Giant Cell Tumor of the Lateral Skull Base: Diagnostic and Management Options

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Abstract

Giant cell tumor of bone (GCTB) is a rare, benign, osteolytic neoplasm that most commonly occurs in early adulthood and often involves the long bones of the body. Although GCTB largely affects the epiphyses of long bones, several reports of GCTB involvement of the cranial and facial bones exist in the literature. In addition to reviewing other reported cases of GCTBs of the lateral skull base in the literature, the authors report here on the clinical presentation, radiographic findings, and neurosurgical management of a patient found to have a GCTB of the middle and infratemporal fossae, which was treated by aggressive en bloc resection of the lateral skull base.

Keywords

► giant cell tumor of bone
► lateral skull base tumor
► neurosurgery
► osteoclastoma
► radiotherapy

Introduction

Giant cell tumor of bone (GCTB; or osteoclastoma) is an uncommon, benign, osteolytic neoplasm. GCTB comprises 3 to 5% of all primary bone tumors and occurs predominantly in early adulthood (peak incidence ages, 20–40 years) with a slight female predominance (3:2).¹⁻³ These tumors are thought to originate from neoplastic nonosteogenic stromal cells of the bone marrow and are characterized histologically by numerous multinucleated osteoclastic giant cells diffusely distributed among a background of mononuclear stromal and macrophage lineage cells.¹⁻⁶ GCTB most commonly affects the epiphyses of long bones, particularly of the distal femur and proximal tibia.⁶ Patients classically present with a combination of pain, swelling, or pathologic fracture at the tumor origin.⁷ Although regarded as benign, GCTB can recur locally following en bloc surgical resection.⁸,⁹ In 2 to 3% of cases, GCTBs can hematogenously metastasize to the lungs, resulting in benign pulmonary implants with rare malignant transformation.⁹,¹⁰ Despite an improved understanding of the molecular and cellular biology underlying the GCTB pathogenesis, the behavior of this tumor is often heterogeneous and can be difficult to predict on the basis of clinical, radiographic, or histologic features.

Although involvement of the appendicular skeleton is more typical for GCTB, axial skeleton involvement, especially of the cranial and facial bones, has also been reported and is becoming increasingly appreciated in the literature. Approximately 2% of GCTBs involve the head and neck.¹¹⁻¹³ Involvement of the axial skeleton is often associated with increased morbidity because of local infiltration of critical structures and the associated difficulty of complete tumor resection, particularly compared with resection of GCTBs of the appendicular skeleton.¹⁴ GCTB of the skull has also been reported to behave in a locally aggressive fashion.¹⁵ Nevertheless, surgery remains the treatment of choice for GCTBs, including those in the skull,
with en bloc or wide local excision portending the lowest risk of recurrence and best clinical outcomes in patients.\textsuperscript{4,16} Although much research has focused on GCTBs involving the long bones, numerous studies have also reported on GCTBs involving the lateral skull base. Here, we review other reported cases of GCTBs involving the lateral skull base and report on the clinical presentation, radiographic findings, neurosurgical management, and outcome of a patient with a GCTB of the middle and infratemporal fossae.

**Methods**

A literature search was performed using the PubMed/Medline database for cases of GCTB of the lateral skull base. The literature search spanned articles published between 1970 and June 2017. The keywords utilized in the search included: “giant cell tumor of bone,” “GCTB,” “GCT,” “osteoclastoma,” “lateral skull base,” and “skull base tumor.” The list of publications was reviewed for articles with relevance to our study (i.e., reports of GCTB of the lateral skull base). Full-text articles in the English language were reviewed and chosen based on whether they included a reported case of a patient with a GCTB involving the lateral skull base.

**Case Report**

**History and Examination**

A 22-year-old man presented to the neurosurgical service after sustaining a traumatic brain injury when he was hit by a vehicle while riding his bike without a helmet. The patient experienced a brief loss of consciousness at the scene and reported a nonfluctuating headache. He was taken to an outside hospital, where a noncontrast head computed tomography (CT) scan demonstrated a left temporal intraparenchymal hemorrhage, left temporal bone fractures, multiple facial bone fractures, and an incidental lytic bone mass of the left lateral skull base (\textsuperscript{\textbullet}Fig. 1). The patient was transferred to our institution for further evaluation.

Upon additional history gathering, the patient reported decreased hearing in the left ear over several months, as well as a recent slight bulging of his left face. On examination, the patient was awake, alert, and oriented to person and place. Cranial nerves were grossly intact, except for diminished sensorineural hearing in his left ear. Motor and sensory examinations were grossly intact throughout. He underwent diagnostic magnetic resonance imaging (MRI), which revealed a large tumor extending from the middle cranial fossa into the infratemporal fossa, with an associated intraparenchymal hemorrhage involving the left temporal lobe (\textsuperscript{\textbullet}Fig. 2). Given this finding, the patient was taken to the operative theater for tumor resection.

**Operative and Postoperative Course**

The patient was positioned supine and secured in a Mayfield frame for microsurgical resection of the lesion. Given the infratemporal extension of the tumor, a Fisch-type approach was utilized, with a preauricular incision providing access to the infratemporal and intracranial components of this neoplasm. After elevation of the temporalis muscle, the tumor was found to be intimately involved with the bony structures. Frozen and eventual final pathology samples were consistent with a giant cell tumor without malignant features (\textsuperscript{\textbullet}Fig. 3). Accordingly, a gross total resection of the tumor with negative margins was performed.

The temporal bone was drilled thoroughly with sacrifice of the left vestibulocochlear nerve to attain adequate margins. The left facial nerve was identified and skeletonized to protect and preserve function. Tumor-infiltrated temporal, frontal, and zygomatic bones were removed. Tumor feeding vessels arising from the superficial and deep temporal

![Fig. 1](image1.png)

**Fig. 1** Preoperative head computed tomography (CT) showing giant cell tumor of bone (GCTB) arising from the left lateral skull base. (A) Coronal head CT without contrast demonstrating a lytic mass of the left squamous part of the temporal bone with extension into the left sphenoid bone, mastoid air cells, and middle ear cavity. Imaging demonstrates destruction of the left lateral wall of the middle cranial fossa with bony fragment displacement laterally, medially, and inferiorly. The mass is also associated with intracranial hemorrhage and air within the hematoma that extends into the left temporal lobe. Moderate mass effect is present with left-to-right shift. (B) Axial head CT without contrast showing a lytic mass originating from the squamous part of the temporal bone. Imaging also reveals comminuted left orbital fractures, left maxillary sinus fractures, and a left zygomatic arch fracture.
arteries were coagulated to devascularize the tumor. Normal bony margins were obtained. With respect to the intracranial compartment, tumor involving the dura was resected. In addition, upon reflection of the dura, the tumor was found to involve the left lateral temporal lobe, causing hemorrhage and mass effect. The left temporal lobe involved by the tumor was surgically resected. At the completion of the procedure, the facial nerve was stimulated to ensure its integrity, and meticulous hemostasis was obtained. To repair the skull base defect, mesh...
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Fig. 4 Postoperative computed tomography (CT) and magnetic resonance imaging (MRI) demonstrating gross total resection of giant cell tumor of bone (GCTB) of the left lateral skull base with mesh cranioplasty. (A) Axial head CT without contrast demonstrating postsurgical changes. Comminuted left orbital and maxillary sinus fractures are present. (B) Axial T2-weighted MRI demonstrating postsurgical changes from left temporal bone craniectomy, tumor resection, and mesh cranioplasty. Imaging shows no signs of residual disease. Complete surgical resection with resultant decompression and normalization of midline shift is apparent on postoperative imaging.

Results

Table 1 summarizes the cases of tumors involving the lateral skull base identified in our review of the English language literature. Including our case, a total of 94 patients with GCTBs of the lateral skull base were identified through our review. As an aggregate, 56% of patients were male (53/94), while 44% were female (41/94). The mean age at presentation was 36.8 years (range: 0.17–79 years). Clinical presentations were variable and included headache (33%, 29/88), hearing loss (31%, 27/88), facial/preauricular swelling (22%, 19/88), facial/preauricular pain (17%, 15/88), tinnitus (15%, 13/88), aural fullness (10%, 9/88), diplopia (10%, 9/88), vision loss (10%, 9/88), ear pain (8%, 7/88), facial nerve palsy (8%, 7/88), proptosis (5%, 4/88), and dizziness (5%, 4/88). GCTB origin, in order of frequency, was temporal bones (62%, 58/94), sphenoid bones (32%, 30/94), occipital bones (5%, 5/94), and frontal bones (1%, 1/94).

Treatment data were reported for 91 patients. Of these patients, 52% (47/91) received gross total resections, 46% (42/91) subtotal resections, and 2% (2/91) did not receive treatment. Of 90 patients with clear documentation, 37% (33/90) received adjuvant radiotherapy following surgical treatment.

Of patients with reported follow-up, 14% (12/86) had local disease recurrence. In addition, of those patients with recurrence, 50% (6/12) had received subtotal resections alone, 25% (3/12) received subtotal resections with adjuvant radiotherapy, and 25% (3/12) received gross total resections alone. Of note, no patients receiving gross total resections with adjuvant radiotherapy developed recurrence (n = 4).

Discussion

GCTB is considered a benign, but locally aggressive, neoplasm of bone. These tumors are thought to originate from nonosteogenic neoplastic stromal cells of the bone marrow admixed with multinucleated osteoclastic giant cells.1,6 GCTBs most commonly affect the epiphyses of long bones, but have also been appreciated in the cranial and facial bones, including the skull base.6 Although considered a benign lesion, GCTB has a variable natural history, with the risk of local recurrence or distant metastasis being highly unpredictable. Unlike other types of cancer, metastatic spread of GCTB does not carry similar prognostic implications.17 Despite improved understanding of the underlying cellular and molecular biology underpinning GCTB pathogenesis, our knowledge regarding this tumor’s behavioral heterogeneity remains incomplete.

GCTBs of the cranial and facial bones most commonly affect the temporal and sphenoid bones.14,15,18–20 GCTBs of the lateral skull base are often locally aggressive and can invade nearby critical structures.18,21 It is believed that these tumors arise in these areas because the bones of the mandible, sphenoid, ethmoid, and parts of the temporal bone form largely through the process of endochondral ossification.22 In contrast, the other cranial bones (i.e., frontal and parietal bones) arise from intramembranous ossification and are less frequently affected by GCTB.15,22 Patients with GCTB of the temporal bone typically present with headache, conductive hearing loss, aural fullness, preauricular pain, or facial weakness.18,20,23 In comparison, patients with GCTB of the sphenoid bone may present with symptoms such as headache, facial hypoesthesia, diplopia, blindness, or visual field defects.18,19

Both CT and MRI are used to identify and characterize GCTB of the lateral skull base. On CT imaging, GCTBs usually...
Table 1: Review of our case and cases in the literature of giant cell tumors of bone involving the lateral skull base

| Study                  | Patient age (y) | Patient sex | Presentation                                      | Location                          | Operative technique/approach | Extent of resection | Adjuvant RT | Recurrence, follow-up (mo) |
|------------------------|-----------------|-------------|---------------------------------------------------|-----------------------------------|------------------------------|---------------------|-------------|---------------------------|
| Carmody et al, 1983    | 16              | M           | Progressive diplopia, esotropia of R eye          | Sphenoid bone and sinus, involvement of ST | Subfrontal craniotomy       | STR                 | Y           | N, 10                     |
| Wolfe et al, 1983      | 25              | F           | HA, blindness in L eye, visual field loss in R eye| Sphenoid bone and ST              | Craniotomy (NFS)             | STR                 | Y           | N, 168                    |
|                        | 16              | F           | HA, diplopia, blurred vision                      | Sphenoid bone and sinus w/ involvement of ST, clivus | Transseptal biopsy and surgical decompression | STR                 | Y           | N, 96                     |
|                        | 19              | F           | Diplopia, progressive loss of vision              | Sphenoid bone and sinus           | Frontal craniotomy           | STR                 | Y           | N, 132                    |
|                        | 20              | M           | HA, blurred vision, facial nerve palsy, R-sided spastic hemiparesis | Sphenoid bone, petrous part of temporal bone, clinoid | Craniotomy (NFS)             | GTR                 | Y           | N, 12                     |
|                        | 69              | M           | Memory loss and expressive dysphasia              | ST                                | Craniotomy (NFS)             | GTR                 | N           | N, 9 days                 |
|                        | 35              | M           | HA                                               | ST                                | Craniotomy (NFS)             | STR x2               | Y           | N, 21                     |
|                        | 16              | M           | Diplopia, visual field loss                      | Sphenoid bone and ST              | Craniotomy (NFS)             | STR                 | Y           | N, 31                     |
|                        | 19              | M           | HA, diplopia, L eye pain, R-sided ptosis          | Sphenoid bone and ST              | Oropharyngeal biopsy, transsphenoidal biopsy, and decompression | STR                 | Y           | N, 6                      |
| Motomochi et al, 1985  | 38              | M           | Chronic R-sided otitis media                      | Temporal bone                     | Temporal craniectomy with Y-shaped incision and retroauricular approach | STR                 | Y           | N, 11                     |
|                        | 53              | M           | HA, dysphagia, dysarthria                         | Occipital bone                    | Suboccipital craniectomy     | STR                 | Y           | N, 26                     |
| Kiwit et al, 1986      | 46              | F           | L-sided hearing loss and tinnitus, L facial palsy| Petrous part of temporal bone     | NA                           | GTR                 | N           | Y, 60                     |
| Findlay et al, 1987    | 23              | M           | R-sided hearing loss and otalgia, R facial palsy  | Temporal bone                     | R ECA ligated preoperatively, R subtemporal approach | STR                 | Y           | N, 8                      |
| Tandon et al, 1988     | 33              | M           | NA                                                | Temporal bone w/ involvement of sphenoid bone | Ablative surgery with Weber–Fergusson incision and transection of zygoma | GTR                 | N           | N, 11                     |

(Continued)
| Study                        | Patient age (y) | Patient sex | Presentation                                                                 | Location                                                                 | Operative technique/ approach | Extent of resection | Adjuvant RT | Recurrence, follow-up (mo) |
|-----------------------------|----------------|-------------|------------------------------------------------------------------------------|--------------------------------------------------------------------------|-------------------------------|---------------------|-------------|---------------------------|
| Bertoni et al, 1992\(^1\)   | 63             | F           | Hx of neurofibromatosis                                                      | Sphenoid and ethmoid bones                                               | NA                            | STR                 | Y           | Y, 34                     |
|                             | 61             | F           | HA, R-sided hearing loss and facial nerve palsy, unsteadiness, dizziness     | Petrous part of the temporal bone w/ involvement of occipital and sphenoid bones | NA                            | STR                 | Y           | N, 120                    |
| 8                           | F              |             | R-sided preauricular swelling                                                | Temporal bone                                                            | NA                            | GTR                 | N           | Y, 31                     |
| 24                          | F              |             | NA                                                                           | Occipital bone w/ involvement of petrous part of temporal bone and sphenoid bone | NA                            | STR                 | N           | N, 78                     |
| 28                          | F              |             | NA                                                                           | Clivus                                                                    | NA                            | STR                 | Y           | N, 84                     |
| 58                          | F              |             | NA                                                                           | Occipital bone                                                           | NA                            | STR                 | N           | Y, 18                     |
| 78                          | F              |             | Blindness, prior hx of Paget’s disease w/ skull involvement                 | Frontal bone                                                             | NA                            | GTR                 | N           | Y, 48                     |
| do Amaral et al, 1994\(^3\) | 14             | F           | HA, visual disturbances                                                      | Sphenoid bone, involvement of anterior ethmoid sinus, and ST             | GTR                           | Y                   | N           | N, 48                     |
| Rock et al, 1994\(^4\)     | 32             | F           | L preauricular and temporal pain; hx of Turner syndrome                     | Sphenoid bone w/ involvement of zygoma                                   | GTR                           | N                   | N           | N, 6                      |
| Saleh et al, 1994\(^5\)    | 36             | M           | R zygomaticotemporal swelling w/ jaw and temporoparietal pain, R-sided hearing loss, and tinnitus | Greater wing of sphenoid bone and squamous part of temporal bone          | STR                           | N                   | N           | N, 33                     |
| Silvers et al, 1996\(^6\)  | 55             | F           | R-sided otalgia and facial pain (previously dx as TMJ syndrome) w/ R-sided facial mass | Temporal bone w/ involvement of glenoid fossa                           | GTR                           | N                   | NA          | NA                        |
| Büter and Chilla, 1997\(^7\) | 49             | F           | NA                                                                           | Temporal and sphenoid bones w/ involvement of condylar fossa of the mandibular joint | NA                            | NA                  | N           | N, 36                     |
Table 1 (Continued)

| Study                  | Patient age (y) | Patient sex | Presentation                                      | Location                                      | Operative technique/approach                                      | Extent of resection | Adjuvant RT | Recurrence, follow-up (mo) |
|------------------------|-----------------|-------------|---------------------------------------------------|-----------------------------------------------|-------------------------------------------------------------------|---------------------|--------------|---------------------------|
| Li et al, 199743        | 36              | F           | Prior hx of GCTB of L temporal bone (local recurrence) | L glenoid fossa                               | Preauricular middle cranial fossa approach                        | GTR                 | N            | N, 12                     |
| Kattner et al, 199844   | 9               | F           | Frontal cephalgia, diplopia                       | Sphenoid bone and sinus w/ involvement of clivus, cavernous sinus | Transseptal transsphenoidal hypophysectomy w/ second resection via transsphenoidal route | STR                 | Y            | N, 12                     |
| Omura et al, 199845     | 18              | M           | L TMJ pain and restricted jaw opening             | Glenoid fossa and condyle                     | Preauricular approach                                             | GTR                 | N            | N, 24                     |
| Lee and Lum, 199912     | 45              | M           | L conductive hearing loss                         | Squamous, mastoid, and petrous portions of the L temporal bone | Sub- and transtemporal craniotomy w/ dissection of facial nerve   | NA                  | NA           | NA                        |
| Rosenbloom et al, 199946| 33              | F           | R aural fullness, pulsatile tinnitus, hearing loss, and otalgia, dysequilibrium | Jugular foramen                               | Preauricular infratemporal fossa approach                        | GTR                 | Y            | NA                        |
| Spallone et al, 199947  | 46              | M           | R-sided hearing loss                              | Temporal bone                                 | Basal subtemporal transzygomatic approach                        | STR                 | N            | N, 10                     |
| Sharma et al, 200225    | 36              | M           | Frontotemporal HA, R eye proptosis, epistaxis     | Sphenoid bone                                | Frontozygomaticotemporal approach w/ R maxillectomy and orbital exenteration | STR                 | Y            | N, 120                    |
|                        | 17              | M           | Recurrent HA, b/l proptosis, blindness            | Sphenoid bone                                | Anterior transbasal and transnasal transsphenoidal approach w/ b/l medial maxillotomies | STR                 | Y            | N, 24                     |
|                        | 40              | M           | HA, R eye proptosis w/ partial ophthalmoplegia    | Temporal bone w/ involvement of sphenoid bone | Frontozygomaticotemporal craniotomy and R maxillectomy           | STR                 | Y            | N, 24                     |
|                        | 18              | F           | Occipital HA, hearing loss, facial nerve palsy, dysphagia, ataxia | Petrous part of the temporal bone            | Retromastoid retrosigmoid approach                               | STR                 | Y            | N, 12                     |
|                        | 12              | F           | Cervicooccipital pain, R-sided hearing loss, facial nerve palsy | Petrous part of the temporal bone            | Retromastoid retrosigmoid approach                               | GTR                 | N            | N, 12                     |
| Study                       | Patient age (y) | Patient sex | Presentation                                                                 | Location                                                                 | Operative technique/ approach                  | Extent of resection | Adjuvant RT | Recurrence, follow-up (mo) |
|-----------------------------|-----------------|-------------|-------------------------------------------------------------------------------|--------------------------------------------------------------------------|-----------------------------------------------|---------------------|-------------|-----------------------------|
| Bibas-Bonet et al, 2003⁴⁸  | 8               | F           | R-sided auricular pain, tinnitus, and hearing loss, R facial numbness, dysphagia, hoarseness, diplopia | Temporal and sphenoid bones w/ involvement of ST, clivus, and pontine cistern | Nonoperative care (per guardians)              | None                | Y           | NA                          |
| Chan et al, 2003⁴⁹          | 77              | M           | Recurrent epistaxis, HA, hx of polyostotic Paget's disease                    | Sphenoid bone and sinus                                                  | Nonoperative care                              | None                | N           | N, 7                        |
| Harris et al, 2004⁵⁰        | 24              | F           | HA, tenderness and swelling over L inferoparietal and occipital regions       | Occipital bone w/ intracranial extension                                 | Occipital craniotomy                           | GTR                 | N           | NA                          |
| Tang et al, 2003⁵¹          | 61              | F           | Ataxia, facial palsy, dizziness, scalp mass over L temporozygomatic region    | L temporal bone w/ expansion into L middle ear                           | Transtemporal approach                         | STR                 | Y           | NA                          |
| Pai et al, 2005⁵²           | 26              | M           | Swelling of R temporal region, R-sided hearing loss, and tinnitus            | Temporal bone w/ large intracranial extension causing uncal herniation   | Frontotemporal approach                        | GTR                 | N           | N, 12                       |
| Wang et al, 2006⁵            | 64              | F           | Pressure in L ear, discomfort in L TMJ                                      | Temporal bone                                                             | Preauricular approach w/ temporal craniotomy   | GTR                 | N           | N, 24                       |
| Zorlu et al, 2006⁵³         | 14              | F           | Frontal HA, diplopia                                                        | Sphenoid bone                                                            | Transsphenoidal approach                       | STR                 | Y           | Y, 17                       |
| Elder et al, 2007⁵⁴         | 2               | F           | Preauricular mass                                                           | Temporal bone                                                             | Preoperative embolization of tumor vessels (90% occlusion); craniotomy (NFS) | GTR                 | N           | N, 13                       |
|                             | 0.13            | F           | Mass in L external auditory canal                                            | Temporal bone                                                             | Craniotomy (NFS)                               | GTR                 | N           | N, 11                       |
| Gupta et al, 2008⁵⁵         | 17              | F           | HA, diplopia, amenorrhea, worsening vision                                  | Clivus w/ involvement of ST, sphenoid bone                              | LeFort I osteotomy                             | STR                 | Y           | N, 24                       |
| Matsushige et al, 2008⁵⁶    | 77              | F           | Sudden-onset L temporal HA w/ emesis, horizontal nystagmus, reduced consciousness | Temporal bone                                                             | Subtemporal craniotomy                         | STR                 | N           | N, 12                       |
| Study | Patient sex | Patient age (y) | Location | Presentation | Operative technique/ approach | Extent of resection | Recurrence, follow-up (mo) | Adjuvant RT | Adjvant RT | Study | Patient sex | Patient age (y) | Location | Presentation | Operative technique/ approach | Extent of resection | Recurrence, follow-up (mo) | Adjuvant RT | Adjvant RT |
|-------|-------------|----------------|----------|--------------|--------------------------------|-------------------|------------------------|-------------|------------|-------|-------------|----------------|----------|--------------|--------------------------------|-------------------|------------------------|-------------|------------|
| Chiarini et al, 200957 | M | 70 | Temporal bone, TMJ | Swelling of the L TMJ, L-sided hearing loss, and tinnitus, HA | Temporal bone, TMJ: Craniotomy (NFS) | NA | N | N | N | Isaacson et al, 200920 | M | 42 | Temporal bone, TMJ | R-sided hearing loss | Temporal bone, TMJ: Middle cranial fossa approach | GTR | N | N | Isaccson et al, 200920 | M | 42 | Temporal bone, TMJ | R-sided hearing loss | Temporal bone, TMJ: Middle cranial fossa approach | GTR | N | N |
| Roeder et al, 2010 | 23 | M | Temporal bone | NA | Sphenoid bone | GTR | N | N | N | Roeder et al, 2010 | 23 | M | Temporal bone | NA | Sphenoid bone | GTR | N | N | Roeder et al, 2010 | 23 | M | Temporal bone | NA | Sphenoid bone | GTR | N | N |
| Venkatesh et al, 2012 | M | 30 | L temporal bone | Swelling of L temporal region w/ jaw pain and restricted jaw motion | L temporal bone | NA | Y | N | Y | Venkatesh et al, 2012 | M | 30 | L temporal bone | Swelling of L temporal region w/ jaw pain and restricted jaw motion | L temporal bone | NA | Y | N | Venkatesh et al, 2012 | M | 30 | L temporal bone | Swelling of L temporal region w/ jaw pain and restricted jaw motion | L temporal bone | NA | Y | N |
| Zhang et al, 2013 | M | 44 | Temporal bone | Proptosis of eye | Temporal bone | NA | N | N | N | Zhang et al, 2013 | M | 44 | Temporal bone | Proptosis of eye | Temporal bone | NA | N | N | Zhang et al, 2013 | M | 44 | Temporal bone | Proptosis of eye | Temporal bone | NA | N | N |
| Gamboa et al. | M | 70 | Temporal bone, TMJ | Swelling of the L TMJ, L-sided hearing loss, and tinnitus, HA | Temporal bone, TMJ: Craniotomy (NFS) | NA | N | N | N | Gamboa et al. | M | 70 | Temporal bone, TMJ | Swelling of the L TMJ, L-sided hearing loss, and tinnitus, HA | Temporal bone, TMJ: Craniotomy (NFS) | NA | N | N | Gamboa et al. | M | 70 | Temporal bone, TMJ | Swelling of the L TMJ, L-sided hearing loss, and tinnitus, HA | Temporal bone, TMJ: Craniotomy (NFS) | NA | N | N | Gamboa et al. | M | 70 | Temporal bone, TMJ | Swelling of the L TMJ, L-sided hearing loss, and tinnitus, HA | Temporal bone, TMJ: Craniotomy (NFS) | NA | N | N |

Table 1 (Continued)
| Study                      | Patient age (y) | Patient sex | Presentation                                      | Location                                      | Operative technique/approach | Extent of resection | Adjuvant RT | Recurrence, follow-up (mo) |
|----------------------------|----------------|-------------|--------------------------------------------------|-----------------------------------------------|------------------------------|---------------------|-------------|---------------------------|
| Billingsley et al, 2014²¹ | 32             | F           | HA, involvement of CNs                           | Sphenoid bone                                | NA                           | STR                 | NA          | NA                       |
|                            | 33             | M           | Involvement of CNs                               | Temporal bone                                | NA                           | GTR                 | N           | N, 12                     |
|                            | 35             | F           | HA, involvement of CNs                           | Temporal bone                                | NA                           | GTR                 | N           | N, 10                     |
| Prasad et al, 2014²       | 44             | F           | R otalgia and auricular fullness                 | Temporal bone                                | GTR                          | N                   | N, 15       |
|                            | 36             | M           | Preauricular mass, hearing loss and tinnitus, temporoparietal pain | Temporal bone w/ involvement of greater wing of sphenoid bone, TMJ | Infratemporal fossa type B approach | GTR | N | N, 120 |
|                            | 48             | F           | Temporoparietal mass                             | Temporal bone w/ involvement of greater wing of sphenoid bone, TMJ | Infratemporal fossa type D approach | GTR | N | N, 108 |
|                            | 31             | F           | Hearing loss and tinnitus                        | Temporal bone w/ involvement of TMJ          | Infratemporal fossa type B approach w/ temporal craniotomy | GTR | N | N, 96 |
|                            | 46             | M           | Temporal swelling, temporoparietal pain, hearing loss, and tinnitus | Temporal bone                                | Infratemporal fossa type B approach | GTR | N | N, 48 |
|                            | 67             | M           | Hearing loss and tinnitus, vertigo               | Temporal bone                                | Transmastoid exploration w/ extended mastoidectomy | STR | Y | Y, 24 |
|                            | 39             | M           | HA, hearing loss                                 | Temporal bone w/ involvement of greater wing of sphenoid bone, TMJ | Infratemporal fossa type B approach | GTR | N | N, 18 |
|                            | 57             | M           | Hearing loss and tinnitus                        | Temporal bone                                | Middle cranial fossa and infratemporal fossa type B approaches | GTR | N | N, 15 |
| Freeman et al, 2016¹²⁵⁸    | 27             | M           | R-sided hearing loss, HA                         | Mastoid portion of temporal bone             | Cortical mastoidectomy      | GTR                 | N           | N, 6                      |
| Study                  | Patient age (y) | Patient sex | Presentation                        | Location                                    | Operative technique/approach                                                                 | Extent of resection | Adjuvant RT | Recurrence, follow-up (mo) |
|------------------------|-----------------|-------------|-------------------------------------|---------------------------------------------|---------------------------------------------------------------------------------------------|---------------------|-------------|---------------------------|
| Carlson et al, 201761  | 43              | F           | R-sided TMJ swelling and pain       | Middle, infratemporal, and glenoid fossae  | Preauricular infratemporal fossa approach w/ condylectomy and resection of glenoid fossa    | GTR                 | N           | N, 166                    |
|                        | 40              | M           | R-sided hearing loss                | Middle, infratemporal, and glenoid fossae w/ involvement of mastoid, external auditory canal, and middle ear | Middle fossa craniotomy w/ tympanomastoidectomy 1-y later                                    | STR                 | Y           | N, 240                    |
|                        | 58              | M           | L-sided aural fullness              | Middle, infratemporal, and glenoid fossae w/ involvement of mastoid, external auditory canal, and middle ear | External beam RT (60 Gy) followed by temporal craniotomy w/ tympanomastoidectomy             | STR                 | N           | N, 226                    |
|                        | 60              | M           | L-sided hearing loss, aural fullness, and pain | Middle and glenoid fossae w/ involvement of mastoid, external auditory canal, and middle ear | Middle fossa craniotomy w/ tympanomastoidectomy                                               | GTR                 | N           | N, 162                    |
|                        | 57              | M           | L-sided hearing loss, tinnitus, aural fullness | Middle and glenoid fossae w/ involvement of mastoid, external auditory canal, and middle ear | Middle fossa craniotomy w/ tympanomastoidectomy                                               | GTR                 | N           | N, 156                    |
|                        | 31              | M           | R-sided TMJ swelling and pain       | Middle, infratemporal, and glenoid fossae w/ involvement of condyle | Preauricular infratemporal fossa approach w/ condylectomy and resection of glenoid fossa       | GTR                 | N           | N, 73                     |
|                        | 42              | F           | Incidental finding                  | Middle, infratemporal, and glenoid fossae  | Modified infratemporal fossa type B approach                                                | GTR                 | N           | N, 116                    |
|                        | 49              | M           | L-sided trismus and pain            | Middle, infratemporal, and glenoid fossae w/ involvement of external auditory canal, and middle ear | Middle fossa craniotomy w/ subtotal petrosectomy                                             | STR                 | N           | Y, 12                     |
|                        | 79              | M           | R-sided hearing loss, aural fullness and otorrhea | Middle, infratemporal, and glenoid fossae w/ involvement of external auditory canal, and middle ear | Middle fossa craniotomy w/ subtotal petrosectomy                                             | GTR                 | N           | N, 29                     

(Continued)
Table 1 (Continued)

| Study            | Patient age (y) | Patient sex | Presentation                   | Location                                      | Operative technique/approach                      | Extent of resection | Adjuvant RT | Recurrence, follow-up (mo) |
|------------------|-----------------|-------------|--------------------------------|-----------------------------------------------|--------------------------------------------------|---------------------|-------------|--------------------------|
|                  |                 |             |                                |                                               |                                                  |                     |             |                          |
| Middle fossa craniotomy w/ subtotal petrosectomy |                     |             |                                |                                               |                                                  |                     |             |                          |
| Patibandla et al, 2017 | 20              | M           | Hemicranial pain, eyelid droop, vomiting | Clivus                                        | Transnasal transphenoidal                          | STR                 | N           | N, 3                     |
| Current study    | 22              | M           | HA, L face swelling, L-sided hearing loss | Temporal bone w/ involvement of frontal and zygomatic bones | Fisch-type approach w/ preauricular incision       | GTR                 | N           | N, 2                     |

Abbreviations: b/l, bilateral; CNs, cranial nerves; ECA, external carotid artery; GTR, gross total resection; HA, headache; Hx, history; L, left; M/F, male/female; N, no; NA, not available; NFS, not further specified; R, right; RT, radiotherapy; ST, sella turcica; STR, subtotal resection; TMJ, temporomandibular joint; Y, yes.
the data are limited by their retrospective nature, small patient numbers, and short follow-up intervals. Given these limitations, general consensus regarding optimal dose and fractionation regimens are lacking. Moreover, there is concern that radiotherapy may contribute to malignant transformation.\textsuperscript{20,25} This risk may be minimized by use of conventional fractionation regimens without compromising tumor control; however, longer follow-up is needed to better characterize this risk.\textsuperscript{15,25}

Recently, several studies have investigated the role of targeted therapy with denosumab, a fully humanized monoclonal receptor activator of nuclear factor kappa-B ligand (RANK-L) antibody, which has shown promise as a potential effective chemotherapeutic treatment option in patients with GCTB.\textsuperscript{29} The osteoclastic giant cells responsible for local bony destruction and invasion in GCTB have been shown to ubiquitously express RANK receptor.\textsuperscript{29–31} Current evidence suggests that the neoplastic stromal cells promote the growth, proliferation, and osteolytic activity of the multinucleated osteoclastic giant cells through the overexpression of RANK-L, thus driving local bony destruction.\textsuperscript{30,32} With ongoing clinical trials studying the effectiveness of denosumab in the treatment of GCTBs, the role of monoclonal therapy in GCTBs of the skull base has not yet been fully characterized.\textsuperscript{31,33,34} Current evidence for the management of GCTBs of the skull recommends complete surgical resection with negative margins to achieve the highest rate of cure and lowest risk of recurrence.\textsuperscript{4,16} Nevertheless, the inhibition of this pathway with a monoclonal RANK-L antibody may limit bony destruction and tumor progression, thereby making these tumors of the lateral skull base more amenable to complete surgical resection and therefore decreasing the morbidity and mortality of this disease.

Conclusion
The skull is a relatively rare location for a GCTB to occur. When this tumor is found, it is normally found in the temporal or sphenoid bones. Although GCTB is a benign tumor, it is also locally aggressive and has the ability to recur or rarely metastasize. Gross total resection is the current treatment of choice in GCTB of the skull, but it can be difficult to achieve due to the proximity of the tumor to important neural and vascular structures. Subtotal resection with adjuvant radiotherapy may be a good alternative treatment in such cases. Although radiotherapy has been the adjuvant therapy of choice in GCTB treatment, recent literature shows that denosumab, a RANK-L antibody, may also prove to be effective in treating the tumor. Future studies should evaluate the efficacy of different adjuvant therapies used to treat partially resected GCTB of the lateral skull base.

Disclosure
None.

Compliance with Ethical Standards
This study was approved by the Institutional Review Board (IRB) of the University of Utah.

Patient Consent
The patient/legal guardian/next of kin has consented to the submission of the case report for submission to the Journal of Neurological Surgery Reports.

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