Pictorial review of CT and MR findings of cerebellopontine angle lesions

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Authors: Y.-W. Kim¹, H. J. Kim², C. K. Eun²; ¹Yangsan/KR, ²Pusan/KR
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Learning objectives

1. Know the normal imaging anatomy of CT and MRI
2. Describe the spectrum of the lesions of the CPA
3. Recognize the CT and MR imaging features of the CPA lesions
4. Propose a diagnosis based on suggestive features for all lesion of the CPA

Background

The cerebellopontine angle (CPA) cistern is a cerebrospinal fluid-filled space bound by the pons, cerebellum, and petrous temporal bone. Lesions in this region are readily identified on cross-sectional images. Lesions of the CPA are frequent and represent 6%-10% of all intracranial tumors. Acoustic schwannomas, which are also called vestibular schwannomas, and meningiomas are the two most frequent lesions and account for approximately 85%-90% of all CPA tumors. The other 10%-15% encompass a large variety of lesions that radiologists will encounter more and more frequently because of the remarkable sensitivity and accuracy of magnetic resonance (MR) imaging in evaluation of a CPA syndrome.

In most cases, MR imaging and computed tomography (CT) show typical features of lesions of the CPA and are sufficient to establish the diagnosis. To define the normal neuroanatomy of the CPA and to know the characteristic CT and MR imaging findings of CPA lesions are helpful in making the correct preoperative diagnosis.

Imaging findings OR Procedure details

This study includes the spectrum of lesions involving cerebellopontine angle: 1) the congenital lesions (epidermoid cyst, arachnoid cyst, dermoid cyst, lipoma),
2) the infection and inflammation lesions (tuberculosis, cysticercosis, sarcoidosis, Ramsay-Hunt syndrome), 3) the vascular lesions (aneurysm, AVM, cavernous angioma, SAH), 4) the benign and malignant tumor for CPA and brain stem or ventricle (schwannoma, mengioma, glioma, choroid plexus papilloma, lymphoma, hemangioblastoma, ependymoma, medulloblastoma, dysembryoplastic neuroepithelial tumor), 5) the CPA invasion by extension from the petrous bone or skull base (cholesterol granuloma, paraganglioma, chondromatous tumors, chordoma, endolymphatic sac tumor, pituitary adenoma, apex petrositis).

Normal Anatomy

On the axial images, the CPA cistern is a triangular space filled with cerebrospinal fluid. The longest leg of the triangle is the lateral border, formed by the petrous temporal bone. Medially, the CPA is continuous with the pontine and medullary cisterns, and the medial side of the triangle is the pons itself. The posterior border is formed by the cerebellar hemisphere. The lateral outlets of the fourth ventricle, at the foramen of Luschka, mark the boundary between the CPA and the cerebellomedullary cistern (Fig. 1). The CPA cistern is contiguous with the cisterna ambiens through the tentorial hiatus. The CPA roof is limited by the tentorium and its attachment to the petrous bone. The fifth through eighth cranial nerves are in the upper part of the CPA cistern, and the lower portion contains the 9th, 10th, and 11th cranial nerves. The CPA cistern extends into the IAC around the seventh (facial) and eighth (vestibulocochlear) cranial nerves.

Congenital

1) Epidermoid cyst

Epidermoid cysts or tumors, also known as primary cholesteatomas, are the third most frequent tumor of the CPA. They arise from normal epithelial cells included during neural tube closure. Their growth is due to accumulation of keratin and cholesterol produced by desquamation of the squamous epithelium lining the mass. These slow-growing tumors encase and surround nerves and arteries in the cisterns rather than displacing them.

On CT scans, epidermoid cysts appear hypoattenuating, almost isoattenuating to CSF, and have characteristic irregular, lobulated margins. As opposed to arachnoid cyst, which is the main differential diagnosis, epidermoid cyst produces no reaction of the adjacent bone structures. Slight marginal calcifications or enhancement after contrast material administration are rarely seen.

At MR imaging, epidermoid cysts have slightly higher signal intensity than CSF on T1- and T2-weighted images, often with heterogeneous and marbled features. Sometimes, when the signal intensity is very similar to that of CSF, the fluid-attenuated inversion-
recovery sequence is more sensitive than conventional sequences in differentiation of epidermoid and arachnoid cysts because it suppresses the signal of CSF. With this sequence, epidermoid cysts have high signal intensity, whereas the signal of arachnoid cysts is suppressed. Diffusion-weighted imaging is also well known to allow differentiation of epidermoid and arachnoid cysts (Fig. 2). The apparent diffusion coefficient of an epidermoid cyst is significantly lower than that of an arachnoid cyst; therefore, epidermoid cysts have high signal intensity on diffusion-weighted images whereas arachnoid cysts, like CSF, have very low signal intensity.

2) Arachnoid cyst

Arachnoid cysts are pouchlike intraarachnoid masses of uncertain origin filled with CSF. At MR imaging, their attenuation and signal intensity match those of CSF almost exactly. These masses have smooth and rounded edges, displace neurovascular structures, and erode adjacent bone structures. There is no calcification or enhancement. On T1- and T2-weighted images they can appear similar to an epidermoid cyst. Fluid-attenuated inversion-recovery and constructive interference in the steady state sequences as well as diffusion-weighted imaging are helpful in making the distinction. The arachnoid cysts, like CSF, have very low signal intensity on diffusion-weighted images (Fig. 3).

3) Dermoid Cyst

Like epidermoid cysts, dermoid cysts result from inclusion of ectodermal elements during neural tube closure but may originate a bit earlier. Dermoid cysts are midline lesions that rarely invade the CPA laterally and contain elements from all layers of the skin. Thus, fat, hair, sebaceous glands, and sweat glands can be found in addition to squamous epithelium. Typically, dermoid cysts have negative attenuation values on CT scans and high signal intensity on T1-weighted images due to their fatty content, may have a very suggestive fat-fluid level, and contain calcifications.

4) Lipoma

Lipomas in the CPA are maldevelopmental masses that arise from abnormal differentiation of the meninx primitiva. They are homogeneous fatty lesions surrounding and encasing normal adjacent neurovascular structures with very dense adhesions. Nevertheless, lipomas are rarely symptomatic, and conservative follow-up is often preferred to aggressive and potentially risky resection.

Lipomas appear as fat: homogeneously hypoattenuating with a negative attenuation value on CT scans and as characteristic and suggestive homogeneous high signal intensity on T1-weighted images, which decreases on fat-suppressed images. There is no enhancement after contrast material administration (Fig. 4).
Infections and Inflammation

1) Meningitis (Tbc & fungal)

Central nervous system tuberculosis usually manifests as a tuberculous basilar meningitis that may be associated with intra-axial tuberculomas or tuberculous abscesses. Solitary tuberculoma presenting as an extra-axial mass mimicking a meningoia is, however, a classic but rare circumstance that is even more uncommon in the CPA. Superficial intraparenchymal tuberculomas, which are more frequent, may be difficult to distinguish from extra-axial lesions, and a high degree of suspicion for tuberculosis must be maintained when faced with a so-called CPA mass in the presence of risk factors for tuberculosis. CT and MR imaging findings vary depending on the stage of the disease and the character of the lesion (i.e., non-caseating, caseating with solid centre or caseating with necrotic centre). This may explain why cases of tuberculomas with no restricted diffusion and normal ADC have been reported. Other cases that are caseating with a solid center present as ring-enhancing lesions, with a central T2 hypointensity that parallels a high signal intensity on diffusion-weighted images and a possible low ADC (Fig. 5).

2) Cysticercosis

Cysticercosis is a parasitosis due to encystment of *Taenia solium* larvae in tissues. In the subarachnoid region, cystic lesions can be found in the CPA and usually occur in the racemose form. They appear as lobulated cysts with no mural nodule or enhancement and have signal intensity similar to that of CSF with all sequences. They are therefore difficult to diagnose, and cysticercosis should be considered whenever a solitary enlarged cistern is seen in a patient from an area where the disease is endemic. In addition, on CT scans, the lack of adjacent bone erosion can be useful in distinguishing neurocysticercosis from arachnoid cyst, which is the main differential diagnosis.

3) Ramsay-Hunt Syndrome (herpes zoster oticus)

Ramsay Hunt syndrome due to varicella zoster viral infection typically is presented with a peripheral facial nerve palsy associated with sensorineural hearing loss, tinnitus, vertigo with nystagmus, painful vesicular eruption within the external ear canal and of the auricle and the tympanic membrane, malaise, and fever. The MR findings in Ramsay-Hunt syndrome have reported contrast enhancement of the seventh and eighth nerve trunks within the distal internal auditory canal and along the labyrinthine segment as well as enhancement of the cochlea, vestibule, and parts of the semicircular canals. Additionally, intense enhancement of the geniculate ganglion and the tympanic and mastoid facial nerve segments has been observed and the blister lesions of the external auditory canal show enhancement as well (Fig. 6).
4) Sarcoidosis

Sarcoidosis involves the nervous system in about 5% of the cases and usually manifests as a granulomatous inflammation of the meninges and the hypothalamic region. The meningeal lesions appear in a diffuse plaque-like pattern, but infrequent focal dural-based masses have occasionally been reported in the CPA. Diagnosis is difficult, but can be considered because the sarcoidosis granulomas are hyperattenuating at CT, isointense on T1-weighted images, intensely enhance after contrast media injection and overall demonstrate a suggestive homogeneous low signal intensity on T2-weighted images (Fig. 7).

Vascular

1) Aneurysm (vertebrobasilar, PICA, AICA)

The vertebral and basilar arteries and some of their branches pass through the cerebellopontine cistern, where a tortuous segment or ectasia or even an aneurysm can develop. Although not neoplasms, such lesions can cause mass effect on the neural structures of the CPA and thus produce neurologic symptoms.

High-flow aneurysms appear as oval or round masses that have no signal (flow void) with all spin-echo sequences. Extreme low signal intensity on T2-weighted images is very suggestive of such lesions and indicates that normal arteries need to be evaluated. When an aneurysm is thrombosed, high signal intensity on T1-weighted images due to methemoglobin could be suggestive, but the signal intensity is variable; radiologists should be aware that enhancement of the mass can be observed due to organization of the thrombus, thus mimicking a schwannoma (Fig. 8).

2) Dural Arteriovenous malformation (AVM)

Unlike brain AVMs, dural AVMs usually lack a discrete nidus. Instead, dural AVMs are composed of numerous microfistulae within the dural wall of a major venous sinus. Dural AVMs rarely hemorrhage unless drainage is through cortical veins or an intracranial venous varix (Fig. 9).

3) Subarachnoid hemorrhage (SAH)

The subarachnoid hemorrhage is the most common presentation of intracranial aneurysm. 80% to 90% of nontraumatic SAH is caused by rupture of an intracranial aneurysm. Another 15% is associated with bleeding from an arteriovenous malformation, the remaining 5% is caused by various other lesions such as carotid artery dissection. The perimesencephalic SAH in which bleeding on CT or MR scans is localized immediately anterior to the brain stem and adjacent areas such as the interpeduncular fossa and
ambient cisterns (Fig. 10). The CT and MR appearance of hemorrhage is influenced by the phase of hemorrhage (Fig. 11).

4) Cavernoma

Cavernous malformations can also be encountered in the CPA. Even if most infratentorial cavernomas are located in the pons, superficial intra-axial cerebellar or even extra-axial cavernomas in the CPA exist and may clinically and radiologically mimic vestibular schwannomas. MRI accurately establishes the diagnosis in most cases of intra-axial cavernomas: they appear as well-circumscribed lesions with a reticulated core of mixed signal intensity on T1-weighted images and usually high signal intensity on T2-weighted images, surrounded by a peripheral rim of hemosiderin that shows hypointensity on all sequences, with moderate to no enhancement after contrast injection. Extra-axial CPA cavernomas are different and arise from the cranial nerves. Most of the reported cases had a faint intrinsic increased signal on T1-weighted images, with variable enhancement after gadolinium administration, and showed more classical central T2 hyperintensity surrounded by a rim of low signal intensity (Fig. 12). The presence of another or multiple intraparenchymal hypointense lesions detected by gradient echo T2-weighted images is a clue that points toward the diagnosis.

Primary tumor in CPA

1) Schwannoma

Schwannomas are encapsulated, benign, slowly growing neoplasms arising from the schwann cells of the cranial, spinal, and peripheral nerves. Primary intracranial nerve sheath neoplasms are nearly always schwannomas, and they do not have malignant potential. In the overwhelming majority of patients, a schwannoma will develop as a sporadic neoplasm. However, approximately 5%-20% of patients with solitary intracranial schwannomas have type 2 neurofibromatosis, and the presence of bilateral "acoustic" schwannomas is sufficient to make a presumptive diagnosis of the disease (Fig. 13). Type 2 neurofibromatosis is an inherited autosomal dominant syndrome characterized by a propensity for developing multiple schwannomas, meningiomas, and gliomas of ependymal derivation. Intracranial schwannomas, either without or with type 2 neurofibromatosis, most often arise from sensory nerves, and the eighth (vestibulocochlear) cranial nerve is overwhelmingly the most common site. Other synonyms for this neoplasm include acoustic neuroma, acoustic neurinoma, and neurilemoma. Because they usually develop from the vestibular component (often from the superior division), rather than the cochlear portion of the eighth cranial nerve, the changing the name from acoustic schwannoma to vestibular schwannoma is considered. The trigeminal (fifth) cranial nerve is the second most common site of intracranial
schwannoma, but it is about five to 10 times less frequent. Both sites relate to the CPA and its cistern; the eighth cranial nerve passes through it, and the fifth nerve forms part of its anteromedial boundary. Patients with the more common sporadic schwannoma usually present in their 30s and 40s. Several reported series have shown no gender predilection, whereas others indicate a female predominance of up to 2:1 for intracranial schwannomas, especially for large tumors. Deafness is the most common presenting symptom for patients with vestibular schwannoma who have type 2 neurofibromatosis, whereas vertigo and balance problems are uncommon (occurring in less than 10% of cases). Often, the patient has a long history of slowly progressive hearing loss, usually affecting the perception of high-frequency sounds more severely. In some cases, the patient may suddenly discover a unilateral hearing loss when using headphones or after holding a telephone to the "wrong" ear.

It is well known that small vestibular schwannomas are usually entirely contained within the IAC (ie, the intracanalicular " schwannoma). The reason for this is that the portion of the eighth cranial nerve traversing the cerebrospinal fluid of the CPA cistern does not have schwann cells but rather oligodendrocytes. However, at the opening of the IAC (ie, the porus acusticus), there is a transition zone at which the myelin production switches from the oligodendrocytes to the schwann cells. Thus, most vestibular schwannomas probably arise inside the IAC, or near its mouth, but then secondarily grow into the fluid-filled CPA cistern. The vestibular schwannoma is a rounded mass, centered on the long axis of the IAC. In more than 70% -90% of cases, there are signs of IAC erosion and enlargement. Conversely, erosion of the IAC (as seen on plain radiographs) indicates a schwannoma in up to 93% of cases. The largest portion of the tumor is usually in the CPA and is roughly spheric, but almost invariably there is a funnel-shaped component that extends into the IAC. Small schwannomas (up to 2 cm in diameter) may be homogeneously solid tumors. As they grow (and age), degenerative changes become more frequent and more prominent so that larger ( > 2-3 cm) schwannomas become heterogeneous, with cystic regions and occasional hemorrhages. On computed tomographic (CT) and MR images, the schwannoma is a spheric mass that forms acute angles with the petrous bone. Compared with the attenuation of the brain on unenhanced CT scans, the schwannoma is usually either the same (isoattenuating) or lower (hypoattenuating). Schwannomas invariably enhance with iodinated contrast material (Fig. 14). Intracanalicular and small CPA schwannomas usually enhance homogeneously (Fig. 15). Larger tumors show variable and heterogeneous features, including old and new hemorrhagic and cystic changes. On unenhanced Ti-weighted images, vestibular schwannomas can be isointense to slightly hypointense relative to the brain. After gadolinium infusion, they enhance intensely and often appear more homogeneous than on unenhanced T1-weighted images. It has been suggested that the intensity and homogeneity of enhancement are produced because of extracellular spaces that are much larger than those of other solid tumors. On T2-weighted images, the vestibular schwannoma usually becomes hyperintense, whereas most meningiomas remain hypo- or isointense. However, these signal intensity changes are not pathognomonic for schwannoma. Overall, the shape (round) and
location (centered on the IAC) are more reliable features, suggestive of a vestibular schwannoma. Eighth cranial nerve schwannomas are usually confined entirely to the posterior fossa. The trigeminal schwannoma usually straddles the boundary between the posterior and middle cranial fossa (Fig. 16).

2) Meningioma

The second most common mass of the CPA is the meningioma. These arise from the "arachnoid cap cells" of the arachnoid granulations (ie, villi). These villi are most numerous in the large dural sinuses but also occur in smaller veins and along the root sleeves of exiting cranial and spinal nerves. Meningiomas have a distinct female predilection that varies, depending on the series, from 2:1 up to 4:1 for intracranial tumors. Similar to the case for schwannomas, patients with meningiomas also present primarily in middle age (peak prevalence at 45-55 years of age). Meningiomas may also occur in patients with type 2 neurofibromatosis, often in multiple locations. Despite this association, patients with multiple meningiomas have only a 10% chance of having other clinical features of type 2 neurofibromatosis. The meningioma is a sharply demarcated, well-circumscribed, slowly growing neoplasm, usually with a wide attachment to the adjacent dura mater. The tumor is usually homogeneous, firm, and rubbery. Meningiomas often stimulate overgrowth (hyperostosis) of the nearby calvaria, even without histologic infiltration into the bone.

On imaging studies, there are several features that are suggestive of meningioma. Unlike the vestibular schwannoma, the meningioma usually grows as an oval or hemispheric mass rather than as a sphere. The meningioma is only rarely centered on the IAC, and, if the tumor does encroach on or grow into the IAC, the canal is usually not enlarged. On unenhanced CT scans, meningiomas are usually homogeneously hyperattenuating masses, compared with the brain. CT scans obtained with windows adjusted for bone detail ("bone windows") may demonstrate characteristic hyperostosis. On MR images, the signal intensity characteristics are less specific. As mentioned, both meningiomas and schwannomas may be isointense relative to the brain on T1-weighted images; however, the meningioma is characteristically more likely to remain isointense on images obtained with other pulse sequences. The meningioma will enhance brightly with gadolinium (on MR images) and iodine (on CT scans). A lack of IAC enhancement is usually suggestive of a meningioma (in contrast to a schwannoma); however, enhancement of the eighth cranial nerve has been seen in cases of en plaque growth of a meningioma extending along the nerve sheath. Several authors have emphasized using the dural tail sign as a differential feature indicative of meningioma. The dural tail sign was originally described as a curvilinear area of enhancement tapering off from the margin of a meningioma (Fig. 17). The causes and specificity of this sign have been debated. The abnormal enhancement has been ascribed to dural infiltration by tumor, but it may also be caused by nonneoplastic vascular and hyperplastic changes in reaction to the adjacent mass. However, we now know that a dural tail is not specific for meningioma and can be associated with schwannomas and other extraaxial masses. In
addition, this nonneoplastic dural reaction may extend into the IAC, thus causing potential confusion with a schwannoma. As a solitary radiologic feature, the dural tail is merely helpful in suggesting the possibility of meningioma, but it is far from pathognomonic.

2ndary invasion from brain stem, ventricle, and cerebellum

1) Lymphoma

Lymphomas can be observed in the posterior cranial fossa and even partly in the CPA. Lymphomas appear as isoattenuating or hyperattenuating homogeneous masses on CT scans with intense enhancement after contrast agent administration. At MR imaging, lymphomas invading the CPA have no specific imaging features; they are hypointense on T1-weighted images and hyperintense on T2-weighted images and enhance after contrast agent injection (Fig. 18). Nevertheless, mass effect and edema are also present and may suggest the intraaxial origin and therefore the correct diagnosis, especially in an immunodeficient patient.

2) Brain stem glioma (pendunculated)

In young adults, brainstem gliomas can manifest as asymmetric expansion of the brainstem with a possible pedicle into the CPA and even then can mimic an acoustic neuroma. Gliomas appear as hypoattenuating masses at CT with variable enhancement depending on the glioma grade. At MR imaging, T1-weighted images show hypointense masses, whereas T2-weighted images show hyperintense tumors as well as hyperintense adjacent edema (Fig. 19). In addition, the exophytic component in the cerebellopontine cistern is much better demonstrated than at CT.

3) Choroid plexus papilloma

Choroid plexus papillomas occur mainly in children but also occur in adults. These tumors derive from the neuroepithelial cells of the choroid plexus and recapitulate the structure of normal choroid plexus when benign. Therefore, papillomas can be encountered wherever choroid plexus is. In adults, choroid plexus papillomas often arise in the fourth ventricle and extend to the CPA through the foramen of Luschka, but they can also primarily develop in the CPA. At CT, these tumors are frequently hyperattenuating on nonenhanced scans with a possible cyst and calcification. MR imaging shows an isointense, irregular, but homogeneous mass that strongly enhances after injection of gadolinium contrast material and is often associated with hydrocephalus (Fig. 20). The hydrocephalus is explained in part by CSF hypersecretion by the tumor. There is usually no edema in the brainstem and no erosion of adjacent bony structures.
3) Ependymoma

Ependymomas of the posterior cranial fossa are more frequent in children but can also occur in young adults. Such lesions usually arise in the fourth ventricle and its lateral recesses and may extend into the CPA by means of an exophytic component. However, an extraaxial origin directly in the CPA is also possible. Ependymomas appear as irregular, lobulated tumors that can invade the cerebellar parenchyma. They are hypointense on T1-weighted images and hyperintense on T2-weighted images and demonstrate irregular enhancement (Fig. 21). Ependymomas are markedly heterogeneous due to calcification, hemorrhage, cystic components, or necrosis.

4) Medulloblastoma

Medulloblastoma is an infratentorial PNET and is sometimes termed PNET-MB. They are primarily, not exclusively, childhood tumors. Nearly three quarters occur before age 15; 50% occur in the first decade. A second, smaller peak of medulloblastomas occurs in adults 24 to 30 years of age. They appear as round or ovoid tumors with smooth margins, are more common in the cerebellar hemisphere than in the vermis, and often extend to the brain surface with possible exophytic invasion of the CPA or internal auditory canal. Irregularity of some portions of the tumor-brain interface is a clue to their intraaxial origin. At nonenhanced CT, medulloblastomas are frequently hyperattenuating and uncommonly demonstrate calcification. At MR imaging, these tumors are hypointense on T1-weighted images and iso- or hyperintense on T2-weighted images with possible cystic or necrotic components and enhance after injection of gadolinium contrast material (Fig. 22).

Secondary invasion from petrous bone and skull base

1) Paraganglioma

Paragangliomas (glomus tumors) that invade the CPA arise from minute bodies present in the jugular foramen along the vagus nerve (glomus jugulare tumor) or along the Jacobson nerve on the promontory of the middle ear (glomus tympanicum tumor). These benign but locally aggressive tumors can destroy the petrous bone and enlarge enough to invade the CPA. At CT, paragangliomas appear as well-defined, enhancing soft-tissue masses associated with moth-eaten erosion of the bony margins of the site of tumor origin (ie, jugular foramen or promontory). At MR imaging, paragangliomas appear as soft-tissue masses with hypervascularity; they demonstrate punctate and serpentine signal voids produced by high-flow blood vessels. In addition, focal intratumoral hemorrhages with methemoglobin appear as high signal intensity on T1-weighted images, producing
a characteristic salt-and-pepper appearance. The tumor enhances intensively after contrast material administration.

2) Chondromatous tumor (chondroma & chondrosarcoma)

Chondromatous tumors develop from embryonic cartilaginous remnants enclosed in the bones of the skull base. They often arise from the petro-occipital or sphen-occipital synchondrosis and destroy the adjacent bones. Chondromatous tumors can be hypoattenuating at CT, possibly with a marginal high-attenuation area due to a dense matrix of hyaline cartilage or massive calcification. Lytic bone erosion may be seen. At MR imaging, the tumor is hypointense on T1-weighted images and heterogeneously hyperintense on T2-weighted images; it enhances poorly due to its hypovascularity.

3) Chordoma

Chordomas develop from remnants of the notochord and are located near the dorsum sellae, from which they can expand into the CPA. At CT, chordomas appear hypoattenuating with possible slight calcification at the periphery of the tumor in association with irregular bone erosion. At MR imaging, especially on T2-weighted images, chordomas usually appear as lobulated, large, hyperintense masses with septa of low signal intensity. Slight enhancement is present (Fig. 23). The overall appearance can be quite similar to that of chondroma.

4) Endolymphatic sac tumor

Endolymphatic sac tumors are papillary adenomatous tumors that originate from the endolymphatic sac, which is located in the distal portion of the vestibular aqueduct of the petrous bone. These tumors occur sporadically but are frequent in von Hippel-Lindau disease. At CT, the tumor destroys the retrolabyrinthine petrous bone with geographic or moth-eaten margins, and intratumoral spiculated or reticulated bone can be seen. At MR imaging, endolymphatic sac tumors appear heterogeneous on both T1- and T2-weighted images with focal high signal intensity due to subacute hemorrhages and low signal intensity due to calcification or hemosiderin. Blood-filled cysts and protein-filled cysts, both of which appear hyperintense on T1- and T2-weighted images, may be present and suggest the diagnosis. Heterogeneous enhancement is seen after contrast material administration.

5) Cholesterol granuloma

Cholesterol granulomas can occur in any obstructed air cells. They often arise from the apex of the petrous bone and may enlarge enough to expand in the posterior cranial fossa and produce nerve disturbances. At CT, cholesterol granulomas appear as sharply and smoothly marginated expansile lesions in the temporal bone, isoattenuating with brain
tissue and nonenhancing. At MR imaging, they characteristically have a large central region of increased signal intensity and a thin peripheral rim of decreased signal intensity on both T1- and T2-weighted images. The latter finding corresponds to expanded cortical bone and hemosiderin deposits. Spontaneous and homogeneous central high signal intensity on T1-weighted images is very suggestive of a cholesterol granuloma.

6) Matastasis, systemic or subarachnoid spread

Intracranial metastases are ubiquitous. They may be extra-axial and mimic a meningioma or a schwannoma in the CPA, as previously described in detail in the first part of this review, or be intra-axial, exactly located in front of the IAC, often surrounded by peritumoral oedema. Multiple lesions or past history of a known cancer will lead to the diagnosis (Fig. 24).

Images for this section:
Fig. 1: Normal Imaging Anatomy The axial (A-C) and Coronal (D) images show that the CPA cistern (star) is bordered by the pons (P), the cerebellar hemisphere (C), and the petrous bone (B). The trigeminal nerve (arrow in A) runs straight anteriorly from the pons. The internal auditory canal (IAC; curved arrow), sigmoid sinus, and fourth ventricle(4) are also seen. The facial nerve (arrow in B) and vestibulocochlear nerve (arrow C) run into IAC from the pons.
Fig. 2: Forty-year old man with left hearing disturbance. The CT image (A) and the conventional spin-echo T2W (B) and CE-T1W images show widening of the SAS in left C-P angle, but tumor was not visible. On the DWI (D), tumor is visible as a hyperintense lobulated mass and has well-demarcated margins.
**Fig. 3:** Arachnoid cyst in a 2-year-old boy with ataxia. CT image (A) and Axial T2-weighted and CE-T1-weighted MR image (B,C) show a well-demarcated lesion with signal intensity similar to that of CSF in right CPA. Diffusion-weighted MR image (D) shows low signal intensity, suggesting the arachnoid cyst displacing the brain stem.
Fig. 4: Forty-eight years old woman with tinnitus. The CT image(A) shows focal low attenuation in right CPA (-102HU). The TSE-T2WI and T1WI (B&C) reveal focal high signal intensity in right CPA. This lesion is low signal intensity on CE-FS T1WI(D). This lesion has signal intensity similar to that of subcutaneous fat on MR images.
**Fig. 5:** Tuberculomas in a 39-year-old man with miliary pulmonary tuberculosis and meningitis. Contrast-enhanced axial and sagittal T1-weighted images (A-C) reveal peripheral rim enhancing lesions left CPA, in front of the left IAC and cerebrum. Axial T2-weighted image (D) shows a mixture of iso- and low signal intensities.
Fig. 6: Ramsay-Hunt syndrome in a 12-year-old boy with headache and left peripheral facial nerve palsy. Sequential contrast-enhanced axial (A-C) and coronal (D) T1-weighted images show abnormal enhancement of the left facial nerve in the distal intrameatal and labyrinthine nerve segments and geniculate ganglion (arrows). Transverse T2-weighted image through the brain stem (not shown here) shows no hyperintense signal in the pontine lesion, and the signal intensity within the right internal auditory canal is reduced.
**Fig. 7:** Neurosarcoidosis in a 41-year-old man with multiple cranial nerve palsies. Contrast-enhanced, axial T1WIs (A,B) reveal intensely enhancing, plaque-like lesion in right pons, CPA, Meckel's cave, and carvenous sinus. This lesion is isointense on T1-weighted image (C) and relatively homogeneous low signal intensity with perilesional edema in pons on T2-weighted image.
**Fig. 8:** Ruptured left AICA aneurysm in a 56-year-old man with coma. Non-enhanced CT scans (A,B) show subarachnoid hemorrhage in both CPA and prepontine cistern. The CT angiography reveal small enhancing aneurysm, connecting with left AICA in front of left IAC. The conventional angiography of left vertebral artery shows contrast-filling, small aneurysm of left AICA.
Fig. 9: AVM in the left trigeminal nerve in a 40-year-old woman with trigeminal neuralgia. Axial heavily T2-weighted (A) and contrast-enhanced T1-weighted images reveal enhancing tortuous vascularity along the cisternal portion of the left trigeminal nerve. Left vertebral artery angiograms, anteroposterior and lateral views (C, D) demonstrate a shunting AVM supplied primarily by a branch of the left PCA and internal maxillary artery that appears to pass through the foramen lacerum to the trigeminal nerve.
Fig. 10: Focal SAH of left CPA in a 72-year-old woman with headache and stupor mentality. The non-contrast CT scan (A) shows SAH of high attenuation in basal cistern. This patient is confirmed as ruptured left PCOM aneurysm on MR angiogram. The axial T1-weighted (B), T2-weighted (C), and CE T1-weighted (D) images shows focal SAH of heterogenous SI in left CPA.

Table 19-1  CT and MR of Intracranial Hemorrhage (Density/Signal Intensity Compared to Cortex)

<table>
<thead>
<tr>
<th>Time</th>
<th>NECT</th>
<th>CECT</th>
<th>T1WI</th>
<th>T2WI</th>
<th>GRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-6h</td>
<td>Hyperdense</td>
<td>—</td>
<td>Iso</td>
<td>Hyper</td>
<td>Hypo</td>
</tr>
<tr>
<td>7-72h</td>
<td>Hyperdense</td>
<td>—</td>
<td>Iso</td>
<td>Hypo</td>
<td>Very hypo</td>
</tr>
<tr>
<td>4-7d</td>
<td>Hyper/iso</td>
<td>—</td>
<td>Iso (center)</td>
<td>Hyper (rim)</td>
<td>Hypo</td>
</tr>
<tr>
<td>1-4wks</td>
<td>Iso/hypo</td>
<td>Rim enh</td>
<td>Hyper</td>
<td>Hyper</td>
<td>Hypo</td>
</tr>
<tr>
<td>Chronic</td>
<td>Hypodense</td>
<td>—</td>
<td>Hypo</td>
<td>Hypo</td>
<td>Hypo</td>
</tr>
</tbody>
</table>
Fig. 11: CT and MR of Intracranial Hemorrhage (Density / Signal Intensity Compared to Cortex)

Fig. 12: Right CPA cavernoma in a 10-year-old girl with headache. Axial T2- and T1-weighted images (A-C) reveal a typical "pop-corn" lesion with a hyperintense core surrounded by a peripheral rim of low signal intensity, contour-bulging into right CPA from pons. Sagittal CE-T1-weighted image (D) show no contrast enhancement of lesion.
**Fig. 13:** A 9-year-old body with NF2. Axial T2 and T1 weighted images (A,B) reveal isointense, round nodules in both CPA. Coronal and axial CE T1-weighted images (C,D) show well-enhancing nodules in both CPA and left IAC.
**Fig. 14:** Left schwannoma in a 47-year-old man presenting with left facial palsy, sensorineural hearing loss and tinnitus. Axial CT scan (A) show heterogenously enhancing mass widening left IAC. This lesion is heterogenous hypointense on T2WI (C) and isointense on T1WI (B). Contrast-enhanced axial T1-weighted image (D) demonstrates a left CPA mass extending into left IAC.
Fig. 15: Left intracanalicular schwannoma in a 37-year-old woman presenting with left facial palsy, sensorineural hearing loss and tinnitus. Axial and coronal T2-weighted images show hypointense mass (A,B) in left IAC. On contrast-enhanced axial and coronal images (C,D) reveal strong contrast enhancement.
**Fig. 16:** Trigeminal schwannoma in a 88-year-old woman with trigeminal palsy. The axial T2-weighted and FLAIR images (A,B) reveal nodular mass of high SI in right CPA and Meckel's cave along the course of trigeminal nerve. On axial and sagittal CE T1-weighted images, this mass is enhanced homogenously.
Fig. 17: Left CPA meningioma in a 49-year-old woman with dizziness and left sensorineural hearing loss. Axial T2-weighted image (B) reveals an homogeneous extra-axial hyperintense mass compressing the brain stem and the anterior aspect of the left cerebellar hemisphere. Contrast-enhanced axial T1-weighted images (C, D) show an intense enhancing lesion with dural tail sign (arrow).
Fig. 18: Primary brain lymphoma in a 66-year-old woman. The axial (B,C) and sagittal (D) gadolinium-enhanced T1-weighted MR images reveals an homogeneously enhanced right CPA lesion with multiple enhancing nodules in cerebrum. On FLAIR image (A), the tumor appears with a high signal intensity.
**Fig. 19:** Brain stem glioma in a 21-year-old woman with progressive right facial palsy, sensorineural hearing loss and dizziness. Axial T2W and FLAIR images (A,B) show a high signal intensity lesion in the right CPA. Axial and sagittal CE-T1W images (C,D) demonstrate the intra-axial location of the tumor with a faint tumor-parenchyma interface and the absence of contrast enhancement and intracanalicular component.
Fig. 20: Papilloma in a 14-year-old boy with vertigo. Axial CE CT and T1W images(A,D) reveal a large enhancing mass in the left CPA extending from the left foramen of Lushka. This mass is isointense on T1- and T2-weighted images(B,C).
Fig. 21: Ependymoma in a 7-year-old boy with vomiting, headaches, and left facial nerve palsy. Contrast-enhanced CT scan and axial T1-weighted MR images (A, C, D) show a heterogeneous ependymoma with a lobulated multicystic component in the left CPA, extending from 4th ventricle. The tumor invades the internal auditory canal without widening the porus. Axial T2-weighted MR image shows heterogenous hyperintense mass of left CPA through the foramen Lushka from 4th ventricle.
**Fig. 22:** Medulloblastoma in a 6-year-old girl with vomiting and headache. Contrast-enhanced CT scan and axial T1-weighted MR images (A, C, D) show relatively dense enhancement in left cerebellum and CPA. Axial T2-weighted MR image (B) reveal heterogeneous mass of mixed intensity (sio- or hyperintense) with possible cystic or necrotic component.
**Fig. 23:** Chordoma in a 50-year-old man with right trigeminal neuralgia and headaches. Axial CT scan shows heterogenous mixed attenuation of high and isodensity around right petrous bone. Axial T2W and contrast-enhanced axial and sagittal T1-weighted MR images reveal a chordoma invading the right CPA from clivus. There are suggestive enhanced septa on CE-sagittal T1WI.
Fig. 24: Nasopharynx Rahbdomysarcoma in a 32-year-old man with mental change. The sequential T2-weighted images (A,B) show round mass of heterogenous SI in right Meckel's cave and CPA (arrow in A), extending from nasopharynx mass (arrow in B). The contrast-enhanced axial and sagittal images reveal enhancing masses in right CPA and Meckel's cave (arrows in C) and diffuse thick meningeal metastasis (arrows in D).
Conclusion

A wide variety of lesions can be encountered in the CPA. A spectrum of the CPA lesions exists and is primarily based on the site of origin of the CPA lesions. Therefore, this characteristic should be analyzed first. Attenuation at CT, signal intensity at MR imaging, enhancement, shape and margins, extent, mass effect, and adjacent bone reaction are also helpful in establishing the diagnosis.

Personal Information

Pusan National University Yangsan Hospital
Departemnt of Radiology

kyw47914@pnuyh.co.kr

References

6. Imaging of cerebellopontine angle lesions: an update. Part 2: intra-axial lesions, skull base lesions that may invade the CPA region, and non-


