaches. J Neurosurg 2006;105(02):200–204
26 Darrouzet V, Martel J, Enée V, Bébéar JP, Guérin J. Vestibular schwannoma surgery outcomes: our multidisciplinary experience in 400 cases over 17 years. Laryngoscope 2004;114(04):681–688
27 Samii M, Tatagiba M. Experience with 36 surgical cases of petroclival meningiomas. Acta Neurochir (Wien) 1992;118(1-2):27–32
28 D'Amico RS, Banu MA, Petridis P, et al. Efficacy and outcomes of facial nerve-sparing treatment approach to cerebellopontine angle meningiomas. J Neurosurg 2017;127(06):1231–1241
29 Ansari SF, Terry C, Cohen-Gadol AA. Surgery for vestibular schwannomas: a systematic review of complications by approach. Neurosurg Focus 2012;33(03):E14
30 Gurgel RK, Theodosopoulos PV, Jackler RK. Subtotal/near-total treatment of vestibular schwannomas. Curr Opin Otolaryngol Head Neck Surg 2012;20(05):380–384
31 El-Kashlan HK, Zeitoun H, Arts HA, Hoff JT, Telian SA. Recurrence of acoustic neuroma after incomplete resection. Am J Otol 2000;21(03):389–392
32 Carlson ML, Van Abel KM, Driscoll CL, et al. Magnetic resonance imaging surveillance following vestibular schwannoma resection. Laryngoscope 2012;122(02):378–388
33 Keiper GL Jr, Sherman JD, Tomsick TA, Tew JM Jr. Dural sinus thrombosis and pseudotumor cerebri: unexpected complications of suboccipital craniotomy and translabyrinthine craniectomy. J Neurosurg 1999;91(02):192–197
34 Shew M, Kavookjian H, Dahlstrom K, et al. Incidence and risk factors for sigmoid venous thrombosis following CPA tumor resection. Otol Neurotol 2018;39(05):e376–e380
35 Jean WC, Felbaum DR, Stemer AB, Hoa M, Kim HJ. Venous sinus compromise after pre-sigmoid, transpetrosal approach for skull base tumors: a study on the asymptomatic incidence and report of a rare dural arteriovenous fistula as symptomatic manifestation. J Clin Neurosci 2017;39:114–117
36 Moore J, Thomas P, Cousins V, Rosenfeld JV. Diagnosis and management of dural sinus thrombosis following resection of cerebellopontine angle tumors. J Neurol Surg B Skull Base 2014;75(06):402–408
37 Tanriover N, Abe H, Rhoton AL Jr, Kawashima M, Sanus GZ, Akar Z. Microsurgical anatomy of the superior petrosal venous complex: new classifications and implications for subtemporal transtentorial and retrosigmoid suprameatal approaches. J Neurosurg 2007;106(06):1041–1050
38 Yates PD, Jackler RK, Satar B, Pitts LH, Oghalai JS. Is it worthwhile to attempt hearing preservation in larger acoustic neuromas? Otol Neurotol 2003;24(03):460–464
39 Coughlin AR, Hunt AA, Gubbels SP. Is hearing preserved following radiotherapy for vestibular schwannoma? Laryngoscope 2019;129(04):775–776