Survival outcomes and prognostic factors in temporal bone malignancies: A retrospective cohort of 20 patients

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Abstract. The present study aimed to describe the clinical features and survival of patients with temporal bone malignant tumors. A total of 20 consecutive cases treated at Beijing Tiantan Hospital (Beijing, China) between March 2014 and March 2022 were retrospectively reviewed. Of the 20 patients, 16 were men and 4 were women, with an age range of 9-90 years old. The pathological types included squamous cell carcinoma (SCC; n=7), adenoid cystic carcinoma (ACC; n=7), chondrosarcoma (n=2), fibrosarcoma (n=1), endolymphatic cystic papillary adenocarcinoma (n=1), rhabdomyosarcoma (n=1) and low-grade malignant peripheral nerve sheath tumor (n=1). Patients initially diagnosed with SCC and ACC were staged according to the revised Pittsburgh classification system (T1, n=1; T3, n=5; T4, n=8). All patients received surgery, followed by postoperative radiotherapy (RT) with/without chemotherapy in 10 patients. Kaplan-Meier analysis was used to calculate the survival rate, and the log-rank test was applied to compare the differences in survival. The duration of follow-up ranged from 1 to 140 months. Notably, the 3- and 5-year disease-specific survival (DSS) rates were 79 and 73%, and the 3- and 5-year overall survival (OS) rates were 74 and 68%. Pathological type and posterior cranial fossa meningeal involvement were significantly associated with both OS and DSS. Furthermore, patients with a positive surgical margin had a significantly worse DSS rate. In conclusion, the incidence of temporal bone malignancies is low with an insidious onset. Radical resection is the main treatment option, and postoperative RT with/without chemotherapy may be supplemented in cases of an advanced stage or when tumors have a positive surgical margin.

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Introduction

Temporal bone malignant tumors are rare and represent a small proportion (0.2%) of head and neck malignancies, with an approximate annual incidence rate of 1-6 cases per million individuals (1,2). Temporal bone squamous cell carcinoma is the most common malignant tumor in this area, representing 80% of all malignancies (2). The remaining cases include adenoid cystic carcinoma and other rare pathologies, such as sarcoma. The tumors can be primary (from the external/middle ear) or secondary (from adjacent sites such as the periauricular skin or parotid gland) and are chiefly diagnosed in patients beyond the age of 60 years (3). These tumors often present with non-specific symptoms such as otorrhea, otalgia, tinnitus, hearing loss, and occasionally, facial paralysis, making early diagnosis challenging. By the time a definitive diagnosis is made, the disease tends to have expanded to a large extent, frequently invading adjacent nerves, blood vessels and other vital organs (1).

The persistent tissue injury stemming from ongoing otitis media and external otitis is a predominant risk factor, which serves as the primary mechanism driving the carcinogenesis of temporal bone malignancies (4-6). Other risk factors include exposure to ultraviolet radiation and prior radiotherapy (RT), older age and immunodeficiency (7). Surgical resection is the mainstay of curative treatment, typically in the form of temporal bone resection with or without RT (8,9).

Despite multidisciplinary treatment, the prognosis of temporal bone malignancies remains poor. The rarity of the disease has impeded the collection of evidence from both clinical and basic research, and there is currently no unified staging system. The present retrospective analysis aimed to evaluate the management strategies, survival outcomes and possible adverse features of patients with temporal bone malignancies treated at Beijing Tiantan Hospital (Beijing, China).

Materials and methods

Patient population. Patients with pathologically confirmed temporal bone malignancies treated at Beijing Tiantan Hospital between March 2014 and March 2022 were retrospectively included in the current study. The study was approved by the Ethics Committee of Beijing Tiantan Hospital (approval no. 2022-255-01) and was carried out in accordance

with the principles of The Declaration of Helsinki. Patients were excluded from the study if they had any of the following: A prior carcinoma in another organ, metastatic disease, a periauricular skin or parotid gland origin, or incomplete treatment records. All patients routinely underwent parotid and cervical lymph node ultrasound, and temporal bone computed tomography (CT) and magnetic resonance imaging (MRI) (Fig. 1) examinations to determine the extent of lesions and bone destruction, and the presence of intracranial invasion before surgery. Positron emission tomography was conducted in selected cases. Facial nerve function was evaluated using the House-Brackmann (HB) grading system (10). Patients with squamous cell carcinoma (SCC) and adenoid cystic carcinoma (ACC) were staged according to the revised Pittsburgh classification system (11).

Treatment strategy. The surgical methods mainly included lateral temporal bone resection (LTBR) and subtotal temporal bone resection (STBR). For patients with involvement of the lateral skull base, the infratemporal fossa approach was used to remove the tumor. The facial nerve was preserved as much as possible, unless it was infiltrated by the tumor and could not be separated. Parotidectomy and neck dissection were performed if clinically indicated, and the temporomandibular joint was resected to achieve complete excision of the tumor when necessary. Surgical margins were determined based on postoperative pathological examination for patients with lateral temporal bone resection applied. A clear margin was defined as a distance of ≥5 mm from the invasive tumor front. However, since early symptoms of malignant temporal bone tumors are often non-specific, most patients presented with advanced disease at the time of treatment. In such cases, subtotal temporal bone resection rarely allows for en bloc excision. After tumor resection, an otological drill is used to remove the diseased bone tissue, which is not included in the histological examination. Therefore, margin assessment requires a comprehensive evaluation that integrates postoperative paraffin-section pathology with intraoperative findings. Regular follow-up was routinely conducted every 3 months for the first 3 years, every 6 months for years 4 and 5, and once a year thereafter.

Statistical analysis. Data were analyzed using SPSS 26.0 software (IBM Corp.). The survival rates were calculated using the Kaplan-Meier method. A log-rank test was employed to compare the differences in patient survival between groups. Survival analysis was confined to univariate comparisons with the log-rank test, as the sample size was too small for a reliable multivariate analysis. $P<0.05$ was considered to indicate a statistically significant difference.

Results

Clinical data. In the group of 20 patients, there were 16 men and 4 women, aged between 9 and 90 years, with a mean age of 50.8 years. The duration of illness varied from 1 month to 40 years. According to the revised Pittsburgh classification system (11), 1 patient presented with a T1 tumor, 5 patients with T3 tumors and 8 patients with T4 tumors, among the 14 patients diagnosed with SCC and ACC. The follow-up period ranged from 1 to 140 months, and 1 patient was lost to follow-up (5%). The clinical symptoms mainly included hearing loss (n=15, 75%), otalgia (n=13, 65%), chronic ear discharge (n=8, 40%), headaches (n=6, 30%), facial paralysis (n=5, 25%), dizziness (n=5, 25%) and tinnitus (n=5, 25%). Regarding HB facial paralysis, 1 case presented as grade II, 2 cases presented as grade V and 2 cases presented as grade VI. A single case had previously undergone surgery for chronic otitis media. Table I summarizes the patient demographics, tumor characteristics and survival outcomes.

Pathological examination confirmed the diagnosis in all 20 cases, with 7 patients diagnosed with SCC, 7 with ACC, 2 with chondrosarcoma, 1 with fibrosarcoma, 1 with endolymphatic cystic papillary adenocarcinoma, 1 with rhabdomyosarcoma and 1 with a low-grade malignant peripheral nerve sheath tumor.

Treatment. Among the 20 cases, as the first treatment, 10 underwent surgical excision only, 7 received surgery and RT, and 3 underwent surgery combined with chemoradiotherapy (CRT). RT with a dose of 60-66 Gy in 30-33 fractions at 1.8-2 Gy per fraction was administrated postoperatively for patients with an advanced tumor or positive margin. Additional concurrent weekly cisplatin chemotherapy (30-40 mg/m^2) was administered in patients with positive margins. For patients unsuitable to receive cisplatin, either carboplatin or RT alone was used. A total of 4 cases underwent LTBR, 12 cases received STBR and 4 cases received lateral skull base tumor resection via the infratemporal fossa approach (Table I).

A parotidectomy was conducted in 8 patients, of which 5 were pathologically confirmed with tumor invasion. A partial temporomandibular joint cyst resection was performed in 8 patients, with tumor invasion in 4 patients. The facial nerve was involved in 9 cases, among which the tumor was resected while preserving the facial nerve in 3 patients. All 3 patients appeared with varying degrees of facial nerve paralysis after surgery (Table II).

The tumor involved the cranial fossa meninges in 9 cases, including 5 cases of medial cranial fossa meninges involvement, 1 case of post cranial fossa meninges involvement and 3 cases of both, among which tumors were resected while preserving the integrity of the meninges without evident cerebrospinal fluid leakage in 8 cases. In the remaining case, the tumor and affected dura were excised, and repair was performed using the artificial dura mater interposition method. The tumor invaded the cochlea and penetrated deep into the skull in 1 case, and cerebrospinal fluid leakage occurred after tumor resection. This was managed by utilizing free fat grafting to fill the cavity, along with temporal muscle flap reinforcement.

Follow-up results. The 3- and 5-year disease-specific survival (DSS) rates were 79 and 73%, and the 3- and 5-year overall survival (OS) rates were 74 and 68%. Univariate analysis (Table III) results indicated that the pathological type (both $P<0.001$) and posterior cranial fossa meningeal involvement ($P=0.005$ and $P=0.014$, respectively) were significantly associated with OS and DSS. Patients with a positive surgical margin tended to have worse DSS ($P=0.037$) (Fig. 2). Due to the limited sample size, further multivariate survival analysis was not conducted.

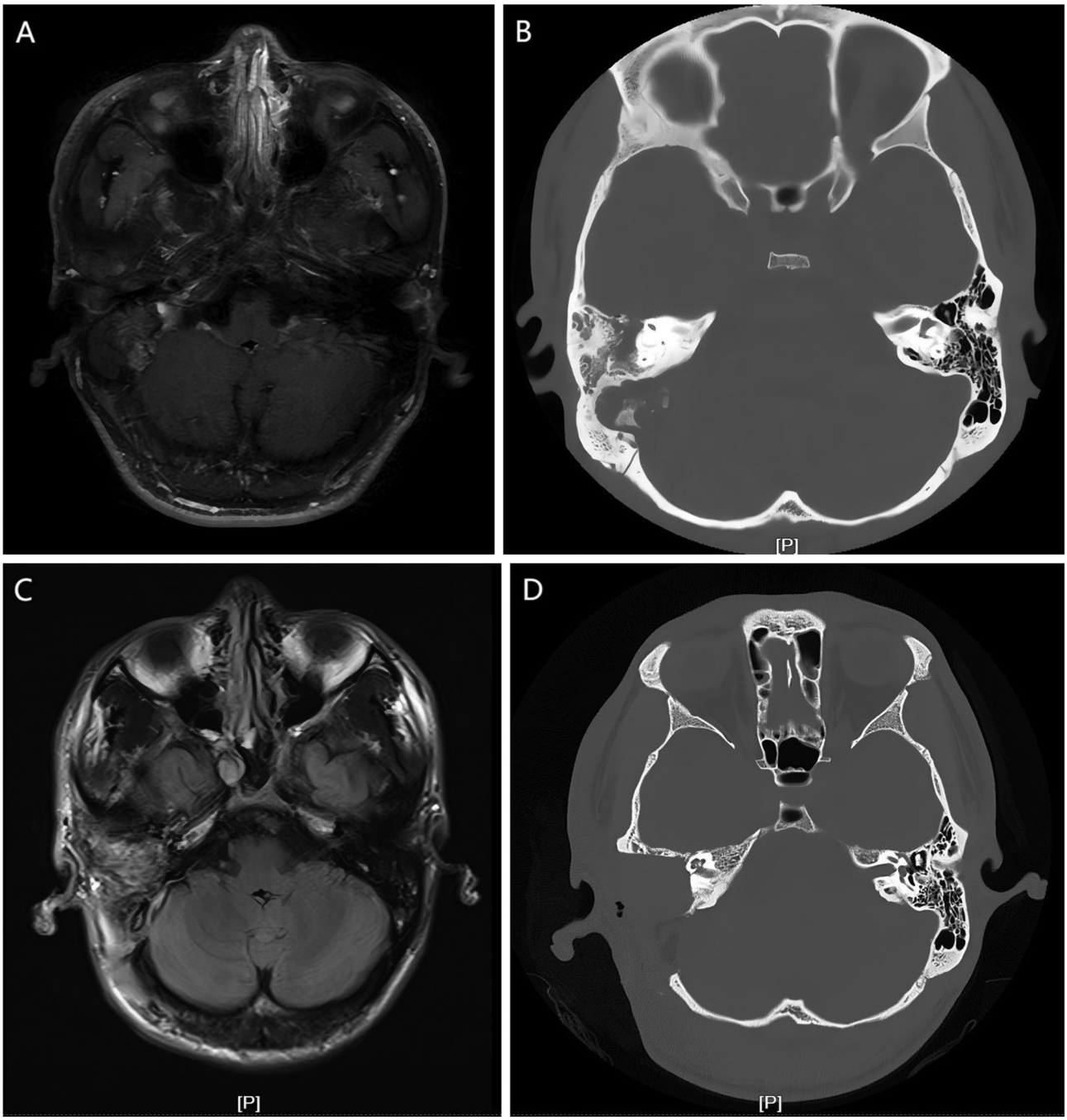

Figure 1. Imaging studies of a patient with chondrosarcoma diagnosed at 28 years old. (A and B) Preoperative contrast-enhanced MRI and CT images showing the invasion of the tumor to the middle ear and sigmoid sinus. (C and D) Post-operative contrast-enhanced MRI and CT images. MRI, magnetic resonance imaging; CT, computed tomography.

Among the 14 patients diagnosed with ACC and SCC, 3 patients experienced local recurrence and underwent a second surgery. A single patient with ACC died of disease at 70 months, while another 2 patients with ACC were alive at 54 and 140 months of follow-up. Only 1 out of the 14 patients had distant metastasis to the lung at 24 months, and this patient received CRT and was alive at 74 months. Another 3 patients died of the disease, at 8, 10 and 37 months postoperatively. A single patient died of pulmonary infection at 16 months without evidence of disease. Another patient diagnosed with a T3 tumor failed to be followed up for unknown reason after receiving surgery and CRT. A further 5 patients survived without showing signs of disease at a mean of 66 months of follow-up (range, 54-85 months) (Table I).

Among the 6 patients with rare temporal bone malignancies, 3 underwent lateral skull base tumor resection via the infratemporal fossa approach and 2 experienced local relapse. A single patient with a low-grade malignant peripheral nerve sheath tumor died of disease at 16 months, while another patient with endolymphatic cystic papillary adenocarcinoma died of glioma at 65 months. In addition, 1 patient with chondrosarcoma was alive at 140 months. Another 9-year-old child with rhabdomyosarcoma underwent incomplete resection due to internal carotid artery invasion and died of disease soon

Table I. Clinical characteristics of temporal carcinoma (n=20).

Patient no.	Pittsburgh stage	Age, years	Sex	Symptoms	Treatment	Pathology	Follow-up status and survival time (months)
1	T3	56	M	Hearing loss, otorrhea, otalgia and headache	STBR	SCC	DOD (37)
2	T4	59	M	Hearing loss, otorrhea, ear bleeding, otalgia and facioplegia	STBR + CRT	SCC	DM (24); A (74)
3	T4	64	M	Hearing loss, otorrhea, otalgia, headache, dizziness and limited mouth opening	STBR + RT	SCC	DOD (10)
4	T4	59	M	Hearing loss, otorrhea, otalgia, ear bleeding and tinnitus	STBR	SCC	DOD (8)
5	T1	56	M	Headache	LTBR	ACC	A (54)
6	T3	56	M	Otalgia	STBR + RT	ACC	A (54)
7	T4	76	M	Hearing loss, otorrhea, otalgia and tinnitus	STBR	ACC	A (73)
8	/	53	F	Hearing loss and headache	LTBR (1st treatment), STBR + END + RT (2nd treatment)	ACC	LR (64); A (140)
9	T4	65	M	Hearing loss, otorrhea, otalgia and dizziness	ITF+RT	SCC	A (85)
10	T4	43	M	Hearing loss and limited mouth opening	STBR+RT	ACC	A (64)
11	/	33	F	Otalgia	LTBR (1st treatment), STBR + CRT (2nd treatment)	ACC	LR (61); DOD (70)
12	T3	33	M	Hearing loss, otorrhea, otalgia, facioplegia, tinnitus and dizziness	STBR + CRT	SCC	LFU
13	/	54	M	Vision loss, headache, dizziness and hearing loss	STBR + RT	Fibrosarcoma	A (56)
14	/	28	M	Facioplegia and mass	ITF	Chondrosarcoma	A (104)
15	/	56	M	Ear stuffy, hearing loss, otorrhea, tinnitus and ear bleeding	STBR + CRT (1st treatment), ITF (2nd treatment)	Endolymphatic cystic papillary adenocarcinoma	LR (11); DWD (65)
16	/	39	M	Facioplegia, otalgia, hearing loss and tinnitus	STBR (1st treatment), ITF (2nd treatment)	Chondrosarcoma	LR (62); A (140)
17	/	9	F	Headache, dizziness and facioplegia	ITF	Rhabdomyo-sarcoma	DOD (1)
18	/	18	M	Hearing loss and otalgia	ITF + RT	LMPNST	LR (8); DOD (16)

Table I. Continued.

Patient no.	Pittsburgh stage	Age, years	Sex	Symptoms	Treatment	Pathology	Follow-up status and survival time (months)
19	T4	36	M	Hearing loss and otalgia	LTBR + RT (1st treatment), STBR (2nd treatment)	ACC	LR (26); A (54)
20	T4	90	M	Hearing loss and otalgia	STBR	SCC	DWD (16)

A, alive; ACC, adenoid cystic carcinoma; CRT, chemoradiotherapy; DM, distant metastases; DOD, dead of disease; DWD, dead without disease; END, elective neck dissection; F, female; ITF, infratemporal fossa approach; LFU, lost to follow-up; LMPNST, low-grade malignant peripheral nerve sheath tumor; LR, local/regional recurrence; LTBR, lateral temporal bone resection; M, male; RT, radiotherapy; SCC, squamous cell carcinoma; STBR, subtotal temporal bone resection.

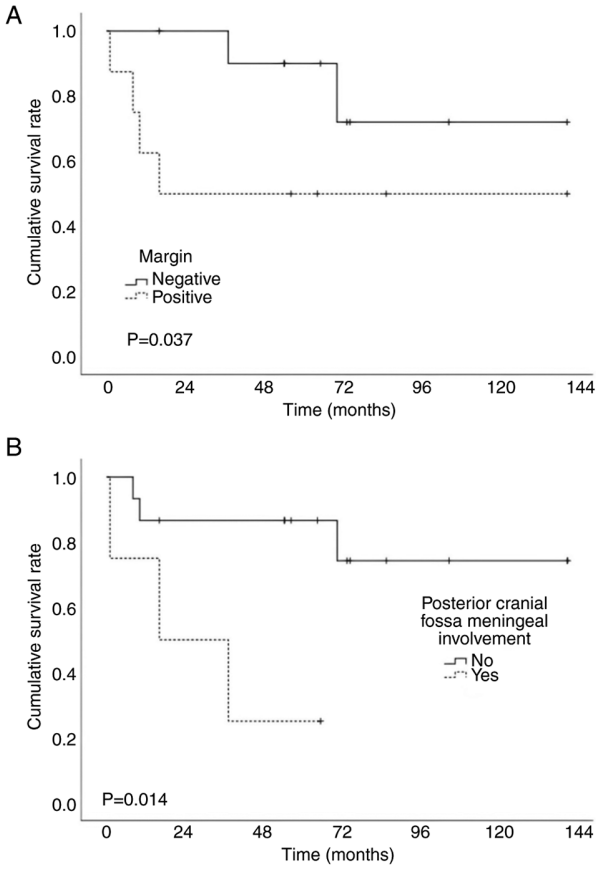

Figure 2. Disease-specific survival in patients with temporal bone malignancies. (A) Kaplan-Meier curves of surgical margin status and (B) posterior cranial fossa meningeal involvement.

after the surgery. Furthermore, 2 patients were alive at 56 and 104 months of follow-up.

Discussion

The present study conducted a thorough examination of the survival rates and possible factors influencing the prognosis for patients diagnosed with temporal bone malignancies at Beijing Tiantan Hospital. The findings confirmed that the pathological type and the presence of positive surgical margins may be significant prognostic indicators of patients with temporal bone malignancies.

At present, the International Union Against Cancer and the American Joint Committee on Cancer have not proposed staging criteria specifically for temporal bone malignancies. The modified Pittsburgh staging criteria (11) is widely accepted for patients with SCC of the temporal bone. However, Nabuurs *et al* (12) recruited 381 patients to assess the prognostic predictive value of the modified Pittsburgh staging system and demonstrated that T4 tumors with different directions of invasion (anterior, posterior, superior, inferior, medial or lateral) had different prognoses, but the staging system did not distinguish between different directions of invasion of T4 tumors. Zanoletti *et al* (13) reported a hazard ratio of 1.13 (95% confidence interval, 0.98-1.32; P=0.089) for patients with tumors spreading in other directions compared with patients with T4 external auditory canal SCC tumors spreading anteriorly (preauricular region and parotid space). Similarly, the results of the present study suggested that patients with posterior cranial fossa meningeal involvement had a worse prognosis. Patients without posterior cranial fossa disease involvement had significantly superior 5-year OS and DSS rates of 80 and 87%, respectively, compared with those with involvement (both 25%). Additionally, Zanoletti *et al* (13) built a new staging system based on the modified Pittsburgh staging criteria combined with additional T4 tumor prognostic factors, such as dural involvement, the direction of invasion and histological grading. This new standard was used to evaluate the prognosis of 44 cases of SCC of the temporal bone, as well as other case series from different studies. The results indicated that the new staging standard not only had better prognostic predictive effects than the modified Pittsburgh staging criteria, but also demonstrated good applicability (13,14). Moreover, as demonstrated in the present study, there are other types of temporal bone malignancies, including ACC and other rare types, and more

Table II. Structures found to be invaded by the tumor during surgery.

Operative details	Patient no.																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SP/pathology confirmed invasion	-/-	+/+	+/-	+/+	-/-	-/-	+/+	-/-	+/-	+/+	+/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	+/+	-/-
TMJ resection/pathology confirmed invasion	-/-	+/+	+/+	+/-	-/-	-/-	+/-	-/-	+/-	+/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	+/+	+/+
Posterior cranial fossa meningeal involvement	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	+	-	-
Medial cranial fossa meningeal involvement	+	-	-	+	-	-	-	-	+	+	-	-	+	+	-	-	+	+	-	-
Facial nerve invasion/resection	-/-	+/+	-/-	+/-	-/-	-/-	-/-	-/-	+/-	+/+	-/-	-/-	-/-	+/+	+/-	+/+	+/+	+/+	-/-	-/-

SP, superficial parotidectomy; TMJ, temporomandibular joint.

research is needed to refine a staging system of temporal bone malignancies.

Depending on the area of tumor invasion, the surgical approaches for temporal osteotomy include LTBR (resection of the ear canal and tympanic membrane), STBR (resection of the labyrinth/cochlea and internal auditory canal) and total temporal bone resection (TTBR; resection of the petrous apex) (15). Typically, LTBR is recognized as a preferred treatment for early-stage (T1-2) carcinoma, dispensing with the need for postoperative RT, provided that the surgical margins are clear of disease (15-19). For advanced-stage tumors, treatment for the majority of patients involves STBR with adjuvant RT, and occasionally, chemotherapy (20). TTBR is now rarely used due to associated surgical complications and lower survival rates without an improvement in prognosis when compared with STBR plus adjuvant therapy (16). In the present study, 12 patients received STBR, 4 underwent LTBR, and 4 received lateral skull base tumor resection via the infratemporal fossa approach.

The lymph node metastasis rate of temporal malignancies is relatively low (21,22). Neck dissection is undertaken mainly for patients exhibiting radiographic or clinical signs of cervical lymph node involvement. In the present group of patients, with the exception of 2 patients who underwent parotid and postauricular lymph node excision with negative pathology, no patient underwent an elective regional neck dissection. Moreover, no local lymph node recurrence was observed in any patient during the follow-up period. There is still considerable debate over whether patients with malignant tumors of the temporal bone should routinely undergo parotidectomy (23,24). Currently, a parotidectomy is performed in cases with notable involvement of the parotid gland or suspicion of facial nerve invasion, and it is also utilized in specific cases to achieve negative margins. In the present study, a parotidectomy was conducted in 8 patients, and in 5 of these cases, tumor invasion was confirmed pathologically.

In terms of functionality, the goal when treating temporal bone malignancies is to completely remove the tumor with negative margin while preserving the integrity of the facial nerve as much as possible. However, temporal bone malignancies are often covert, and by the time they are diagnosed, the extent of the disease can be quite high. Compared with LTBR, STBR often requires consideration as to whether to preserve or sacrifice the facial nerve, and it may be necessary to sacrifice it. Since malignant tumors of the external auditory canal and middle ear have a high degree of malignancy and pose a threat to life, the focus is on completely removing the lesion and extending survival, rather than emphasizing the preservation of hearing. In the present group of patients, the facial nerve was resected in 6 cases, and the tumor was peeled off the surface of the facial nerve in 3 cases. All patients had varying degrees of hearing loss after surgery.

Surgery combined with postoperative supplementary RT is an effective intervention for controlling temporal bone tumors, even though ACC and tumors of mesenchymal origin are not particularly sensitive to RT (25-28). Generally, RT is applied postoperatively for advanced/recurrent disease, as well as for individuals exhibiting positive surgical margins, lymph node metastasis, nerve invasion and extracapsular spread. However, definitive CRT is emerging as a primary treatment for

Table III. Variables associated with survival (univariate analysis by log-rank test).

Variables	Ovall survival P-value	Disease-specific survival P-value
Sex (male/female)	0.301	0.442
Age (≤55/>55 years)	0.492	0.974
Facial paralysis (yes/no)	0.421	0.703
Medial cranial fossa meningeal involvement (yes/no)	0.369	0.121
Posterior cranial fossa meningeal involvement (yes/no)	0.005	0.014
Parotid gland/TMJ involvement (yes/no)	0.428	0.265
T stage (T4/T1-3)	0.888	0.762
Margin (positive/negative)	0.287	0.037[a]
Histology (SCC/ACC/FSa/CS/ELST/RMS/LMPNST)	<0.001	<0.001
Treatment modality (surgery/surgery + RT/CRT)	0.630	0.513

[a]Breslow test. ACC, adenoid cystic carcinoma; CRT, chemoradiotherapy; CS, chondrosarcoma; ELST, endolymphatic sac tumor; FSa, fibrosarcoma; LMPNST, low-grade malignant peripheral nerve sheath tumor; RMS, rhabdomyosarcoma; RT, radiotherapy; SCC, squamous cell carcinoma; TMJ, temporomandibular joint.

advanced or unresectable disease. Morita *et al* (19) observed comparable 5-year OS rates among patients with T3-4 tumors who underwent definitive CRT (52.1%) in contrast to patients who received surgery followed by postoperative RT, with or without chemotherapy (55.6%).

Limited research shows that molecular-targeting agents, such as cetuximab and isocitrate dehydrogenase 1 inhibitors, exhibit promising antitumor activity in patients with advanced temporal bone malignancies (29,30). Additionally, Yan and Sui (31) reported the long-term survival of a 47-year-old man with uncontrolled locally advanced temporal bone SCC after immunotherapy followed by CRT. Addressing these challenges will lead to improved prognosis for patients with unresectable, residual, or recurrent temporal bone malignancies.

The 5-year OS rate has been reported to vary in different studies, ranging from 51.7 to 66.8% (6,32-34), while the DSS rate for patients with T1 and T2 temporal bone tumors has been shown to range from 92 to 100%, compared with 48 to 65% for those with T3 and T4 tumors (21). The majority of patients included in the present study presented as advanced and recurrent cases, and the 5-year DSS and OS rates were 73 and 68%, respectively.

A positive margin is often considered a poor prognostic factor (20,35), as reported in the present study. The 5-year DSS rates of patients with negative and positive margins were 89 and 50%, respectively. However, what should be noted is that the correct judgment of tumor margins must take into account both histological examinations and surgical records, distinguishing between 'false-positives' and 'true-positives' due to piecemeal resection. Other reported factors associated with a poor prognosis include clinical facial nerve palsy at presentation and advanced stage disease (11,36-39). However, a recent multivariate analysis revealed the sole poor prognostic indicator with statistical significance was surgery on patients with recurrent disease (2). Dean *et al* (40) also found no difference between local control rates for cases that required facial nerve resection (67.6%) compared with those that did not (76.9%) (P=0.13), a finding that aligns with the results of the current study. Manolidis *et al* (41) noted that tumors of mesenchymal origin were generally less invasive and tended to exhibit better local control rates in comparison to other types of malignancies. Similar results were observed in the present study, since pathological type statistically affected prognosis (P<0.001). Notably, the SCC pathological type was associated with worse OS and DSS rates compared with the ACC (P=0.028 and P=0.073, respectively). However, given the small number of patients with other pathological types, interpretation of the prognostic data requires caution.

The present study has some limitations. Owing to the rarity of temporal bone malignancies, conducting large-scale prospective studies within a single institution has been challenging. Thus, the present study is a single-centre retrospective case series, which may have potential selection bias. The small sample size precluded statistical analysis of several adverse features and further multivariable survival analysis to rule out the influence of confounding factors. Multicenter collaboration is warranted to validate these findings in a larger, more diverse cohort. In addition, the retrospective study design relied on the accuracy and completeness of medical records, which may result in potential information bias. Moreover, with the progression of technology, surgical techniques and adjuvant treatment strategies, it may be challenging to compare treatment results with those from other studies and to determine the optimal therapeutic approach.

In conclusion, temporal bone malignancies are rare and are associated with a poor prognosis. Factors predictive of poor survival outcomes include SCC pathology, a positive surgical margin and posterior cranial fossa meningeal involvement. Treatment is complex, and surgery combined with RT/CRT is currently the main effective treatment plan. Nevertheless, further multi-institutional prospective investigations are required to specify the biological behavior of temporal malignancies, and to identify unified staging and optimal treatment strategies.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

All authors had full access to the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. LG and YX were responsible for conceptualization. LG and RG were responsible for the methodology. Study investigation was performed by LG and TY. Formal data analysis and interpretation was performed by LG, TY, RG and WZ. The original draft was written by LG. YX and RG reviewed and revised the manuscript. RG supervised the study. Data curation was the responsibility of LG and TY. Project administration was performed by RG, and validation was performed by YX and RG. LG and YX confirm the authenticity of all the raw data. All authors have read and approved the final version of the manuscript.

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Beijing Tiantan Hospital (Beijing, China; approval no. 2022-255-01). Written informed consent was obtained from all participants.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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