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Teaching Case

Gamma Knife Treatment of Vestibular Schwannoma Planned With Computed Tomography Cisternography

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Introduction

Vestibular schwannomas (VSs) are Schwann cell-derived tumors that most commonly arise from the vestibular portion of cranial nerve VIII. These constitute 6% of all intracranial neoplasms and approximately 80% of all cerebellopontine angle (CPA) neoplasms.[1] The growth rate for VS is approximately 1 to 2 mm per year, but certain tumors grow at a rate greater than 4 mm/y.[2,3] Magnetic resonance imaging (MRI) with and without contrast is the gold standard for evaluation of VS.

Management options for VS include observation, surgery, or stereotactic radiosurgery (SRS). Treatment options are influenced by patient-specific variables such as age, tumor size, tumor growth rate, and medical comorbidities. SRS is often recommended in elderly patients or those who are poor surgical candidates. When SRS is indicated, planning for the procedure is generally developed based on postcontrast-enhanced MRI.[4] When patients are unable to undergo MRI, limited options exist for SRS planning. This case describes an alternative SRS planning option for patients with VS who are unable to undergo MRI.

Case Report

A 76-year-old woman with a past medical history significant for right chronic otitis media treated with canal wall down mastoidectomy many years ago, complete heart block requiring cardiac pacemaker (MRI-incompatible), atrial fibrillation, severe chronic obstructive pulmonary disease, interstitial lung disease, and prior severe anaphylactic reaction to intravascular iodinated contrast, initially presented with imbalance and worsening hearing in her left ear. Audiometric testing was consistent with left sensorineural hearing loss with a decrease in the pure tone average from 38 dB (Gardner-Robertson Class II - serviceable) to 93 dB (Gardner-Robertson Class IV - poor) and a decrease in word recognition score from 100% to 8% over 3 years.[4] The patient had no other cranial nerve deficits. Because she was unable to undergo MRI or intravascular contrast-enhanced computed tomography (CT) scan, she underwent noncontrast CT, which showed widening of the left internal auditory canal (IAC) with local bone erosion. This presumed VS was elected to be observed due to her medical comorbidities. She was followed with yearly noncontrast CT. Over 3 years, the CPA neoplasm had increased the maximum width of the IAC from 6.8 to 8.7 mm, causing dehiscence

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of the roof of the IAC; the anterior-posterior dimension of the CPA component of the lesion had increased from 6.8 to 13.3 mm (Fig 1). Overall, the size of the CPA neoplasm had increased from a Koos grade II to IV tumor.[5]

Given her cardiac and pulmonary comorbidities, SRS was recommended to prevent further growth of the neoplasm. The Gamma Knife Icon is the modality of SRS available at our institution. Because the patient's non-contrast CT scan was unable to specifically delineate the borders of the tumor, the clinical dilemma was how to best image this lesion for development of a SRS plan. After multidisciplinary discussion, and a week before her actual Gamma Knife treatment, she underwent CT cisternography with 15 mL of Isovue-200 iodinated contrast (iopamidol injection 41% containing 200 mg/mL organically bound iodine) injected intrathecally at the level of L3-L4 under fluoroscopy.[6] She was premedicated with prednisone (50 mg by mouth for 3 doses 13 hours before CT cisternography, 7 hours before, and 1 hour before) and diphenhydramine (50 mg by mouth 1 hour before CT cisternography) due to her history of anaphylaxis to intravascular iodinated contrast. Figure 2 shows an axial CT image of the bilateral IACs after intrathecal contrast was administered. A Gamma Knife Icon preplan was generated with Gamma Plan (Version 11.1.1) from the CT cisternography images. On the day of her Gamma Knife treatment delivery, the Gamma Plan preplan was fused with a Gamma Knife Icon flat-panel CT scan obtained with head frame immobilization (Fig 3). The dose of radiation was 12 Gy prescribed to the 50% isodose line (maximum dose 24 Gy) delivered over 97 minutes. The dose to the cochlea was minimized to the 8 Gy isodense line, although the patient already had profound sensorineural loss on the right side (pure tone average 93 dB) and preservation of the cochlea to any higher degree would not have influenced hearing preservation. The patient tolerated the procedure well. Follow-up CT without contrast has been scheduled 1 year after Gamma Knife treatment.

Discussion

MRI with and without gadolinium contrast and contrast-enhanced CT are the principal imaging choices for CPA lesions, as they allow for the differentiation between the 3 most common types of CPA neoplasm: VS, meningioma, and epidermoid cyst.[7] However, the diagnostic imaging modality preferred for VS is MRI with contrast. On MRI, VS is isointense or mildly hyperintense to brain parenchyma on T1 images, are mildly hyperintense on T2 images, and have avid enhancement with gadolinium contrast. CT, although not the preferred imaging modality, provides information regarding the osseous anatomy near the lesion and can be used in

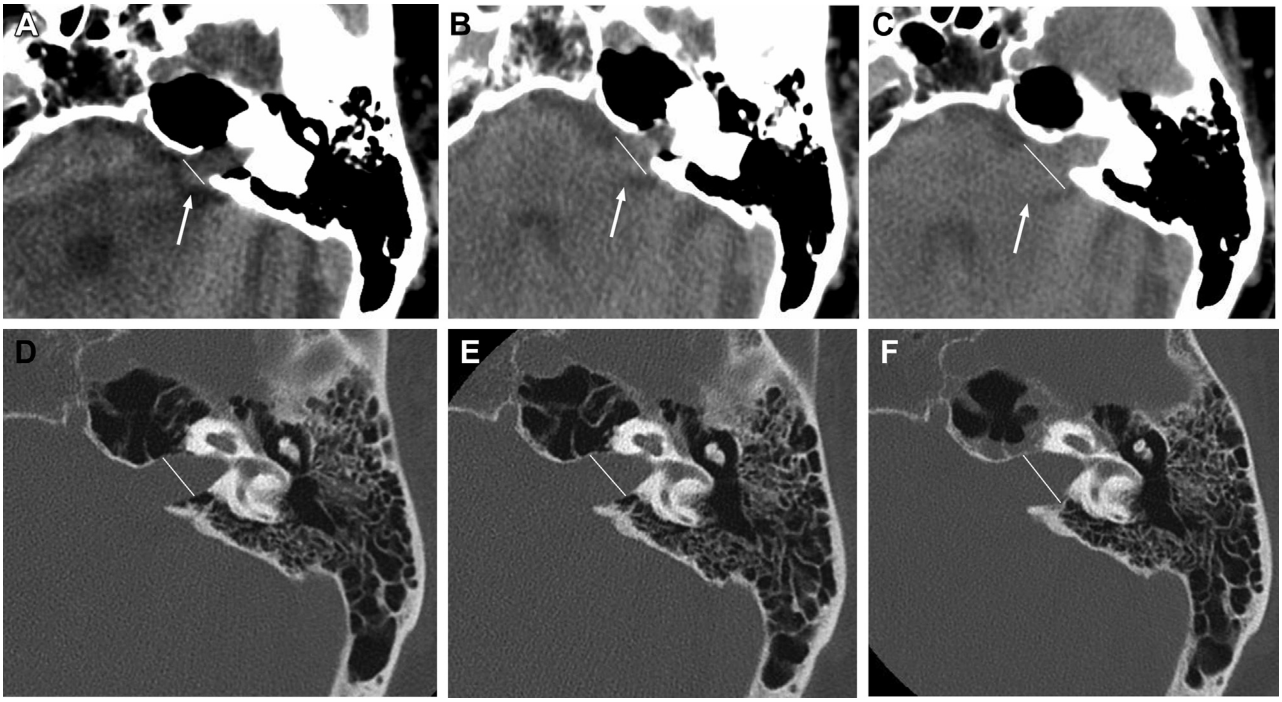

Figure 1 Interval growth of the patient's left cerebellopontine angle (CPA) neoplasm. (A) July 2016: internal auditory canal (IAC) maximum width was 6.8 mm, anterior posterior dimension of CPA component was 6.8 mm. (B) May 2018: IAC maximum width was 8.5 mm, anterior-posterior dimension of CPA component was 10.5 mm. (C) August 2019: IAC maximum width was 8.7 mm, anterior posterior dimension of CPA component was 13.3 mm. White arrow indicates CPA neoplasm.

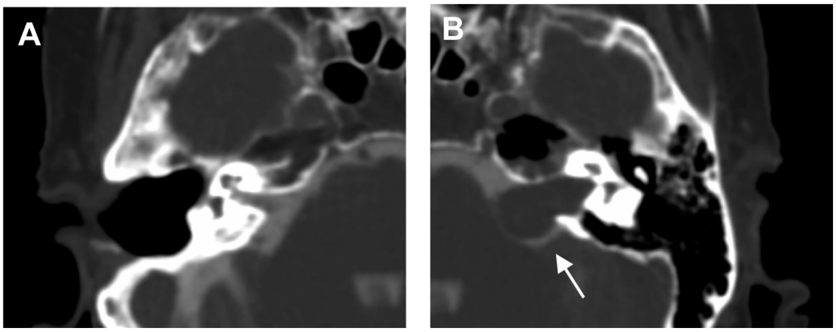

Figure 2 Axial cut of the bilateral internal auditory canals (IACs) on computed tomography (CT) cisternography. (A) The normal right IAC and sequela of the patient's prior canal wall down mastoidectomy. (B) A neoplasm (arrow) in the left IAC and cerebellopontine angle (CPA) (largest axial dimensions: 2.2 × 1.2 cm). The tumor extended to the fundus and is distinct from the petrous apex.

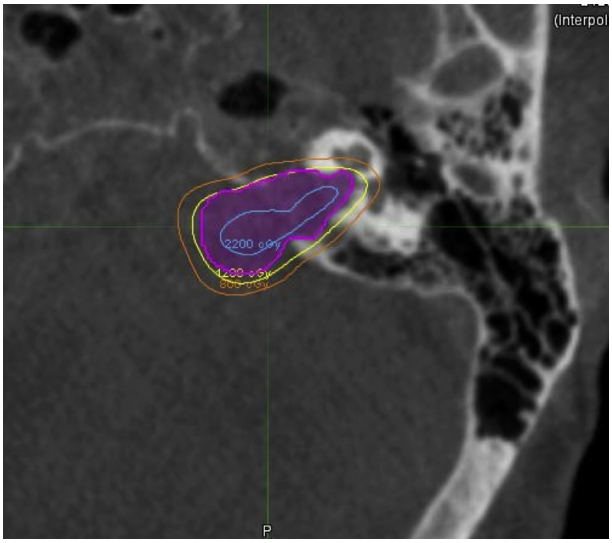

Figure 3 Axial cut of the left internal auditory canal (IAC) and the planned stereotactic radiation fields on fused computed tomography (CT) cisternography and day of treatment Gamma Knife Icon CT scan. The patient was treated at 12 Gy (1200 cGy) at the 50% isodose line. The tumor is shaded in pink. The 2200 cGy isodense line is outlined in blue, the 1200 cGy isodense line is outlined in yellow, and the 800 cGy isodense line is outlined in orange.

patients who are unable to undergo MRI.[8,9] Both gas and radiopaque contrast CT cisternography can be used to identify CPA tumors.[10] CT cisternography is able to mimic the thin-section heavily T2-weighted sequences (eg, Fast Imaging Employing Steady-state Acquisition), which are typically obtained with IAC protocol MRI, by outlining the suspected mass in cerebrospinal fluid with high density contrast. Although anaphylaxis to intravascular iodinated contrast is a relative contraindication to CT cisternography with intrathecal contrast and other CT studies using iodinated contrast, its use with premedication (steroids and diphenhydramine) can be considered when there is no other viable option.[11,12] Although iopamidol is rapidly absorbed in the bloodstream from cerebrospinal fluid (appears in plasma in 1 hour, and almost all of the drug reaches systemic circulation within 24 hours), CT cisternography requires a lower volume, and thus lower dose of contrast than CT with intravascular contrast (15 mL or less is used for intrathecal administration, up to 150 mL can be used for intravascular administration).[6,13] Lower contrast doses are associated with a decreased rate of hypersensitivity reactions to iodinated contrast.[14] Therefore, using intrathecal contrast allowed for a lower dose of iodinated contrast material, decreasing the risk of anaphylaxis and still achieving high resolution of the CPA lesion by outlining it in high density contrast. Limitations to CT cisternography include its invasive and time-consuming nature and potential for lack of patient compliance, as it involves lumbar puncture. There is also a risk of infection (meningitis), bleeding, and headache with this procedure.

CT cisternography has previously been reported in SRS for the treatment of trigeminal neuralgia to define cranial nerve (CN) V. This has been used in patients with an MRI-incompatible cardiac pacemaker, patients with previous microvascular decompression during which Teflon spacers were placed that cause MRI artifact, or when CN V was poorly visualized on MRI secondary to a tortuous basilar artery or other aberrant vasculature.[15,16] Lim et al[17] published a study of 29 patients in whom CT cisternography was used to reliably delineate the cisternal portion of CN V to the ganglion for trigeminal neuralgia treatment with SRS. This process was used to reduce suspected spatial distortion with MRI, and not to avoid magnet or contrast exposure. CT cisternography has also been used in conjunction with 2-dimensional planning for radiosurgery for VS, but there have been no previous reports in the literature of CT cisternography utilization in modern SRS planning for VS.[18]

In this case, the patient was unable to undergo MRI due to an MRI-incompatible pacemaker. She was also unable to have intravascular iodinated contrast due to a previous anaphylactic reaction. Given her comorbidities as well as her enlarging CPA neoplasm, she was also a poor candidate for observation or microsurgery. Planning for her Gamma Knife SRS was successfully completed using CT cisternography with intrathecal administration of a small volume of contrast and appropriate premedication − strategies used to minimize the risk of anaphylaxis.

Conclusions

Although this patient had contraindications to MRI and intravascular iodinated contrast, she was able to undergo Gamma Knife SRS treatment for VS via planning with CT cisternography. This is the first report of CT cisternography to plan Gamma Knife SRS for the management of a VS.

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