Acta Scientific Neurology (ISSN: 2582-1121)

Volume 3 Issue 6 June 2020

Research Article

Cerebellopontine Angle Tumors: Surgical and Non-Surgical Outcomes in a Cohort 321 Cases

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Received: May 04, 2020

Published: May 31, 2020

Abstract

Objective: The purpose of the current study is to investigate a large series of surgical and non-surgical outcomes of CPATS at a single institution.

Methods: The authors performed a retrospective analysis of 321 patients from September 2014 to July 2018 who had undergone surgical and non-surgical or both approaches. Pure tone audiometry was done to assess the degree of hearing loss. The relationships between tumor size and either surgical and non-surgical approach, extent of resection, complication rate, need of re-operation, KPS were analyzed. The impact of surgical approach and tumor size on pre-post-operative HBS, KPS at discharge, and histopathology report was analyzed.

Results: Acoustic neuroma accounts for 65.1% with predominance of Female > Male. CPATs were categorized by largest diameter: < 15 mm in 95 cases, 16 - 30 mm in 152 and > 30 mm in 74 cases with majority 83.17% in CPA region in relation to extension. Sensorineural hearing loss (44.54%) was the most common symptoms which accounts 60.28% in acoustic neuroma. Among 321 cases, 202 cases underwent SORSA, 5 STA, 1 by EA-RMRSA and 113 by GKRS approach. GTR was achieved in 175 (84.13%), STR 18 (8.65%) and PTR 15 (7.21%) $P < 0.05$ giving rise to n = 29 patients treated with surgery plus GKRS P-value (0.001) at a median of 2.5 months. Among, n = 18 recurrence, GTR 16 and STR 2 were treated with GKRS in 6 patients $P < 0.05$, at a median of 45 (average: 36 - 72) months and 12 patients with surgery at a median of 84 (average: 36 - 216) months $P < 0.05$. Hearing loss (50%) was most common complication followed by facial palsy and hydrocephalus. According to HBS, tumor > 3 cm shows 24.51% and overall 89.90% facial nerve Grade I-II outcome post-operatively. Microsurgery showed preservation of hearing with (91.58%, 98/107 and not preserved in (8.41%, 9/107) patients presenting with useful hearing preoperatively while those who had hearing loss preoperatively, post-operatively (7.76%, 7/102) gained with hearing and hearing could not be gained in (93.13%, 95/102) patients. Also, Post-GKRS showed hearing loss in 37.16% with preservation of hearing in (98.61%, 71/72) and not preserved in (1.38%, 1/72) who had useful hearing Pre-GKRS while hearing was not preserved in (100%, 41 cases) who presented with Pre-GKRS hearing loss with no evidence of facial palsy. 17 patients underwent VPN shunt due to hydrocephalus. CSF leakage presents in 1.44% and were managed conservatively. The median KPS at discharge was 80 $P < 0.05$. Death related to surgery occurred in one patient which was due to intracranial hemorrhage and pleural effusion.

Conclusion: Although microsurgery provides long term cure, incomplete resection due to microsurgical approach, small and recurrent tumors can be managed conservatively by GKRS with possible preservation of hearing and facial nerve in relation to microsurgery.

Keywords: Cerebellopontine Angle Tumors; Suboccipital Retro-Sigmoid Approach; House Brackmann Score

Abbreviation

CPATs: Cerebellopontine Angle Tumors; SORSA: Suboccipital Retro-Sigmoid Approach; HBS: House Brackmann Score; KPS: Karnofsky Performance Scale; GKRS: Gamma Knife Radiosurgery; GTR: Gross Total Resection; STR: Subtotal Resection

Introduction

Approximately 10% of all intracranial tumors are in triangular space bounded antero-medially by pons, postero-medially by cerebellum and laterally by petrous part of temporal bone named cerebellopontine angle (CPA) region. Vestibular schwannoma (also known as acoustic neuroma) accounts over 85% are in CPA region. The second most frequent non-acoustic CPA tumors are meningiomas 3 - 6%, epidermoid (primary cholesteatomas) 2 - 6% and other rare tumors in CPA are trigeminal neuromas which comprises 1-8% of intracranial schwannoma, facial or lower cranial nerve schwannomas (1 - 2%) [1-7]. They are mostly benign tumors commonly seen in adults, which usually present after a long asymptomatic period. Presenting symptoms, treatment considerations, and outcome are strongly related to the size and extension of CPATs.

Common strategies for the treatment of CPATs especially VS include the wait and scan policy, microsurgical resection, and gamma knife radiosurgery (GKRS) [8,9]. However, advances in microsurgical techniques, neuro-anesthesia, and intensive care coupled with intraoperative neurophysiological monitoring, have led to remarkable improvements in clinical outcome and reduce morbidity [10,11]. Also, stereotactic GKRS has emerged as an important alternative treatment option for brain tumors including CPATs. Because of the very complex anatomical structure of the area, CPATs pose unique and significant surgical challenges, surgery in CP angle is always been a challenge [12]. However, the goals of treatment include complete tumor resection with preservation of hearing and facial nerve function and avoidance of severe perioperative complications. Postoperatively, how additional non-surgical treatments assist in the prevention of recurrence is also important [13]. Patients now also have the option of undergoing stereotactic GKRS to halt the growth of the tumor. Some patients might also be candidates for a combination of these therapies [14]. However, considering this, the aim of surgery has evolved to preserve the patient's quality of life, even residual tumor exists. This is in part due to the concurrent rise of Leksell GKRS (1980) [15] as a non-surgical treatment and hence be a preferred as an acceptable treatment modality for newly diagnosed < 3 cm tumors involving inaccessible areas of brain, recurrent, or progressive Vestibular schwannomas with low risk of permanent facial nerve palsy [16] and large series demonstrating excellent-tumor control rates and minimal adverse effects [9,11,17-27].

Purpose of the Study

The purpose of this retrospective study is to investigate our experience with 321 CPA tumors, among a large series of patients who underwent surgical or non-surgical approach or both approaches with outcomes at a single institution.

Materials and Methods

Standard protocol approval, registration and patient consent

This study was approved by the Hospital's Ethics Committee, Affiliated Hospital of Xuzhou Medical University. The medical ethics committee approved a waiver of consent for collection of these data as part of routine clinical care and quality control. All methods were carried out in accordance with CONSORT 2010 checklist guidelines and regulations.

Selection criteria and patients population

This is a retrospective analysis of 321 cerebellopontine angle tumors (CPATs) (Figure 1) patients (median age: 56 yrs) who underwent surgical or non-surgical or both approaches from September 2014 to July 2018 at Affiliated Hospital of Xuzhou Medical University, Jiangsu province, China; with an initial radiographic diagnosis of CPATS were included in this study. The duration of recurrence was obtained from patients' history; hence it varies. The data were collected from the medical records with the patient's demographics, duration of symptoms, pre and postoperative neurological examination, operative procedure and treatment, complication, tumor size and pathology. All of the data were analyzed on the basis of clinical, radiological, surgical, histopathology reports and follow-up that affect the outcome and prognosis. These cases were categorized on the basis of Karnofsky performance status (KPS) and House-Brackmann scale (HBS) to assess the pre and postoperative status, extent of tumor resection (EOR), tumor size, pathology and facial nerve outcome. Pre-operative pure tone audiometry (PTA) was done to assess the degree of hearing loss. A criterion for useful hearing was taken as hearing loss < 50 decibel (Gardener-Robertson modification [28] of the Silverstein and Norell system [29]. Postoperative hearing assessment was done in patients who had useful and no useful hearing pre-operatively. This is an unequal randomization study and cases associated with Neurofibromato-

sis-II were excluded from the study. All operations were performed by senior Neurosurgeons within hospital and few were referred cases. A literature reviewed paper was conducted during one decade (2009 to 2019) on CPATs and all articles were obtained from either PubMed or Academia.edu (Table 12).

Figure 1: Incidence of cerebellopontine angle tumors (CPATS).

There were 111 male (34.6%) and 210 female (65.4%) who ranged in age from 20 - 86 years (Median age in AN: 58 yrs, CPA-meningioma: 56 yrs, Cholesteatoma: 49 yrs and Trigeminal neuroma: 47 yrs). There were 148 (46.1%) cases on right side and 173 (53.9%) on the left side (Table 1). The most frequent complaints were sensorineural hearing loss (44.54%) (Table 2 and 3), dizziness (32.08%) and facial hypoesthesia-numbness (20.56%) followed by headache (16.82%) (Table 2). Incidence of tumor recurrence were 5.60%. The tumor was imaged by magnetic resonance in 215 (66.96%) cases and/or computed tomography imaging in 71 (22.11%) cases and both in 35 (10.90%).

Overall, the median follow-up was 7.5 months (range 2 - 24 months) for CPATs. Thereafter, intervals were based on each follow-up result. All patients were followed up with MRI/CT imaging 3 months/6 months after surgery in the out-patient department. Surgical mortality was defined as death occurring within 30 days from the date of surgery and 20% increase in residual tumor or the appearance of a new lesion with atleast 10 mm in longest diameter on follow-up neuroimaging was termed as tumor recurrence [30].

Size and extension of tumors (EOT)

Based on the data we collected, pre-operative and intra-operative, mean tumor size was 2.6 cm. The CPA tumors were stratified into three group, according to the largest diameter: small (< 1.5 cm) in 95 cases (29.59%), medium (1.6 - 3 cm) in 152 (47.35%) and large (> 3 cm) in 74 cases (23.05%) in 321 cases (Table 4). The mean tumor size was 1.17 cm (range from 0.8 - 1.5 cm), 2.86 cm (1.6 - 3 cm) and 4.42 cm (more than 3 cm) in small, medium and large CPA tumors. Tumor invasion to CPA, tentorium, Internal auditory canal (IAC), trigeminal nerve, auditory nerve was mainly based on the CT, MRI and intraoperative views. we also found petrous bone and vein, cranial base dura, cavernous sinus and brainstem invasion in medium and large tumors (Table 4).

Characteristics	AN	CPA-M	C	TN	Total	
Sex, n (%)						
Male	69	13	11	5	111 (34.6%)	χ^2 (30.533) $P < 0.05$
Female	140	57	16	10	210 (65.4%)	
Age, years						
Median	58	56	49	47	56	
Range	21 - 86	35 - 75	20 - 65	25 - 71	20 - 86	
Side						
Right	102	31	14	6	148 (46.1%)	
Left	107	39	13	9	173 (53.9%)	
Preoperative KPS						
Median	80	80	80	80	80	
Range	40 - 100	0 - 100	40 - 100	40 - 100	0 - 100	
Follow-up months						
Median	8	7	9	6.5	7.5	
Range	3 - 24	2 - 24	3 - 24	3 - 24	2 - 24	

Table 1: Basic demographic chart in 321 cases of CPA tumor patients.
CPA: Cerebellopontine Angle Tumors; KPS: Karnofsky Performance Status; AN: Acoustic neuroma; CPA-M: Cerebellopontine Angle Meningioma; C: Cholesteatoma; TN: Trigeminal Neuroma.

Surgical approach

Out of 321 patients, 208 cases underwent surgical procedures in our institution (Table 5). A suboccipital retro-sigmoid approach

Symptoms and signs	AN	CPA-M	C	TN	Total (%)
Sensorineural hearing loss	126	13	2	2	143 (44.54)
Dizziness	69	25	4	5	103 (32.08)
Tinnitus	41	5	1	1	48 (14.95)
Facial hypoesthesia, numbness	38	12	8	8	66 (20.56)
Headache	21	19	10	4	54 (16.82)
Gait instability	11	4	2	1	18 (5.60)
Facial palsy	10	1	1	1	13 (4.04)
Limb weakness	14	3	5		22 (6.85)
Nausea and vomiting	9	7	2		18 (5.60)
Blurring of vision and rotation	4	4		4	12 (3.73)
SOL in CPA region	4	3	1	2	10 (3.11)
Recurrence of tumor	11	4	2	1	18 (5.60)
Ptosis of eyelid	4			3	7 (2.18)
Loss of sensation	8		1		9 (2.80)
Unclear speech	2		1		3 (0.93)
Seizure	2		1		3 (0.93)
Obstructive hydrocephalus	2				2 (0.62)

Table 2: Presenting symptoms and signs in 321 cases of CPA tumors.
CPAT: Cerebellopontine Angle Tumors; KPS: Karnofsky Performance Status; AN: Acoustic Neuroma; CPA-M: Cerebellopontine Angle Meningioma; C: Cholesteatoma; TN: Trigeminal Neuroma; SOL: Space Occupying Lesion.

Class	No. of patients	(%)
I and II (Serviceable hearing)	178	55.46
III and IV (non-serviceable)	143	44.54

Table 3: Distribution of cases according to pure tone audiometry (PTA) preoperatively.

Tumor diameter and extension in CPA region	AN	CPA-M	C	TN	
	(n = 209)	(n = 70)	(n = 27)	(n = 15)	
0.8 - 15 mm					Total (%)
IAC	3				3 (0.93)
CPA	68	11	3	1	83 (25.85)
Tentorium		3			3 (0.93)
Trigeminal nerve				2	2 (0.62)
Auditory nerve	4				4 (1.24)
Total	75 (23.36)	14 (4.36%)	3 (0.93%)	3 (0.93)	95
16-30mm					
IAC	1				1 (0.31)
CPA	76	29	19	6	130 (40.49)
Tentorium	1	3			4 (1.24)
Lateral cerebellum	3		1		4 (1.24)
Trigeminal nerve				1	1 (0.31)
Petrous bone		4			4 (1.24)
Petrous vein	1				1 (0.31)
Auditory nerve	5				5 (1.55)
Cranial base of dura		2			2 (0.62)
Total	87 (27.10)	38 (11.83)	20 (6.23)	7 (2.18)	152
>30mm					
IAC	2				2 (0.62)
CPA	37	9	4	4	54 (16.82)
Tentorium		5			5 (1.55)
Lateral cerebellum	3				3 (0.93)
Trigeminal nerve				1	1 (0.31)
Petrous bone		2			2 (0.62)
Petrous vein	2				2 (0.62)
Auditory nerve	3				3 (0.93)
Cranial base of dura		1			1 (0.31)
Cavernous sinus and brainstem		1			1 (0.31)
Total	47 (14.64)	18 (5.60%)	4 (1.24%)	5 (1.55)	74

Table 4: Tumor diameter and extension of CPA tumors.
CPA: Cerebellopontine Angle Tumors; AN: Acoustic Neuroma; CPA-M: Cerebellopontine Angle Meningioma; C: Cholesteatoma; TN: Trigeminal Neuroma. IAC: Internal Auditory Canal. [Note: Extension of tumors are based on CT/MRI/intraoperative view scans].

was applied in all (except 6 cases) operated cases using standard microsurgical techniques. Each patient was placed in lateral position head turned towards the opposite side of the tumor and fixed by Mayfield® framework (Integra Life science corp. Cincinnati OH) [13,31]. An "C" shaped scalp incision about 8-10cm was made behind the ear. The incision was long enough to allow an ideal craniotomy to obtain a large bone flap and Sigmoid sinus was partially exposed and if the mastoid air cells were opened, sealing the air cells with bone wax to avoid postoperative leakage of cerebrospinal fluid. The dura was incised in "C" shaped fashion and the cerebellar hemisphere was gently retracted to expose and open the cerebello-medullary cistern. The CSF was released in a great degree to ensure a wider operative space. A serpentine retractor was used to get a stable operative window. Debulking the tumors in a piecemeal fashion under an operative microscope to achieve resection of the tumor. The tumor cavity was completely hemostasis. Suturing and repairing the dura defect with artificial dura. One drainage tube was subcutaneously, bone flap, the muscles, fascia and scalp were sutured routinely.

Stereotactic radiosurgery

Although microsurgery is still the preferred treatment for large tumors, Gamma knife is an effective treatment for small, medium-sized, recurrent tumors and patients with mild clinical symptoms with the advantages of safety, minimal trauma and rapid recovery. The treatment dose should be determined according to the location and size of the tumor. Gamma knife stereotactic radiosurgery (Elekta AB, Stockholm, Sweden) was performed by fixing the head frame under local anesthesia and enhanced MRI localization. High resolution contrast enhanced axial pictures of the brain were taken in the 3-D SPGR sequence. The imaging data was then transferred to the Gamma Knife planning computer via the Ethernet. The Leksell Gamma Plan software, version 5.34, was used to perform the dose planning. The medial marginal dose of the tumor was 8.8Gy (7.2 - 12.8) and the mean isodose line was 45%.

Out of 321 cases, 113 patients received gamma surgery due to either small in tumor size or advanced age or patients' condition-

	Suboccipital Retro-sigmoid approach (n=202)				
Tumor diameter, mm	**AN**	**CPA-M**	**C**	**TN**	**Total (%)**
0.8 - 15 mm	1 (0.48)		3 (1.44)		4 (1.92)
16 - 30 mm	81 (38.94)	30 (14.42)	17 (8.17)	5 (2.40)	133 (63.94)
> 30 mm	40 (19.23)	14 (6.73)	7 (3.36)	4 (1.92)	65 (31.25)
Total	122 (58.65%)	44 (21.15%)	27 (12.98%)	9 (4.32%)	202
	Sub-temporal approach (n = 5)				
Tumor diameter, mm	**AN**	**CPA-M**	**C**	**TN**	**Total**
0.8 - 15 mm					
16 - 30 mm		5 (2.40)			5 (2.40)
> 30 mm					
Total		5 (2.40)			5
	EA-Retro-mastoid RSA (n = 1)				
Tumor diameter, mm	**AN**	**CPA-M**	**C**	**TN**	**Total**
0.8 - 15 mm					
16 - 30 mm	1 (0.48)				1 (0.48)
> 30 mm					
Total	1 (0.48)				1
	Gamma knife radio-surgery (n = 113)				
Tumor diameter, mm	**AN**	**CPA-M**	**C**	**TN**	**Total (%)**
0.8 - 15 mm	74 (8.2-12.8Gy)	14 (12.8Gy)		3 (12.8Gy)	91 (80.53)
16 - 30 mm	12 (7.2-12.8Gy)	7 (8.5-12.8Gy)		3 (8.5-12.8Gy)	22 (19.46)
> 30 mm					
Total	86 (76.10%)	21 (18.58%)		6 (5.30%)	113

Table 5: Approach and tumor diameter of CPA tumors.

AN: Acoustic Neuroma; CPA-M: Cerebellopontine Angle Meningioma; C: Cholesteatoma; TN: Trigeminal Neurinoma; EA-RM-RSA: Endoscopic Assisted Retro-Mastoid Retro-Sigmoid Approach.

wish. Details of location with tumor size and dose are listed in table 5. Non-surgical management following surgery (n = 29); in AN 12 patients with medium sized tumors received 8.5 - 12.5Gy and large 4 patients with 7.2 - 12.5Gy radiation dose. In CPA-M, medium sized 7 Patients were given 8.6 - 12.6Gy and large 5 cases with 12.6Gy radiation doses. Similarly, in trigeminal neuroma, large size tumor 1patient received 8.5Gy radiation dose and recurrence in acoustic neuroma patients received 8.6 - 12.8Gy in medium and 12.1Gy in large tumor with GKRS therapy (Table 9).

Statistical analysis

The relationship between surgical approach and either tumor diameter, extent of tumor resection, complication rate, need of reoperation, and postoperative KPS and post-GKRS KPS was analyzed. Chi-square test was performed by using SPSS version 16.0 (SPSS Inc, Chicago, IL) and $P < 0.05$ was considered statistically significant. Comparison of categorical variables was performed by χ^2 statistic using the Fisher exact test when appropriate.

Results

Surgical approach and tumor size

Out of 208 procedures, 202 procedures were performed by SORSA, 5 procedures by STA and one by EA-RMRSA in our institution. Among them, 4 (1.92%) were of small sized, 139 (66.82%) operation was medium (Figure 2) and 65 (31.25%) were of large size (Figure 3) CPA tumors. 7 patients had gone through ICU management. Of 202 procedures that used SORSA, 122 (58.65%) were performed in acoustic neuroma, 44 (21.15%) in CPA-meningioma, 27 (12.98%) in cholesteatoma and 9 (4.32%) in trigeminal neuroma. Among 4 Small sized CPATs operated by SORSA, 1 (0.48%) is acoustic neuroma and 3 (2.40%) are cholesteatoma. Among the 133, medium sized CPATs operated by SORSA, 81 (38.94%) are Acoustic neuroma, 30 (14.42%) CPA-M, 17 (8.17%) Cholesteatoma, 5 (2.40%) Trigeminal neuroma. Similarly, among the 66, large sized CPATs operated by SORSA, 40 (19.23%) are Acoustic neuroma, 14 (6.73%) CPA-M, 7 (3.36%) Cholesteatoma and 4 (1.92%) trigeminal neuroma. Medium sized CPA-M (n = 5, 2.40%) were approached through STA and (n = 1, 0.48%) acoustic neuroma through EA-RMRSA (Table 5).

Surgical approach and extent of resection (EOR)

GTR was achieved in 175 procedures (84.13%) (Figure 3), whereas subtotal in 18 procedures (8.65%) (Figure 2) and partial tumor resection in 15 procedures (7.21%) (Figure 4) χ^2 (30.449) P value < 0.05. In Acoustic neuroma, total removal was achieved in 102 of 123 (49.03%), subtotal 9 of 123 (4.32%) and partial removal 12 of 123 (5.76%). In CPA-meningioma, total removal was achieved in 40 of 49 (19.23%), subtotal in 8 of 49 (3.84%) and partial in 1 of 49 (0.48%). In cholesteatoma, total removal was 26 of 27 (12.5%), and partial removal in 1 of 27 (0.48%). In trigeminal neurinoma,

Figure 2: Illustrative case of large sized Acoustic neuroma (30 * 35 * 35 mm) Upper panel: Preoperative axial, coronal, sagittal, and gadolinium-enhanced T1-and axial T2-weighted MR images showing the tumor in CPA region. Lower panel: From left to right; postoperative CT scan illustrated 1st day, 4th day and 14th day subtotal tumor resection after suboccipital retro-sigmoid approach.

Figure 3: Illustrative case of Large sized CPA meningioma (48 * 50 * 50 mm) Upper panel, preoperative axial, coronal, sagittal, gadolinium-enhanced T1-and axial T2-weighted MR images show the tumor base attached to tentorium and CPA region. Lower panel: Postoperative CT scan from left: 1st day, 4th day and on 11th day illustrating total tumor resection after Suboccipital retro-sigmoid approach.

total removal was in 7 of 9 (3.36%), subtotal in 1 of 9 (0.48%) and partial removal in 1 of 9 (0.48%) (Table 6). All operated tumors were diagnosed pathologically in our institution. Among 208 histopathology reports, 123 (59.13%) are acoustic neuroma, 49 (23.55%) CPA-meningioma, 27 (12.98%) cholesteatoma and 9 (4.32%) trigeminal neuroma.

Figure 4: Illustrative case of large sized Acoustic neuroma (35*40*40mm) Upper panel: Preoperative axial, coronal, sagittal, and gadolinium-enhanced T1-and axial T2-weighted MR images showing the tumor in CPA region. Middle panel: From left to right: Postoperative CT scan illustrating 1st day, 4th day, 7th day and Lower panel: On follow up after 5 months: MRI Scan showing coronal, sagittal, T1 and T2 FLAIR axial scan partial tumor resection after suboccipital retro-sigmoid approach.

Surgical and non-surgical approach complications

The surgical complication occurring most frequently was hearing loss (50%), followed by facial palsy (10.09%) and hydrocephalus (8.65%) (Table 7). Death related to surgery occurred in one patient in CPA meningioma and is large size tumor operated by SORSA. Postoperative CSF leakage was observed in (1.44%) cases and managed by lumbar subarachnoid drainage. Overall, conservative management requiring CSF fluid diversion by Lumbar subarachnoid drainage was in 35 (16.82%) cases. Diplopia (n = 1) and CSF diversion by Lumbar puncture (n = 3) was found in sub-temporal approach as complications. There was no complication through EA-RMRSA procedure. Among (n = 113) non-surgical (GKRS) complication, 42 (37.16%) present as hearing loss followed by trigeminal neuralgia 0.88% and tinnitus 2.65% (Table 7).

Resection grade Histopathology					
Tumor diameter	**GTR**	**STR**	**PTR**	**Total**	
0.8 - 15 mm	1			1	Acoustic neuroma
16 - 30 mm	73	5	4	82	
> 30 mm	28	4	8	40	
Total	102 (49.03%)	9 (4.32%)	12 (5.76%)	123 (59.13%)	
Tumor diameter	**GTR**	**STR**	**PTR**	**Total**	
0.8 - 15 mm					Meningioma
16 - 30 mm	33	4		37	
> 30 mm	7	4	1	12	
Total	40 (19.23%)	8 (3.84%)	1 (0.48%)	49 (23.55%)	
Tumor diameter	**GTR**	**STR**	**PTR**	**Total**	
0.8 - 15 mm	3			3	Cholesteatoma
16 - 30 mm	17			17	
> 30 mm	6		1	7	
Total	26 (12.5%)		1 (0.48%)	27 (12.98%)	
Tumor diameter	**GTR**	**STR**	**PTR**	**Total**	
0.8 - 15 mm					Trigeminal neurinoma
16 - 30 mm	2	1	1	4	
> 30 mm	5			5	
Total	7 (3.36%)	1 (0.48%)	1 (0.48%)	9 (4.32%)	

Table 6: Tumor diameter in relation to resection of grade and histopathology. GTR: Gross Total Resection; STR: Subtotal Resection; PTR: Partial Tumor Resection [Resection grade χ^2 (30.449) $P < 0.05$].

	Surgical procedure (n = 202 SORSA; n = 5 Sub-temporal approach; n = 1 EA-RMRSA)					Non-Surgical procedure (n = 113 GKRS)				
Complications	**AN**	**CPAM**	**C**	**TN**	**Total (%)**	**AN**	**CPAM**	**C**	**TN**	**Total (%)**
Facial palsy	14	5	1	1	21 (10.09)					
Hearing loss	89	11	2	2	143 (50)	40	2			42 (37.16)
Hydrocephalus	14	1	2	1	18 (8.65)					
Lagophthalmos	17				17 (8.17)					
Nausea, vomiting	6	2	5		13 (6.25)					
Hemiplegia	9	2	1		12 (5.76)					
Trigeminal neuralgia			8	2	10 (4.80)				1	1 (0.88)
Headache	1	4	4		9 (4.32)					
Tracheostomy	2	1			3 (1.44)					
Brain abscess	3	1			4 (1.92)					
Ptosis	4		2		6 (2.88)					
Diplopia	1	1	1	1	4 (1.92)					
Hoarseness voice	1	1			2 (0.96)					
Bleeding (ICH)	4	1	1	2	8 (3.84)					
CSFleak (rhinorrhea)		2	1		3 (1.44)					
III CN palsy	1				1 (0.48)					
VI CN palsy	1			1	2 (0.96)					
Seizure	1	1	1		3 (1.44)					
Pleural effusion		2			2 (0.96)					
Tinnitus	3	3	1		7 (3.36)	3				3 (2.65)
Meningitis			1		1 (0.48)					
Death		1			1 (0.48)					

Table 7: Complications of surgical and non-surgical procedures in CPATS.

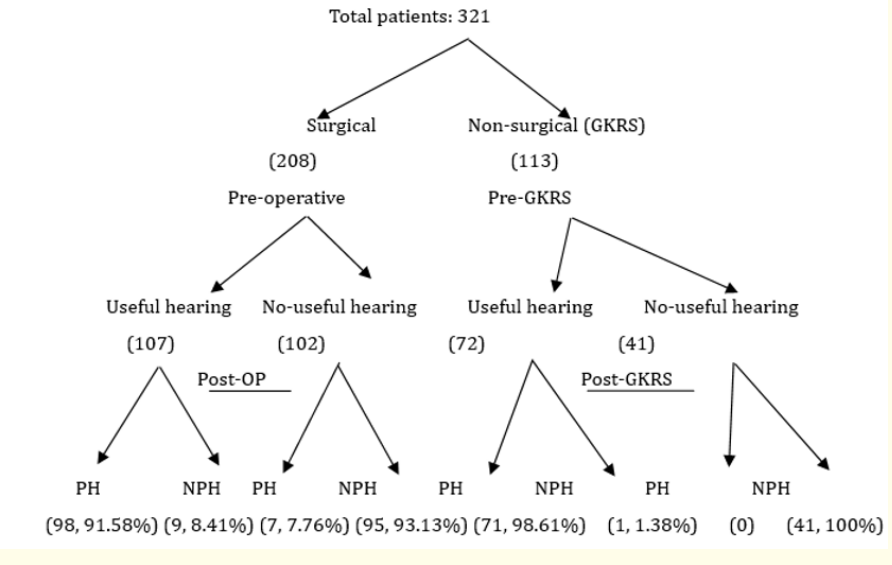

Figure 5: Distribution of surgical and non-surgical hearing though pure tone audiogram.
Post-OP: Post-Operative; PH: Preserved Hearing; NPH: Not Preserved Hearing.

Out of 208 surgery performed, 27 cases were re-operated. Decompressive craniotomy was performed in 1 (3.70%), 17 (62.96%) had VPN shunt, 1 (3.70%) had EVD and 8 (29.62%) had surgically removal of hematomas (Table 8). Overall, Post-operative ICU stay was 5 - 7 days in CPA-Meningioma 2 cases and acoustic neuroma 5 cases. Following surgery n = 29; 10 (17.24%) GTR, 15 (51.72%) STR and 4 (13.79%) PTR patients underwent GKRS in duration of median 2.5 months (1 - 12 months). Due to large size, persisting hearing loss and facial palsy GKRS was recommended in GTR patients (Table 9).

Outcome

Surgical

(A) CPA tumors size was small in 95 cases (29.59%), medium in 152 (47.35%) and large in 74 cases (23.05%) in 321 cases (Table 4). In patients who underwent surgical approach, (202 SORSA, 5 STA and 1 EA-RMRSA), GTR was achieved in 175 (84.13%), STR 18 (8.65%) and PTR in 15 (7.21%) (Table 6).

Reoperation (n = 27)	AN	CPA-M	C	TN	Total
Removal of hematomas	4 (14.81%)	1 (3.70%)	1 (3.70%)	2 (7.40%)	8 (29.62%)
Decompressive craniotomy		1 (3.70%)			1 (3.70%)
VPN shunt	13 (48.14%)	1 (3.70%)	2 (7.40%)	1 (3.70%)	17 (62.96%)
EVD	1 (3.70%)				1 (3.70%)

Table 8: Re-operation for complication of CPA tumors.

CPA: Cerebellopontine Angle Tumors; AN: Acoustic Neuroma; CPA-M: Cerebellopontine Angle Meningioma; C: Cholesteatoma; TN: Trigeminal Neuroma; EVD: External Ventricular Drainage [χ^2 (11.732) $P < 0.05$].

Surgery+ GKRS						
Tumor diameter	**AN**	**CPA-M**	**C**	**TN**	**Total (%)**	**Duration Median (months)**
Non-surgical management following surgery (n = 29)						
0.8 - 15 mm						
16 - 30 mm	12 (41.37%) (8.5-12.5Gy)	7 (24.13%) 8.6-12.6Gy)			19 (65.51%)	
> 30 mm	4 (13.79%) (7.2-12.5Gy)	5 (17.24%) (12.6Gy)		1 (3.44%) (8.5Gy)	10 (34.48%)	
Total	16 (55.17%)	12 (41.37%)		1 (3.44%)	29	
Extent of resection						
GTR	5 (17.24%)	4 (13.79%)		1 (3.44%)	10 (34.48%)	2 (1-12)
STR	7 (24.13%)	8 (27.58%)			15 (51.72%)	4 (1-12)
PTR	4 (13.79%)				4 (13.79%)	2.5 (1-6)
Total	16 (55.17%)	12 (41.37%)		1 (3.44%)	29	
Non-surgical (GKRS) management following tumor recurrence (n = 6)						
Tumor diameter	**AN**	**CPA-M**	**C**	**TN**	**Total**	**Duration Median (months)**
0.8 - 15 mm						
16 - 30 mm	5 (27.77%) (8.6-12.8Gy)				5 (27.77%)	
> 30 mm	1 (5.55%) (12.1Gy)				1 (5.55%)	
Total	6 (33.33%)				6	
Extent of resection	AN	CPA-M	C	TN	Total	
GTR	4 (22.22%)				4 (22.22%)	48 (36 - 72)
STR	2 (11.11%)				2 (11.11%)	42 (36 - 48)
PTR						
Total	6 (33.33%)				6	

Surgical management following tumor recurrence (n = 12)						
Tumor diameter	**AN**	**CPA-M**	**C**	**TN**	**Total (%)**	**Duration**
						Median (months)
0.8-15 mm			1 (5.55%)		1 (5.55%)	
16 - 30 mm	4 (22.22%)	3 (16.66%)	1 (5.55%)		8 (44.44%)	
> 30 mm	1 (5.55%)	1 (5.55%)		1 (5.55%)	3 (16.66%)	
Total	5 (27.77%)	4 (22.22%)	2 (11.11%)	1 (5.55%)	12	
Extent of resection	**AN**	**CPA-M**	**C**	**TN**		
GTR	5 (27.77%)	4 (22.22%)	2 (11.11%)	1 (5.55%)	12 (66.66%)	84 (36-216)
STR						
PTR						
Total	5 (27.77%)	4 (22.22%)	2 (11.11%)	1 (5.55%)	12	

Table 9: Surgical and non-surgical management on tumor recurrence due to incomplete resection or due to persisting complications. AN: Acoustic Neuroma; CPA-M: Cerebellopontine Angle Meningioma; C: Cholesteatoma; TN: Trigeminal Neuroma (1 patient had 3 episodes of operation@ 4yrs intervals following GKRS). [Non-surgical management following surgery χ^2 (14.652) P-value (0.001) $P < 0.05$; Non-surgical (GKRS) management following tumor recurrence χ^2 (25.952) $P < 0.05$; Surgical management following tumor recurrence χ^2 (10.035) P-value (0.001) at $P < 0.05$].

Surgical approach and tumor diameter	Median KPS at discharge	Non-surgical approach	Median KPS at discharge
SORSA (n = 202), EA-RMRSA (n = 1), STA (n = 5)			
1. Acoustic neuroma (n = 123)	80	(N = 86)	80
0.8 - 15 mm (n = 1)	80	n = 74	80
16 - 30 mm (n = 82)	80	n = 12	80
> 30 mm (n = 40)	70		
2. CPA meningioma (n = 49)	80	(N = 21)	80
0.8 - 15 mm (n = 0)	NA	n = 14	80
16 - 30 mm (n = 35)	80	n = 7	80
> 30 mm (n = 14)	70		
3. Cholesteatoma (n = 27)	80		
0.8 - 15 mm (n = 3)	80		
16 - 30 mm (n = 17)	80		
> 30 mm (n = 7)	70		
4. Trigeminal neuroma (n = 9)	80	(N = 6)	80
0.8 - 15 mm (n = 0)	NA	n = 3	80
16 - 30 mm (n = 5)	85	n = 3	80
> 30 mm (n = 4)	70		

Table 10: Surgical and non-surgical approach tumor size outcome in CPA tumors. CPA: Cerebellopontine Angle Tumors; AN: Acoustic Neuroma; CPA-M: Cerebellopontine Angle Meningioma; C: Cholesteatoma; TN: Trigeminal Neuroma; STA: Sub-Temporal Approach; EA-RMRSA: Endoscopic Assisted Retro-Mastoid Retro-Sigmoid Approach [KPS at discharge χ^2 (1.185E3) $P < 0.05$ which is statistically significant].

(B) n = 29 (10/29 GTR, 15/29 STR and 4/29 PTR) patients were treated with surgery plus GKRS at a median of 2.5 months and n = 18 with previous history of surgery were entered during this period as recurrence. Among, n = 18, GTR 16 (88.88%) and STR 2 (11.11%) recurrence were treated in 6 patients with GKRS at a median of 45 (average: 36 - 72) months and 12 patients with surgery at a median of 84 (average: 36 - 216) months.

(C) Tumor origin and presence of CPA invasion were significantly involved in EOR except 91 small and 22 medium size tumors. Tumors originating from cranial base of dura underwent GTR, and cavernous sinus and brainstem invasion was associated with recurrence of tumor and again underwent microsurgical procedure (Table 4).

(D) In an effort to characterize preservation of facial nerve motor function using our treatment algorithm, we examined pre- and postoperative facial nerve function in all patients treated with either surgical resection or GKRS. Facial nerve outcome was assessed by HBS pre-operative and post-operative. Pre-operatively, 199 (95.67%) had HBS score of Grade I, 7 (3.36%) Grade II, 1 (0.48%) Grade III, 1 (0.48%) Grade IV and 206 (99.03%) had score of 1 or 2 and 2 (0.96%) had score of 3 or 4 χ^2 (200.077) $P < 0.05$. Post operatively 154 (74.03%) had HBS Score of Grade I, 35 (16.85%) score of Grade II, 6 (2.88%) score of Grade III, 8 (3.84%) score of IV, 5 (2.40%) score of Grade V and 187 (89.90%) had score of 1 or 2, 16 (7.62%) had score of 3 or 4 and 5 (2.40%) had score of 5 χ^2 (3.004E2) $P < 0.05$ (Table 11) which is statistically significant.

(E) Microsurgery showed Facial palsy/Hearing loss was (10.09%, χ^2 (3.004E2) $P < 0.05$/50%, χ^2 (1.490E2) $P < 0.05$) resulting in preservation of hearing with (91.58%, 98/107) and not preserved hearing in (8.41%, 9/107) patients presenting with useful hearing preoperatively Whereas those who had hearing loss preoperatively, (7.76%, 7/102 patients) gained with hearing and those were 5 medium sized and 2 large size tumors and no improvement in hearing was observed in (93.13%, 95/102) patients (Figure 5).

(F) Due to complications re-operation was managed in 27 cases (Table 8). Histopathology report shows 123 acoustic neuroma, 49 meningioma, 27 cholesteatoma and 9 trigeminal neuromas (Table 6).

(G) The median preoperative KPS score was 80 (range 40 - 100) acoustic neuroma, 80 (0 - 100) CPA-meningioma, 80 (40 - 100) cholesteatoma and 80 (40 - 100) trigeminal neuroma for SORSA, Sub-temporal and EA-RMRS approach (Table 1). Overall, the median KPS at discharge is 80 χ^2 (1.185E3) $P < 0.05$ (Table 10).

(H) Death related to surgery occurred in one patient (0.49%) which was due to intracranial hemorrhage and pleural effusion.

Non-Surgical

(A) 113 patients received gamma knife radiosurgery were acoustic neuroma 86 (76.10%), CPA meningioma 21 (18.58%) and 6 (5.30%) trigeminal neuroma (Table 5).

Tumor size and Facial nerve outcome by House-Brackmann grade pre-operatively in 208 cases. Excellent Intermediate Poor						
Tumor size	**Grade I**	**Grade II**	**Grade III**	**Grade IV**	**Grade V**	**Grade VI**
0.8 - 15 mm	4 (1.92%)					
16 - 30 mm	136 (65.38%)	3 (1.44%)				
> 30 mm	59 (28.36%)	4 (1.92%)	1 (0.48%)	1 (0.48%)		
Total	199 (95.67%)	7 (3.36%)	1 (0.48%)	1 (0.48%)		
Tumor size and Facial nerve outcome by House-Brackmann grade post-operatively in 208 cases. Excellent Intermediate Poor						
Tumor size	**Grade I**	**Grade II**	**Grade III**	**Grade IV**	**Grade V**	**Grade VI**
0.8 - 15 mm	3 (1.44%)	1 (0.48%)				
16 - 30 mm	105 (50.48%)	27 (12.98%)	2 (0.96%)	3 (1.44%)	2 (0.96%)	
> 30 mm	46 (22.11%)	5 (2.40%)	6 (2.88%)	5 (2.40%)	3 (1.44%)	
Total	154 (74.03%)	33 (15.86%)	8 (3.84%)	8 (3.84%)	5 (2.40%)	

Table 11: Tumor size and facial nerve outcome by House-Brackmann grade.
[HBS Pre-operative χ^2 (200.077) $P < 0.05$; HBS Post-operative χ^2 (3.004E2) $P < 0.05$].

(B) Post-GKRS showed hearing loss in 38.14% with preservation of hearing in (98.61%, 71/72) and not preserved in (1.38%, 1/72) who had useful hearing Pre-GKRS while hearing function could not be gained in (100%,41 cases) who presented with Pre-GKRS hearing loss (Figure 5) and facial nerve motor function and House-Brackmann grades remained unchanged in all patients (100%) who received GKRS as initial therapy. Due to old age and large tumor size, 1 case had VPN prior to GKRS. 21 patients in acoustic neuroma, 1 CPA-meningioma and 1 trigeminal neuroma received twice GKRS and were advice to follow-up on 3 months interval.

Discussion

In the present study, our finding constituent incidence of Acoustic neuroma (65.1%), CPA meningioma (21.8%), Cholesteatoma (8.4%), Trigeminal neurinoma (4.6%) with female predominance (65.4%) χ^2 (30.533) $P < 0.05$ and those results are very close to the study made in literature [12,32-39]. Unilateral hearing loss is more common according to Ricardo Ferreira Bentol., *et al.* [40] and most published in world literature [12,32-39] which is approximately 69 - 90% in acoustic neuroma. In our series, hearing loss (44.54%) (Table 2 and 3) was more common, which accounts 60.28% in acoustic neuroma. In a study done by Diane S Lazard., *et al*. [34] and Joarder MA., *et al*. [12], they reported 11% and 35% total tumor resection while VK Jain., *et al.* [41] achieved 96.5% total tumor resection and gives evidence resection grade outcome is based on approach and tumor size. In a study performed by Hirofumi Nakatomi., *et al.* [42], among 18 patients treated with STR, 15 experienced recurrence which is 11-fold risk in STR, whereas among 396 patients treated with GTR, 52 experienced recurrence at a median of 7.5 years following resection (IQR 5.5 - 13.3, range 2.0 - 22.5) of sporadic VS. Similarly, Randy S. D'Amico., *et al.* [11] showed among 34 GTR and 17 STR patients treated with microsurgery in meningioma, 5 experienced recurrence in GTR and 7 in STR and recurrence were treated in 8 patients with GKRS and 4 patients with surgery plus GKRS. In our studies, overall GTR was 175 (84.13%), STR 18 (8.65%) and PTR 15 (7.21%) χ^2 (30.449) $P < 0.05$ giving rise to n = 29 (10/29 GTR, 15/29 STR and 4/29 PTR) patients treated with surgery plus GKRS χ^2 (14.652) P-value (0.001) $P < 0.05$, at a median of 2.5 months which explains incomplete or complete tumor resection needs non-surgical approach following surgery and n = 18 with previous history of surgery were entered during this period as recurrence, Among, n = 18, GTR 16 (88.88%) and STR 2 (11.11%) and recurrence were treated in 6 patients with GKRS χ^2 (25.952) $P < 0.05$, at a median of 45 (average: 36 - 72) months and 12 patients with surgery at a median of 84 (average: 36 - 216) months χ^2 (10.035) P-value (0.001) at $P < 0.05$ which explains STR alone should not be considered for tumor recurrence, long-term surveillance is also required following GTR.

The most common complication encountered in our surgical study was hearing loss (50%) followed by facial palsy (10.09%) and hydrocephalus (8.65%). The SORSA allowed a significant percentage of facial nerve outcome by HBS. Pre-operatively (99.03%) had score of 1 or 2 (Excellent) and (0.96%) had score of 3 or 4 (Intermediate) χ^2 (200.077) $P < 0.05$. Post operatively (89.90%) had score of 1 or 2 (Excellent), (7.62%) had score of 3 or 4 (Intermediate) and (2.40%) had score of 5 (Poor) χ^2 (3.004E2) $P < 0.05$ which is statistically significant. In a study performed by VK Jain., *et al.* [41] facial nerve preservation was 84.3%, Diane S Lazard., *et al.* [34] reported with 53%, Joarder MA., *et al*. [12], Farmarz Memarizl [37], Randy S. D'Amico., *et al*. [11], Samii Matthias., *et al*. [43] and Nedzelski JM., *et al*. [44] reported with 61%, 64%, 84.3%, 93% and 97% of facial nerve outcome post operatively. Our present study with tumor > 3 cm shows 24.51% and overall, 89.90% facial nerve Grade I-II outcome post-operatively which is comparable to VK Jain., *et al*, Randy S. D'Amico., *et al*. and Samii Mathias., *et al.* and explains surgical approach and tumor size affects the post-operative outcomes. Life threatening complication compared to other series of study (Table 9) is relatively more in our study. Intracranial hemorrhage (3.84%) was managed by re-operation with removal of hematoma. CSF leakage as reviewed in literature [12,32,34,36-39] range from 6 - 18% with the average approximately 11.6%. In the present study, we had 1.44% cases with CSF leakage and were managed conservatively. Re-operation of complication was performed by VPN shunt in 17 patients (Table 8) giving evidence that large tumors were more prone to shunt in comparison to other size.

Microsurgery versus Radiosurgery: Leksell introduced Gammaknife in 1980 as a non-surgical treatment. Since then, it has gained popularity for tumor size < 3 cm or recurrent or towards patient wish or following resection grade. Myrseth., *et al.* in 2005, showed microsurgery and gamma knife were not statistically different (89.2% versus 94.2%) and Gamma knife boasted a facial nerve preservation rate of 94.2% while surgery only showed 79.8% HB grade I/II [45]. In another study by Pollock., *et al.* in 2006, he found, facial nerve function/hearing preservation were both significantly worse in those treated with surgery versus those treated with gamma knife (75%/5% versus 96%/63%) [46]. In whole series of combined microsurgery and GKRS of Roy Thomas Daniel [47] 100% facial nerve preservation along with preservation of hearing for all patients those with useful pre-operative hearing pre-operatively was achieved in large VS. In a study by Joarder MA [12], 60% hearing preservation was achieved in 5 patients who had useful hearing preoperatively and VK Jain., *et al.* [41] reported hearing preservation in 29.6% of their patients who had useful pre-operative hearing. In our current study, microsurgery used as stand-alone treatment showed Facial palsy/Hearing loss was (10.09%, χ^2 (3.004E2) $P < 0.05$/50%, χ^2 (1.490E2) $P < 0.05$) resulting in preservation of hearing with (91.58%, 98/107) and not preserved in (8.41%, 9/107) patients presenting with useful hearing preoperatively while those who had hearing loss preoperatively, Post-operatively (7.76%, 7/102) gained with hearing and hearing was not gained in (93.13%, 95/102) patients. Also, Post-GKRS showed hearing loss

in 37.16% with preservation of hearing in (98.61%, 71/72) and not preserved in (1.38%, 1/72) who had useful hearing Pre-GKRS while hearing function could not be gained in (100%, 41 cases) who presented with Pre-GKRS hearing loss (Figure 5) with no evidence of facial palsy.

Suboccipital approach is the standard procedure in all cases described in our study as it provides exposure to the lateral cerebellum and cerebellopontine angle [36,48]. The trans-labyrinthine or enlarged trans-labyrinthine [37,49] or modified trans-labyrinthine approach, as well as in combination with a retro-sigmoid exposure [50] is appropriate to removal of VSs for any size. Similarly, V.K. Poshataev., *et al.* [35] reported endoscopic assisted in retro-sigmoid approach is significant with less than 2 cm tumor and difficult to use the endoscopic technique to remove large and giant tumors because of significant bleeding. We had one acoustic neuroma case operated by EA-RMRSA and the tumor size was 1.9 * 1.4 cm with no complication. Similarly, our study also included 5 cases operated by Sub-temporal approach in CPA-meningioma with negligible morbidity.

In a literature reviewed (Table 12), mortality rate following surgery range from 0% to 6% and our study encroach between this with 0.48% which is due to intracerebral hemorrhage and pleural effusion. Age < 60, tumor diameter < 3 cm, KPS at discharge > 80, HBS Grade I-II (Excellent) and GTR 84.13% were significant prognosticator for overall longer outcome.

Although, the first surgical approach to remove CPA tumors was in 1894, a review of the CPA tumors published during the last decades shows that the surgical treatment of CPATs still carries a non-negligible risk of mortality, life-threatening complications, facial palsy and tumor recurrence due to its complex anatomy, vasculature, different surgical approaches and resection grading (Table 12). This single-center analysis of surgically treated CPA tumors is limited by the retrospective design with SORSA, STA, EA-RMRSA and GKRS. It should be emphasized that this is an institutional series. Therefore, case selection, surgical and non-surgical approach reflects different possible outcomes.

Author, Year	No. cases	Diameter > 3 cm (%)	Surgical approach	HBS PO (Grade I-II%)	Life threatening complication (%)	Mortality (%)	CSF leakage	Recurrence (%)	Mean follow-up (months)
Yang Shi-Ming 2009 [39]	25	NA	OEA	13	NA	0	2	NA	NA
Diane S. Lazard 2011 [34]	72	NA	TLA, RSA, TOA	28 (53%)	ICH (3%)	0	12 (17%)	8 (11%)	NA
Selena E. HemanAckah., *et al*. 2012 [36]	197	33 (17.7%)	RSA	NA	PE (0.5%)	0	13 (6.6%	NA	NA
V.K. Poshataev 2014 [35]	33	NA	EA-SRSA	P < 0.05	NA	0	NA	NA	NA
G. Raja Sekhar Kennedy 2015 [32]	50	48	RM-RSA	13pts	ICH (2%)	3 (6%)	8 (16%)	NA	NA
Seema Zahid 2015 [33]	26	NA	NA	NA	NA	0	NA	NA	NA
Joarder MA 2015 [12]	34	29 (85%)	SORSA	61%	NA	1 (3%)	2 (6%)	NA	NA
Faramarz Memari 2015 [37]	50	8	TLA (34) RSA (14)	64%	ICH	1 (2%)	9 (18%)	NA	12
Jawad MSM 2017 [38]	30	6	SORSA	25pts	NA	1 (3%)	2 (6%)	NA	NA
Present series (2019)	321	66 (31.73%)	SORSA (202) STA (5) EA-RMRSA (1)	89.90%	ICH (3.84%)	1 (0.48%)	3 (1.44%)	18 (5.60%)	7.5

Table 12: Literature review of CPA tumors published during one decade.

SORSA: Sub-Occipital Retro-Sigmoid Approach; TLA: Trans-Labyrinthine Approach; RM-RSA: Retro-Mastoid Retro-Sigmoid Approach; EA-SORSA: Endoscopic-Assisted Sub-Occipital Retro-Sigmoid Approach; TOA: Trans-Otic Approach; NA: Not Available; ICH: Intracranial Hemorrhage; HBS PO: House-Brackmann Score Post-operative; CSF: Cerebrospinal Fluid; PE: Pulmonary Embolism; STA: Sub-Temporal Approach; EA-RMRSA: Endoscopic Assisted Retro-Mastoid Retro-Sigmoid Approach. #Recurrence of tumor presents during our study as they had P/H/O surgery. Therefore, duration varies with our current study.

Conclusion

In this large series of CPA tumors, suboccipital retro-sigmoid approach is more sufficient to achieve Gross-total resection and recurrence of tumors are connected to tumor size and resection grade. Although microsurgery provides long term cure, incomplete resection due to microsurgical approach, small and recurrent tumors can be managed conservatively by GKRS with possible preservation of hearing and facial nerve in relation to microsurgery.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest

None.

Ethical Approval

Affiliated Hospital of Xuzhou medical university Ethics Committee issued approval. This study was approved by the hospital's ethics committee.

Informed Consent

The medical ethics committee approved a waiver of consent for collection of these data as part of routine clinical care and quality control.

Bibliography

1. Samii M and Gerganov V. "Surgery of Cerebellopontine Lesions". Springer-Verlag Berlin Heidelberg (2013).
2. Springborg JB., *et al*. "Nonvestibular schwannoma tumors in the cerebellopontine angle: a structured approach and management guidelines". *Skull Base* 18.4 (2008): 217-227.
3. Barnes L. "Surgical Pathology of the Head and Neck in forma healthcare" (2009).
4. Yilmaz C., *et al*. "Rare lesions of the cerebellopontine angle". *Turkish Neurosurgery* 20.3 (2010): 390-397.
5. Machinis TG., *et al*. "History of acoustic neurinoma surgery". *Neurosurgical Focus* 18.4 (2005): e9.
6. Patel N., *et al*. "Diagnostic and surgical challenges in resection of cerebellar angle tumors and acoustic neuromas". *Surgical Neurology International* 3 (2012): 17.
7. Alam S KA., *et al*. "The surgical management of trigeminal schwannomas". *The ORION Medical Journal* 32.2 (2009): 659-662.
8. Van de Langenberg R., *et al*. "Management of large vestibular schwannoma. Part I. Planned subtotal resection followed by Gamma Knife surgery: radiological and clinical aspects". *Journal of Neurosurgery* 115.5 (2011): 875-884.
9. Bir SC., *et al*. "Long-term outcome of gamma knife radiosurgery for vestibular schwannoma". *Journal of Neurological Surgery Part B: Skull Base* 75.4 (2014): 273-278.
10. Harati A., *et al*. "Clinical features, microsurgical treatment, and outcome of vestibular schwannoma with brainstem compression". *Surgical Neurology International* 8 (2017): 45.
11. D'Amico RS., *et al*. "Efficacy and outcomes of facial nerve-sparing treatment approach to cerebellopontine angle meningiomas". *Journal of Neurosurgery* 127.6 (2017): 1231-1241.
12. Joarder M., *et al*. "Surgical Outcomes of Cerebellopontine Angle Tumors in 34 Cases". *Pulse* 8 (2015).
13. He X., *et al*. "Surgical Management and Outcome Experience of 53 Cerebellopontine Angle Meningiomas". *Cureus* 9.8 (2017): e1538.
14. Iwai Y., *et al*. "Surgery combined with radiosurgery of large acoustic neuromas". *Surgical Neurology International* 59.4 (2003): 283-289.
15. L Leksell. "Cerebral radiosurgery I Gammathalanotomy in two cases of intractable pain". *Acta Chirurgica Scandinavica* 134.8 (1968): 585.
16. Lin EP and Crane BT. "The Management and Imaging of Vestibular Schwannomas". *American Journal of Neuroradiology* 38.11 (2017): 2034-2043.
17. Dale D., *et al*. "Gamma knife radiosurgery for cerebellopontine angle meningiomas: a multicenter study". *Journal of Neurosurgery* 75.4 (2014): 398-408.
18. Boari N., *et al*. "Gamma Knife radiosurgery for vestibular schwannoma: clinical results at long-term follow-up in a series of 379 patients". *Journal of Neurosurgery* 121.2 (2014): 123-142.

19. Wong RX., *et al*. "Local experience with radiosurgery for vestibular schwannomas and recommendations for management". *Singapore Medical Journal* 59.11 (2018): 590-596.

20. Kreil W., *et al*. "Long term experience of gamma knife radiosurgery for benign skull base meningiomas*". Journal of Neurology, Neurosurgery, and Psychiatry* 76.10 (2005): 1425-1430.

21. Conti A., *et al*. "Post-Treatment Edema after Meningioma Radiosurgery is a Predictable Complication". *Cureus* 8.5 (2016): e605.

22. Muzevic D., *et al*. "Stereotactic radiotherapy for vestibular schwannoma". *The Cochrane Database of Systematic Reviews* 12.12 (2014): CD009897.

23. Régis J., *et al*. "Wait-and-see strategy compared with proactive Gamma Knife surgery in patients with intracanalicular vestibular schwannomas: clinical article". *Journal of Neurosurgery* 119.6 (2013): 105.

24. Lunsford LD., *et al*. "Radiosurgery of vestibular schwannomas: summary of experience in 829 cases". *Journal of Neurosurgery* 102 (2005):195-199.

25. Moosa SDD. "Role of Stereotactic Radiosurgery in the Management of Cerebellopontine Angle Tumors". *Austin Journal of Radiation Oncology and Cancer* 1.1 (2015): 1004.

26. Mahboubi H., *et al*. "CyberKnife for Treatment of Vestibular Schwannoma: A Meta-analysis". *Otolaryngology–Head and Neck Surgery* 157.1 (2017): 7-15.

27. Troude L., *et al*. "Adjunctive Gamma Knife Surgery or Wait and Scan Policy After Optimal Resection of Large Vestibular Schwannomas: Clinical and Radiologic Outcomes". *World Neurosurgery* 118 (2018): e895-e905.

28. Gardner G and Robertson JH. "Hearing Preservation in Unilateral Acoustic Neuroma Surgery". *Journal of Annals of Otology, Rhinology and Laryngology* 97.1 (1988): 55-66.

29. Silverstein H., *et al*. "Hearing preservation after acoustic neuroma surgery using intraoperative direct eighth cranial nerve monitoring". *Journal of American Journal of Otolaryngology* 3 (1985): 99.

30. Eisenhauer EA., *et al*. "New response evaluation criteria in solid tumours: revised RECIST guideline (version 1.1)". *European Journal of Cancer* 45.2 (2009): 228-247.

31. Vince DN. "Suboccipital Surgery for Acoustic Neuroma". *Mayfield Brain and Spine* (2018).

32. G Raja Sekhar Kennedy J. "A Study of the Incidence of Cerebellopontine Angle Tumors and their Management in a Tertiary Care Hospital". *Journal of Evidence based Medicine and Healthcare* 2.17 (2015): 2517-2524.

33. Zahid S., *et al*. "Frequency and clinical presentation of cerebellopontine angle tumors: An experience in Department of Neurosurgery Lady Reading Hospital Peshawar". *Journal of Postgraduate Medical Institute* 30.3 (2016): 226-229.

34. Lazard DS., *et al*. "Early complications and symptoms of cerebellopontine angle tumor surgery: a prospective analysis". *European Archives of Oto-Rhino-Laryngology* 268.11 (2011): 1575-1582.

35. Poshataev VK., *et al*. " [Endoscopic assistance in surgery of cerebellopontine angle tumors]". *Zh Vopr Neirokhir Im N N Burdenko* 78.4 (2014): 42-49.

36. Heman-Ackah SE., *et al*. "Retrosigmoid approach to cerebellopontine angle tumor resection: Surgical modifications". *The Laryngoscope* 122.11 (2012): 2519-2523.

37. Memari F., *et al*. "Surgical Outcomes of Cerebellopontine angle Tumors in 50 Cases". *Iranian Journal of Otorhinolaryngology* 27.78 (2015): 29-34.

38. Mohammed Jawad MS. "Cerebellopontine Angle Tumors; Tumor Size and Surgical Outcome". *Open access Journal of Neurology and Neurosurgery* 3.4 (2017).

39. Shi-ming Y., *et al*. "Endoscope-Assisted Cerebellopontine Angle Surgery". *Journal of Otology* 4.1 (2009): 44-49.

40. Pinna MH., *et al*. "Vestibular schwannoma: 825 cases from a 25-year experience". *International Archives of Otorhinolaryngology* 16.4 (2012): 466-475.

41. Jain VK., *et al*. "Surgery of vestibular schwannomas: an institutional experience". *Neurol India* 53.1 (2005): 41-55.

42. Nakatomi H., *et al*. "Long-term risk of recurrence and regrowth after gross-total and subtotal resection of sporadic vestibular schwannoma". *Journal of Neurosurgery* (2017): 1-7.

43. Matthies C and Samii M. "Management of 1000 vestibular schwannomas (acoustic neuromas): Clinical presentation". *Journal of Neurosurgery* 40.1 (1997): 11-21.

44. Nedzelski JM and Tator CH. "Surgical management of cerebellopontine angle tumors". *Journal of Otolaryngology* 9.2 (1980):105.

45. Myrseth E., *et al*. "Vestibular schwannomas: clinical results and quality of life after microsurgery or gamma knife radiosurgery". *Neurosurgery* 56.5 (2005): 927-935.

46. Pollock B., *et al*. "Patient outcomes after vestibular schwannoma management: a prospective comparison of microsurgical resection and stereotactic radiosurgery". *Journal of Neurosurgery* 59.1 (2006): 77.

47. Daniel R., *et al*. "Optimally Invasive Skull Base Surgery for Large Benign Tumors". Nova Science Publishers, Inc (2013).

48. Ramina R., *et al*. "Surgical management of trigeminal schwannomas". *Neurosurgical Focus* 25.6 (2008).

49. Zhang Z., *et al*. "Removal of Large or Giant Sporadic Vestibular Schwannomas via Translabyrinthine Approach: A Report of 115 Cases". *International Journal of Otorhinolaryngology* 74.5 (2012): 271-277.

50. Peng Z., *et al*. "Functional outcome and postoperative complications after the microsurgical removal of large vestibular schwannomas via the retrosigmoid approach: a meta-analysis". *Journal of Neurosurgical Review* 37.1 (2014): 15-21.