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Temporal Bone Carcinoma – Treatment Patterns and Survival

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Abstract

Introduction.—Carcinomas of the temporal bone are rare, and appropriate treatment, staging, and survival data are limited. This study evaluates clinical characteristics and survival rates for patients with temporal bone carcinoma treated with resection at a single tertiary-care institution, with a focus on the outcomes of patients with locally advanced disease including skull base and/or dural invasion.

Methods.—Demographic, tumor-specific, and survival data were collected for patients with primary carcinomas of the external auditory canal with involvement of the temporal bone from 2003–2015. All patients were staged according to the modified Pittsburgh system. Kaplan-Meier and logistic regression analysis were used to calculate factor specific survival outcomes.

Results.—Sixty-seven patients met inclusion criteria; 85.0% were male. There were 43 squamous cell carcinomas (SCC, 64%) and 24 basal cell carcinomas (BCC, 36%). Tumor stage was 24 (36%) T2, 12 (18%) T3, and 31 (46%) T4 tumors; 53% had recurrent disease. Surgical management included 49 lateral temporal bone resections and 18 subtotal temporal bone resections. Kaplan-Meier analyses revealed more favorable 5-year survival rates associated with BCC histology ($p=0.01$), lateral temporal bone resection compared to subtotal temporal bone resection ($p<0.01$), lack of immunocompromise ($p=0.04$), and absence of perineural/lymphovascular invasion ($p=0.01$). Multivariate regression analysis did not yield statistically significant results.

Conclusion.—Factors predictive of more favorable survival include lack of immunocompromise, BCC histology, absence of perineural/lymphovascular invasion, and disease extent amenable to lateral temporal bone resection. Dural invasion is not an absolute contraindication to surgery, with a subset of patients surviving >5 years.

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Keywords

temporal bone carcinoma; temporal bone resection; basal cell carcinoma; squamous cell carcinoma

Introduction

Temporal bone carcinoma is a rare clinical entity, with an estimated incidence of one to six cases per one million people annually, accounting for less than 0.2% of all tumors of the head and neck.^{1–2} The most common symptoms are typically otorrhea, pain, and hearing loss.³ Squamous cell carcinoma (SCC) is the most frequent neoplasm in the external auditory canal (EAC), about four times more common than basal carcinomas (BCC).¹

Due to the rare nature of temporal bone carcinoma, evaluation of these tumors has been largely limited to retrospective, single-institution case series, although some population-based cancer databases have been used for evaluation.^{4–6} These studies confirm that extent of disease is a primary determinant of survival and advanced disease carries a poor prognosis. Depending on stage of disease and treatment protocols, 5-year survival rates range from 10% for advanced disease to 83% for early disease.⁷

Data on appropriate treatment, particularly of advanced stage disease, are relatively limited. Disease factors linked to poor prognosis include advanced T stage, advanced overall stage, poorly differentiated cell type, presence of nodal disease, facial nerve paralysis, positive surgical margins, and recurrent disease.^{1,8–11} While specific treatment guidelines are controversial, early-stage tumors limited to the EAC are often treated with lateral temporal bone resection (LTBR), while advance-staged tumors are often treated with subtotal temporal bone resections (STBR), typically followed with post-operative radiotherapy with or without chemotherapy.¹²

Whether aggressive surgery offers survival benefit in far-advanced disease remains unknown and subject to ongoing debate, with some now suggesting definitive chemoradiation as first line therapy for advanced stage or “unresectable” disease.^{13–16} Morita et al.¹⁴ found similar 5-year overall survival rates for patients with T3–4 disease treated with definitive chemoradiation (52.1%) compared to those treated with surgical resection and adjuvant radiation with or without chemotherapy (55.6%). Despite a slightly superior survival rate for surgically treated patients, they argued that chemoradiation may be preferred as a first line therapy due to significant morbidity and mortality of surgical resection of locally advanced disease, particularly in the case of unresectable tumors. The definition of unresectable disease varies by study, but is commonly defined as involvement of the petrous apex, carotid canal, dura, or brain parenchyma, with some also including the jugular canal and sigmoid sinus.^{13–17} Others challenge the definition of unresectability particularly in the case of skull base and dural involvement, and have demonstrated favorable survival outcomes for patients with intracranial extension treated with surgical resection.^{18–20} The objective of this study was to evaluate clinical characteristics and survival rates for patients with temporal bone carcinoma treated with temporal bone resection at a single tertiary-care institution, with a

specific focus on the outcomes of patients with locally advanced disease with skull base and/or dural invasion.

Methods

Patient Selection:

After receiving Institutional Review Board approval, patients were identified by searching hospital-maintained patient databases for ICD-9 codes representing external and middle ear carcinoma and CPT codes for temporal bone resections between the years of 2003 to 2015. Inclusion criteria consisted of patients who underwent surgical resection via temporal bone resection, with or without adjuvant therapy, for a primary, histopathologically-confirmed squamous or basal cell carcinoma of the EAC or temporal bone. Exclusion criteria were histopathologic diagnosis other than SCC or BCC, tumors originating from the subjacent sites of the parotid and periauricular skin that secondarily involved or invaded the ear canal or other sites of the temporal bone, and patients who did not undergo surgical resection as a modality of treatment. Specifically, cutaneous malignancies of the pinna were excluded from analysis. However, tumors that appeared to arise from the EAC with secondary involvement of the pinna (e.g. conchal bowl or more lateral pinna structures) due to advanced stage of presentation were included in the study cohort.

Data extraction:

A retrospective chart review was performed on the study population. Records were reviewed for age, sex, tumor location and extent, histology, TNM and overall stage, extent of surgical resection, presence of perineural or lymphovascular invasion, nodal disease burden, margin status on histopathology of surgical resection, history of prior head and neck radiation, treatment with adjuvant therapy, immunodeficiency status, length of follow up, and overall survival. Patients were considered immunocompromised if they met one or more of the following criteria: known diagnosis of a primary immunodeficiency, prior history of organ transplantation on immunosuppression, known diagnosis of autoimmune or inflammatory condition requiring long term steroids or other immunomodulators, and presence of a hematological malignancy. Patients for whom staging information was not documented were retrospectively staged based on available clinical information, imaging, operative reports, and final pathology reports using the modified Pittsburgh staging system.² Marginal status was based on pathology reports; in many cases of advanced there was a positive margin at the medial resection margin of the lateral temporal bone specimen which was addressed intraoperatively with further resection of medial structures (e.g. otic capsule, facial nerve, TMJ, etc).

Surgical Procedures and Indications:

At our center, surgical excision of temporal bone malignancy is achieved through lateral temporal bone resection or subtotal temporal bone resection based on extent of disease. Lateral temporal bone resection is indicated for malignancies involving the osseous external auditory canal but not extending medial to the tympanic membrane. The procedure includes complete mastoidectomy, epitympanic dissection extending into the temporal mandibular joint (TMJ), an extended facial recess approach, separation of the incudostapedial joint, and

removal of the specimen en bloc. Subtotal temporal bone resection is indicated for malignancies with extension beyond the external ear canal into for example, the middle ear, facial nerve, skull base, TMJ, etc. The procedure is customized to the extent of disease and can include an infratemporal fossa/jugular foramen dissection, temporal craniotomy, otic capsule removal, sectioning or decompression of the facial nerve, dural or sinus resection, mandibular condylectomy, and either en bloc or piecemeal removal of specimen. At our institution, temporal bone resections are often performed in concert with customized skull base resections and reconstructions according to the specific extent of disease.²¹ Neck dissection is performed only in patients who have radiographic or clinical evidence of cervical lymphadenopathy. Parotidectomy is performed in patients with gross parotid involvement or concern for facial nerve invasion, and is also used in certain cases to obtain negative margins.

Treatment Patterns:

Treatment plans for all patients were discussed at a multidisciplinary tumor board. There were no patients with T1 disease that met inclusion criteria for this study. Patients with early stage T2 cancers were treated exclusively with lateral temporal bone resection due to the limited extent of the disease. Patients with more locally advanced T3–4 cancers were treated with lateral temporal bone resection or customized subtotal temporal bone resection according to the structures involved, as detailed above. Indications for adjuvant radiation therapy included nodal disease, extracapsular extension, margin positivity, and advanced stage III/IV disease. In each case, the decision to proceed with surgical resection and use of adjuvant therapy was directed by multidisciplinary tumor board consensus opinion. The extent of resection was planned preoperatively by the operating surgeon and guided by disease extent according to intraoperative findings and frozen sections.

Follow up:

In accordance with surveillance protocols at our center, postoperative follow up occurred approximately every 3–4 months for a total of 1–2 years, then semiannually or annually. Due to logistical reasons, a subset of patients elected to undergo routine surveillance visits outside of our center. Date of recurrence was defined as the first visit where clinical or radiographic data demonstrated recurrence of local, regional, or distant disease. Date of death was extracted from patient charts and used to determine overall survival. Due to inconsistencies in retrospective data collection, disease-specific and disease-free survival could not be reliably studied. If a patient was not recorded as deceased, the length of follow-up and confirmed survival time were determined using the date of the patient's last clinic visit at our institution. Patients not classified as deceased in the electronic medical record were presumed to be living.

Statistical analysis:

Analyses were performed on the data set as a whole, followed by subgroup analyses on patients with SCC histology and those with BCC histology. Logistic regression analysis was performed using imputed data for the outcome of 5-year overall survival regardless of disease status. Kaplan-Meier time-to-event analyses based on the outcome of five-year observed survival were performed with Stata software version 15 (College Station, Texas).

Significant differences in survival rates were determined by log rank analysis of survivor function equality. Results were considered statistically significant for p values <0.05.

Results

Sixty-seven patients were identified in the final study population, with an average age of 69 years. Eighty-five percent were male and 15% were female. SCC was more common than BCC and was found in 64% of the population. Fifty-four percent presented with locally recurrent disease, and had been previously treated with either mastoidectomy or local excision of the EAC without or without partial auricectomy (19 patients), excision with adjuvant radiation (16 patients), or definitive radiation (1 patient). There were no cases of regional or metastatic recurrence. Lateral temporal bone resection was the most common surgical procedure, and was performed in 73% of resections. Adjuvant radiation was administered in 43% of patients, adjuvant chemotherapy in 6%, and in 46% no adjuvant therapy was recorded. Neoadjuvant chemotherapy and radiation are not routinely performed at our institution and there were no recorded cases of either within our population sample.

While there were no patients who underwent neoadjuvant radiation, 20 patients (30%) had a history of prior head and neck radiation. Of these patients, 15 underwent radiation as adjuvant therapy following either a prior wide local excision of the external auditory canal with or without partial auricectomy or a mastoidectomy. One patient underwent definitive radiation therapy to the external auditory canal preceding salvage surgery for recurrence. The remaining 4 patients underwent radiation for conditions unrelated to the temporal bone carcinoma, including: a base-of-tongue cancer irradiated 5 years prior to development of temporal bone carcinoma; seborrheic dermatitis irradiated over 50 years prior to development of temporal bone carcinoma; childhood ALL irradiated about 30 years prior to development of temporal bone carcinoma; and a preauricular merkel cell carcinoma irradiated 5 years prior to development of temporal bone carcinoma. Staging data, histologic findings, type of surgical procedure, immune status, use of adjuvant radiation therapy, and other population characteristics are summarized in Table 1.

The most common TNM stage of this population was T2N0 (33%), followed by T4N0 (28%), and T3N0 (12%). Nodal disease was found in 18 patients (27%). Of these, 8 patients had metastases to level II only, 3 patients had metastases to both level II and intraparotid nodes, 3 patients had metastases to intraparotid nodes only, 2 patients had metastases to level I only, one patient had metastases to level IV only, and one patient had metastases to levels II and III as well as intraparotid nodes. There were no patients with distant metastases in this study population. Staging distribution of the patient population stratified by tumor and nodal status is summarized in Table 2.

Kaplan-Meier analyses of differential clinical characteristics revealed more favorable 5-year overall survival rates to be associated with BCC histology ($p=0.01$), lateral temporal bone resection compared to subtotal temporal bone resection ($p<0.01$), lack of immunocompromise ($p=0.04$), and absence of perineural or lymphovascular invasion ($p=0.01$) (Figure 1A–E). Variables that did not reach significance include sex ($p=0.31$), T stage (0.18), overall stage (0.29), margin positivity (0.07), nodal disease (0.29), history of

prior head and neck radiation (0.46), and adjuvant radiation therapy (0.93). Kaplan-Meier analyses of the subgroup of patients with squamous cell histology revealed more favorable 5-year overall survival rates to be associated with lateral temporal bone resection over subtotal temporal bone resection ($p=0.03$) and use of adjuvant radiation therapy ($p=0.02$) (Figure 2A–B). Variables that did not reach significance include sex ($p=0.26$), immunocompromised status ($p=0.14$), recurrence (0.64), T stage (0.27), overall stage (0.49), margin positivity (0.48), nodal disease (0.35), presence of perineural or lymphovascular invasion ($P=0.12$), and prior history of radiation ($p=0.49$). Analyses of the subgroup of patients with basal cell histology did not yield any statistically significant results. To control for confounding, multivariate regression analysis was performed. A list of variables with associated odds ratios and p-values are listed in Table 3.

Thirty-one patients with T4 disease were identified in the study population. Of these, 8 (26%) had survival of at least 5 years, with the longest being 12.5 years after initial resection. Five patients with T4 disease were found to have dural invasion. Of these, 3 patients (60%) survived at least 5 years after their primary treatment. Data on the clinical characteristics and functional as well as survival outcomes for patients with T4 disease are summarized in Table 4.

Discussion

Temporal bone carcinomas are rare tumors of the head and neck. In this series, SCC was the most common histological type with the worst prognosis. This finding is similar to data recently reported in other large series of patients with temporal bone carcinoma.^{11,18} Temporal bone malignancies most often present at advanced stages, although nearly a third are found at a very early stage. Advanced staged carcinomas of the temporal bone have a poor prognosis with high mortality rates.

High-risk features for temporal bone carcinoma have been shown to include nodal metastasis, high grades of facial paralysis (House-Brackmann grade III–VI) or facial nerve sacrifice in surgery, positive final resection margins, mandibular and parotid invasion, and a primary site of the tumor other than the ear.^{22–23} A recent study by Breen et al.²⁴ also suggests that BCC may be associated with a better prognosis relative to other temporal bone malignancies. Our study found SCC histology, perineural and/or lymphovascular invasion, immunocompromised status, and treatment with subtotal temporal bone resection to be factors indicative of a less favorable prognosis. Importantly, this study demonstrates that immunocompromise is an important, adverse prognostic factor in temporal bone cancer in concordance with clinical observations. Although Kaplan-Meier analyses suggested a worse prognosis with more advanced T stage and margin positivity, these results did not reach statistical significance, likely due to the limited sample size of the study and/or incomplete survival data. Subgroup analyses of patients with BCC and SCC pathologies were limited by their respective sample size, which likely accounts for the lack of statistical significance in most characteristics expected to affect survival.

Of note, margin status in many advanced cases was based on the pathology report of the lateral temporal bone specimen showing a positive margin at the medial extent (e.g. medial

side of the annulus) (Table 4). Typically, the medial extension of the disease was recognized intraoperatively and additional resection of the medial temporal bone was performed to address the disease. Thus, our reported marginal status in the dataset for advanced disease may not accurately reflect the actual status.

It has previously been reported that patients with dural involvement of their temporal bone malignancies have an 11.1% five-year survival, which did not change with resection of dural margins.²⁵ Poorer survival for intracranial extension was reported by Morris et al.²³ when they found that the need for a craniotomy correlated with a 4.34 hazard ratio ($p=0.008$). Such findings raise the question of whether any surgery in the context of dural invasion is futile. Indeed, some argue that dural invasion is a contraindication to surgery.^{13–17}

While intracranial or dural involvement of temporal bone carcinoma undoubtedly suggests aggressive disease, aggressive treatment could be warranted to improve survival in patients with dural involvement. In our study, 5 patients were found to have dural invasion, and another 5 patients underwent skull base or dural resection in pursuit of negative surgical margins intraoperatively. Three of five (60%) patients with dural invasion survived for at least 5 years after treatment, suggesting that dural invasion need not be a categorical contraindication to surgical resection and not all tumors with dural invasion ought to be considered “unresectable” disease. This finding was supported by a recent study showing 10 and 11-year survival for 2 of 7 patients presenting with brain involvement treated with complete resection.¹⁹ Dean et al.¹⁸ reported a 65% 2-year survival in 16 of their patients who underwent dural or brain resection for intracranial extension of disease. Similarly encouraging data have been reported about extending the traditional resection limits with dural and intracranial resection of SCC in the anterior skull base.²⁰ Despite the favorable surgical outcomes reported here for highly advanced the disease, the rarity of this clinical presentation and lack of a nonsurgical cohort for comparison render systematic study difficult. The highly complex skull base anatomy and heterogenous patient factors necessitate a highly multi-disciplinary and individualized clinical decision-making process for each patient.

This single-center retrospective study is subject to multiple biases. While we sought to exclude primary carcinomas of the pinna from the primary temporal bone carcinomas under study due to their differential biological and clinical behavior, in cases of advanced disease with tumor involvement of both the EAC and parts of the pinna, the true location of the primary neoplasm could not be determined and may confound the analysis performed here. The difficulty in acquiring adequate follow-up data longitudinally for a geographically diverse patient population afflicted by a rare disease entity renders adequately-powered statistical comparisons challenging, and speaks to the need for a national registry for this disease entity. The small sample size and incomplete mortality data likely account for the lack of statistical significance in the multivariate regression analysis. Likewise, only overall, and not disease-specific, survival could be studied. Patients not recorded as deceased in the medical record system were presumed to be living, which may overestimate survival. Furthermore, cause of death could not be determined consistently and reliably from review of medical records and therefore, even in cases of disease-specific mortality, the specific pattern of treatment failure (i.e. local, regional, or distant) could not be discerned. Despite

these limitations, the results represent a relatively large patient sample for this rare condition and correlate with the findings of similarly sized studies.^{26–28}

Conclusions

Temporal bone carcinoma is a rare condition with a poor prognosis for advanced stage disease. Factors predictive of more favorable survival outcomes include basal cell pathology, lack of immunocompromise, absence of perineural and lymphovascular invasion, and disease limited to ear canal. While dural invasion may portend aggressive disease and poorer prognosis, it may not necessarily be a contraindication to surgery when customized skull base resections are utilized in the context of a multi-modality treatment paradigm, with a subset of patients surviving at least 5 years after aggressive surgical extirpation of disease. However, further investigation is necessary to expand on the limited patient cohort studied here.

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Figure 1.

Kaplan-Meier survival analyses of overall population. *A.* Overall survival of patients undergoing temporal bone resection according to T stage. Although T2 disease appears to have better survival outcomes than T3 and T4 disease, results did not reach statistical significance ($p=0.16$). *B.* Overall survival of patients undergoing temporal bone resection according to cancer histology. Patients with basal cell carcinoma (BCC) showed improved survival over patients with squamous cell carcinoma (SCC) ($p=0.01$). *C.* Overall survival of patients undergoing temporal bone resection according to type of temporal bone resection. Patients undergoing lateral temporal bone (LTBR) resection showed improved survival over patients undergoing subtotal temporal bone (STBR) resection ($p<0.01$). *D.* Overall survival of patients undergoing temporal bone resection according to presence of perineural/lymphovascular invasion. Patients without invasion showed improved survival over patients

with invasion on final histopathology ($p=0.01$). *E*. Overall survival of patients undergoing temporal bone resection according to immune status. Patients who were immunocompetent showed improved survival over patients with immunocompromise ($p=0.04$).

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Figure 2.

Kaplan-Meier survival analyses of subgroup of patients with squamous cell carcinoma (SCC) histology. *A.* Overall survival of patients with SCC undergoing temporal bone resection according to type of temporal bone resection. Patients undergoing lateral temporal bone (LTBR) resection showed improved survival over patients undergoing subtotal temporal bone (STBR) resection ($p=0.03$). *B.* Overall survival of patients with SCC undergoing temporal bone resection according to use of adjuvant radiation therapy. Patients undergoing adjuvant radiation showed improved survival over patients who did not have adjuvant radiation ($p=0.02$).

Table 1.

Patient, disease, and treatment characteristics for all patients with temporal bone carcinoma undergoing temporal bone resection (N=67), patients with basal cell carcinoma only (N=24), and patients with squamous cell carcinoma only (N=43).

Characteristic	Overall population N = 67 (100%)	Basal cell only N = 24 (100%)	Squamous cell only N = 43 (100%)
Mean age	69.6 years	70.7 years	68.9 years
Sex			
Male	57 (85%)	20 (83%)	37 (86%)
Female	10 (15%)	4 (17%)	6 (14%)
Histologic type			
Squamous cell carcinoma	43 (64%)	0 (0%)	43 (100%)
Basal cell carcinoma	24 (36%)	24 (100%)	0 (0%)
Tumor Recurrence			
Previously untreated disease	31 (46%)	11 (46%)	20 (49%)
Recurrent disease	36 (54%)	13 (54%)	23 (51%)
T stage			
2	24 (36%)	14 (58%)	10 (23%)
3	12 (18%)	4 (17%)	8 (19%)
4	31 (46%)	6 (25%)	25 (58%)
Overall stage			
2	22 (33%)	14 (58%)	8 (19%)
3	10 (15%)	4 (17%)	6 (14%)
4	35 (52%)	6 (25%)	29 (67%)
Perineural/Lymphovascular invasion			
Present	28 (42%)	2 (8%)	26 (60%)
Not present	39 (58%)	22 (92%)	17 (40%)
Margins			
Positive	25 (37%)	10 (42%)	15 (35%)
Negative	42 (63%)	14 (58%)	28 (65%)
Nodal disease			
Present	18 (27%)	0 (0%)	18 (42%)
Level I	2 (3%)	0 (0%)	2 (5%)
Level II	11 (16%)	0 (0%)	11 (26%)
Level III	1 (1%)	0 (0%)	1 (2%)
Level IV	1 (1%)	0 (0%)	1 (2%)
Intraparotid nodes	7 (10%)	0 (0%)	7 (16%)
Absent	49 (73%)	24 (100%)	25 (58%)
Surgical procedure			
Lateral temporal bone resection	49 (73%)	23 (96%)	26 (60%)

Characteristic	Overall population N = 67 (100%)	Basal cell only N = 24 (100%)	Squamous cell only N = 43 (100%)
Subtotal temporal bone resection	18 (27%)	1 (4%)	17 (40%)
Parotidectomy	48 (72%)	13 (54%)	35 (79%)
Neck dissection	47 (70%)	11 (46%)	36 (84%)
Immune status			
Immunocompromised	11 (16%)	1 (4%)	10 (23%)
Immunocompetent	56 (84%)	23 (96%)	33 (77%)
Prior history of radiation			
Yes	20 (30%)	5 (21%)	15 (35%)
No	47 (70%)	19 (79%)	28 (65%)
Adjuvant radiation			
Yes	29 (43%)	5 (21%)	24 (56%)
No	38 (57%)	19 (79%)	19 (44%)

Table 2.

Tumor and nodal staging distribution for patient population with either squamous cell carcinoma or basal cell carcinoma of the temporal bone.

TNM staging of temporal bone carcinoma patients [†]				
	N0	N1	N2	N3
T2	22	0	2	0
T3	8	1	2	0
T4	19	4	7	2

[†] All patients were M0, without evidence of metastatic disease at the time of surgery.

Table 3.

Multivariate regression analysis for variables of sex, immune status, history of radiation, adjuvant radiation, lymphovascular/perineural invasion, margin involvement, cancer histology, procedure type, T stage, overall stage, and nodal involvement. None of the variables were found to have statistically significant odds ratios.

Variable	Reference variable	Odds ratio [†]	p-value
Male sex	Female sex	2.4	0.9
Presence of immunocompromise	Absence of immunocompromise	0.07	0.7
History of radiation	No history of radiation	154.3	0.6
Adjuvant radiation therapy	No adjuvant radiation	0.2	0.8
Perineural or lymphovascular invasion	No invasion	7E-4	0.7
Positive margins	Negative margins	13.7	0.7
Squamous cell histology	Basal cell histology	83.0	0.7
Lateral temporal bone	Subtotal temporal bone	0.04	0.9
T2	T4	140.0	1.0
T3	T4	1.2	1.0
Stage II	Stage IV	1E-5	1.0
Stage III	Stage IV	1136.0	1.0
Nodal involvement	No nodal involvement	876.5	0.7

[†]Odds ratios and p-values are for overall population only. Multivariate regression analysis did not yield valid results for the squamous cell and basal cell histology subgroups due to limited sample size.

Table 4.

Pathologic characteristics of patients with T4 disease.

Patient	Sex	Age at diagnosis	Staging/Histology	Disease extent	Resection extent	Margins	Invasion	Adjuvant therapy	Preop HB	Postop HB	Overall survival
1	M	66	T4N2bM0 SCC	EAC, mandible, parotid	Subtotal temporal bone resection, radical parotidectomy, partial mandibulectomy, excision of zygomatic arch, external carotid, CNs VII and V3, and skull base	Positive at medial resection margin	Perineural	Adjuvant radiation to 66 Gy in 33 fractions	I	VI [‡]	8 years
2	M	46	T4N1M0 SCC	EAC, preauricular skin, parotid	Lateral temporal bone resection, auriculectomy, parotidectomy, neck dissection	Negative	Perineural, lympho-vascular	Adjuvant radiation to 66 Gy in 33 fractions	I	III [‡]	10.5 years
3	F	72	rT4N0M0 BCC	EAC, auricle, mastoid, parotid	Lateral temporal bone resection, auriculectomy, superficial parotidectomy, neck dissection	Positive at mastoid cortex and medial temporal bone resection margins	None	Adjuvant radiation to 64 Gy in 32 fractions	I	I	11.5 years
4 [‡]	M	75	rT4N3M0 SCC	Carotid space, masticator space, para-pharyngeal space, mandibular foramen and canal, skull base dura, sigmoid sinus	Subtotal temporal bone resection, mandibulectomy, Fisch B, resection of dura along sigmoid sinus, radical neck dissection	Negative	None	Adjuvant chemo-therapy with cisplatin and 5FU	VI	VI	8.5 years
5 [‡]	F	57	rT4N2aM0 SCC	EAC, preauricular skin, middle and posterior fossae dura, sigmoid sinus, mandible	Subtotal temporal bone resection, auriculectomy, trans-labyrinthine craniotomy, resection of middle and posterior fossa dura, parotidectomy, mandibulectomy, neck dissection	Positive at medial temporal bone resection margin	None	Adjuvant radiation to 60 Gy in 30 fractions	I	I	12.5 years
6	M	83	rT4N0M0 SCC	EAC, auricle	Lateral temporal bone resection, auriculectomy	Negative	None	None	I	I	3.75 years
7	M	79	rT4N0M0 SCC	EAC, preauricular skin, parotid, CN VII, infra-temporal fossa	Subtotal temporal bone resection, auriculectomy, parotidectomy, V3, foramen ovale, infratemporal craniotomy, neck dissection	Positive at medial temporal bone resection margin	Perineural	None	I	VI [‡]	1 year
8	M	72	rT4N1M0 SCC	IAC, parotid, infra-auricular skin, stylomastoid foramen, CN VII	Subtotal temporal bone resection, parotidectomy, translabyrinthine craniotomy, neck dissection	Negative	Perineural	None	VI	VI	1 year
9 [‡]	M	54	T4N0M0 BCC	EAC, mastoid, squamous temporal bone, zygomatic arch, preauricular region, temporal fossa, dura, middle fossa, mandible	Subtotal temporal bone resection, parotidectomy, mandibular condylectomy, excision of MCF floor and adjacent dura	Positive at medial temporal bone resection margin	Perineural	Adjuvant radiation to 66 Gy in 33 fractions	II	VI [‡]	3.5 years
10	M	57	T4N2aM0 SCC	EAC, parotid, preauricular skin, carotid space, paraspinal muscles, mastoid, jugular fossa	Subtotal temporal bone resection, auriculectomy, parotidectomy, neck dissection	Negative	Lympho-vascular	none	VI	VI	0.5 years
11 [‡]	F	69	rT4N2bM0 SCC	Canal wall down surgical bed, lateral skull base, carotid canal, jugular foramen, glenoid fossa, mandible, infra-temporal fossa	Subtotal temporal bone resection, parotidectomy, infratemporal approach with extradural tumor excision, transcochlear craniotomy, naso-pharyngectomy, modified radical neck dissection	Positive at medial temporal bone resection margin	Perineural	Adjuvant Radiation to 70 Gy in 35 fractions	I	VI [‡]	6.5 years
12	M	62	T4N0M0 BCC	EAC, auricle, tympanic membrane, mastoid, squamous temporal bone	Lateral temporal bone resection, auriculectomy, parotidectomy, neck dissection	Positive at external auditory canal margin	Perineural, lympho-vascular	Adjuvant radiation to 66 Gy in 33 fractions	I	I	1 year
13	M	69	rT4N0M0 BCC	EAC, middle ear	Lateral temporal bone resection	Negative	None	None	I	I	8 years

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Patient	Sex	Age at diagnosis	Staging/Histology	Disease extent	Resection extent	Margins	Invasion	Adjuvant therapy	Preop HB	Postop HB	Overall survival
14	M	79	rT4N0M0 SCC	EAC, mandible, skull base, jugular foramen, foramen ovale, infra-temporal fossa	Subtotal temporal bone resection, total parotidectomy, mandibulectomy, infratemporal fossa resection, skull base resection, neck dissection	Negative	Perineural	Adjuvant radiation to 50 Gy in 20 fractions	VI	VI	2 years
15	M	76	rT4N0M0 SCC	EAC, parotid, middle ear, CN VII	Lateral temporal bone resection, auriculectomy, parotidectomy, neck dissection	Negative	Perineural	Adjuvant radiation to 66 Gy in 33 fractions	VI	VI	1 year
16	M	79	rT4N0M0 SCC	EAC, glenoid fossa, mastoid	Lateral temporal bone resection, auriculectomy, parotidectomy, neck dissection	Negative	None	None	I	I	3 years
17	M	66	rT4N0M0 SCC	EAC, middle ear, mastoid, zygoma	Subtotal temporal bone resection, resection of zygomatic root, infratemporal facial nerve decompression, parotidectomy, resection of CN VII	Negative	Perineural	None	VI	VI	1 year
18	F	54	T4N0M0 BCC	EAC, post-auricular skin, mastoid, parotid	Lateral temporal bone resection, auriculectomy, parotidectomy, neck dissection	Negative	None	None	I	I	3 years
19	M	68	T4N0M0 SCC	EAC, mastoid, mandibular condyle	Lateral temporal bone resection, mandibular condylectomy, neck dissection	Negative	Lympho-vascular	None	V	VI [‡]	3 years
20	M	50	T4N0M0 SCC	EAC, middle ear, mastoid, parotid	Subtotal temporal bone resection, Fisch A, middle cranial fossa, resection of CNs VII and V3, parotidectomy, neck dissection	Negative	None	None	I	VI [‡]	0.5 years
21	M	47	T4N0M0 SCC	EAC, middle ear, CN VII, carotid canal	Right subtotal temporal bone resection, neck dissection	Positive at external auditory canal margin	Perineural	Adjuvant radiation to 60 Gy in 30 fractions	I	I	0.5 years
22	M	64	rT4N1M0 SCC	EAC, superior SCM, mastoid, CN VII, stylomastoid foramen	Lateral temporal bone resection, auriculectomy, parotidectomy, neck dissection	Positive at stylomastoid foramen margin	Perineural	Adjuvant radiation to 66 Gy in 33 fractions	I	VI [‡]	5 years
23	M	65	rT4N1M0 SCC	EAC, middle ear, mastoid, parotid, CN VII, tegmen tympani	Subtotal temporal bone resection, auriculectomy, parotidectomy, condylectomy, infratemporal fossa resection	Negative	Perineural	None	V	VI [‡]	1 year
24 [‡]	F	57	T4N2bM0 SCC	EAC, parotid, stylomastoid foramen, hypotympanum, skull base, jugular fossa	Lateral temporal bone resection, parotidectomy, partial zygoma excision, drill out of IAC, Dural excision, resection of CNs IX and XI, neck dissection	Negative	Perineural, lympho-vascular	Adjuvant radiation to 60 Gy in 30 fractions	VI	VI	1 year
25	M	79	rT4N2bM0 SCC	EAC, preauricular skin, parotid	Lateral temporal bone resection, auriculectomy, parotidectomy, neck dissection	Positive at cheek skin and deep resection margins	Perineural, lympho-vascular	Adjuvant radiation to 60 Gy in 30 fractions	I	VI	0.5 years
26	M	74	T4N2bM0 SCC	EAC, parotid, masseter, zygomatic arch, CN VII	Lateral temporal bone resection, parotidectomy, excision of masseter and zygomatic arch	Negative	Perineural	Palliative radiation to 30 Gy in 10 fractions	I	VI [‡]	1.5 years
27	M	55	rT4N3M0 BCC	EAC, stylomastoid foramen, sub-mandibular space, masseter, mandible	Subtotal temporal bone resection, infratemporal fossa resection, parotidectomy, auriculectomy	Positive at medial temporal bone resection margin	Perineural	None	VI	VI	0.5 years
28	M	77	rT4N0M0 SCC	EAC, parotid, stylomastoid foramen, retro-mandibular vein, mandibular condyle	Subtotal temporal bone resection, auriculectomy, parotidectomy	Negative	Lympho-vascular	None	VI	VI	0.25 years
29	M	81	T4N0M0 BCC	EAC, auricle, parotid, tympanic membrane	Lateral temporal bone resection, auriculectomy, parotidectomy	Negative	None	None	I	VI	0.25 years

Patient	Sex	Age at diagnosis	Staging/ Histology	Disease extent	Resection extent	Margins	Invasion	Adjuvant therapy	Preop HB	Postop HB	Overall survival
30	M	74	rT4N0M0 SCC	EAC, auricle, parotid, pre-auricular skin	Lateral temporal bone resection, auriculectomy, parotidectomy	Positive at medial temporal bone resection margin	Perineural	None	I	VI [‡]	1.5 years
31	M	55	T4N0M0 SCC	EAC, middle ear, mastoid, parotid	Subtotal temporal bone resection, parotidectomy, neck dissection	Negative	None	None	I	VI [‡]	0.5 years

[‡]Patients with dural involvement.

[‡]Postoperative change in House Brackman secondary to intraoperative facial nerve sacrifice.