Cerebellopontine Angle Tumours
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Introduction
Cerebellopontine angle (CPA) tumours can be divided into extra-axial tumours, intra-axial tumours, extradural tumours and petrous apex lesions[6].

Extra-axial tumors can be divided into those common and rare. Acoustic tumours or more precisely vestibular schwannomas (VS) are by far the most common extra-axial tumour. Other common extra-axial tumours include meningiomas and cysts of the posterior fossa (epidermoid, arachnoid, etc…). Rare extra-axial tumours include other cranial nerve neuromas (V, VII, IX, X, XI, XII) and vascular malformations (aneurysms, malformations).

Intra-axial tumours include parenchymal lesions such as astrocytomas, ependymomas, papillomas, haemangioblastomas and metastases.

Extradural tumours include glomus tumours and bone lesions.

Petrous apex lesions include cholesterol granulomas, epidermoid cysts, mucoceles and aneurysms of the carotid artery.

Anatomy
The CPA is a triangular area bounded by the temporal bone anterolaterally, pons medially, cerebellar hemisphere anteriorly, tentorium cerebelli superiorly and lower cranial nerves inferiorly.

Its contents include the anterior inferior cerebellar artery (AICA) and 7th and 8th cranial nerves. These nerves emerge from junction of pons and midbrain and course through the CPA to reach the internal acoustic meatus (IAM).

The IAM extends from porus to the medial wall of the vestibule. The lateral wall of the meatus is divided by two crests. The horizontal (crista transversalis) and vertical (falciform or Bill's Bar) crests divide the meatus into four compartments. The larger anterior compartment contains facial nerve superiorly and cochlear nerve inferiorly. The posterior compartment contains the superior vestibular nerve superiorly and inferior vestibular nerve inferiorly. The inferior vestibular nerve supplies the saccule and through a separate nerve (the singular nerve) the ampula of the posterior semicircular canal.

Arterial and venous relations in the CPA are variable. The AICA for example can loop into the meatus. The jugular bulb if high can interfere with surgical access.

Acoustic Neuroma (Vestibular Schwannoma)

Vestibular Schwannoma (VS) represent more than 90% of all CPA tumours and more than 10% of all primary brain tumours. VS's are oncologically benign typically slow growing tumours.

Histopathology
Until recently little was known about the etiology of the VS until advances in genetics showed a defect on chromosome 22q to be responsible for development of sporadic and bilateral (as seen in Neurofibromatosis type II) tumours.
Grossly the tumour is usually firm and has a distinct capsule with good plane between it and the surrounding structures. The inside the tumor is often much softer than its capsule and might contain cysts and areas of necrosis. Spontaneous bleeding inside the tumour can lead to a sudden dangerous increase in the size.
The site of origin is thought to arise from the glial neurilemmal junction.
Histologically VS's can be divided into two main types by their appearance; Antoni A and B. Both of which can be present in the same tumour. In Antoni A the cells have an orderly arrangement into whorls while in Antoni B the cells have a disorderly appearance mixed with areas of degeneration.

Clinical presentation
This usually depends on the size of the tumour and its location. At the early stage a VS in the CPA may be completely asymptomatic. There might be unilateral tinnitus or an asymmetrical sensorineural hearing loss. In a few patients a sudden sensorineural hearing loss occurs possibly due to a vascular event. Due to slow tumour growth, vertigo and imbalance is very uncommon as the normal side usually compensates for the gradually progressive loss. Very few patients present with acute vertigo. When this occurs it is most likely due to a vascular event in the labyrinth. Although the facial nerve is often significantly stretched by the tumour, facial weakness is relatively uncommon as the motor neurons appear more resilient than sensory nerves. If there is significant facial weakness one should be alerted to the possibility of a facial nerve schwannoma. When the tumour exceeds 3cm it might involve the trigeminal nerve resulting in a depressed corneal reflex and later frank facial numbness or pain on the ipsilateral side of the face..
With continued growth the cerebellum and the brain stem are compressed which leads to problems with balance and coordination. Ataxia and an intentional tremor might develop. The patient will have the tendency to fall to the side of the lesion. When a critical stage is reached the patient starts developing severe headaches with hydrocephalus and raised intracranial pressure.

Clinical Examination
A relevant examination should include an examination of the ear and assessment of hearing, cranial nerve, oculomotor and cerebellar function.
Ear examination should include otoscopy. Although this is most often normal it will help exclude other causes of hearing loss. Tuning fork tests will confirm the side of a sensorineural loss.
Cranial nerves should be examined with special attention to the trigeminal, facial and lower cranial nerves. The eyes should be examined for signs of nystagmus.
Cerebellar examination should include finger to nose testing for intention tremor, the Romberg's and Unterberger's tests with eyes closed and finally tandem gait testing with eyes open and closed. The patient often tends to fall or list to the side of lesion.

Investigations

Magnetic resonance imaging (MRI) with gadolinium enhancement is the investigation of choice when available. Even small intracanalicular tumours (< 4mm) can be identified. The lateral extension of a tumour can be assessed by this method as this might affect surgical planning for the consideration of a hearing preservation procedure.

Alternatively high resolution computerized tomography (CT) with contrast can pick up slightly larger tumours approximately 1-1.5 cms in size. Brain stem evoked response audiometry (BSERA) can be a useful tool in diagnosis of vestibular schwannomas. The brain stem response is recorded as the ears are exposed to clicking noises. The wave patterns seen can be compared with the normal side. Should there be a significant interaural delay or abnormal waveform morphology this would be highly suggestive for a retrocochlear lesion. Unfortunately this test does not have a high sensitivity and specificity especially for small tumours. Another problem with this test is its difficulty in obtaining good electrical responses should the hearing loss be more than 70 decibels at 2 kHz.

Although caloric testing does not have a great diagnostic value it is an important preoperative investigation to assess any balance loss especially on the contralateral side.

Management

This falls into three main categories: conservative management, radiotherapy and microsurgical removal.

With the advent of highly sensitive imaging such as MRI scanning several authors have reported a valuable role for the conservative management of small tumours should hearing preservation not be of concern[2]. In one study Walsh et al showed that of 72 patients managed conservatively over three years the average growth rate was approximately 1.4mm/year. Over 80% grew less than 2mm/year. In another study Nedzelski et al showed the average growth to be 1.1 mm/year. In this same study it was suggested that some form of active management should be considered when the growth rate is greater than 2mm/year.

Conservative management in general has a role to play for small tumours, tumour involvement in an only hearing ear, advanced age, poor general health and in Neurofibromatosis type II [2]. A MRI should be performed at six months then on a yearly basis. The advantage of conservative management is avoidance of all the complications associated with active treatment. The disadvantage would be the risk of rapid growth making the surgical result poorer as far as hearing preservation and facial nerve function is concerned.

Stereotactic (gamma knife or LINAC) radiosurgery is becoming a popular method for management of small to medium size tumours in some centers. The main advantage of radiosurgery is that the preservation of facial nerve function is almost 100% with a 13-Gy tumour margin dose[3]. Hearing (not necessarily useful or aidable) can be preserved only in about 60% of the patients. The main concern about radiosurgery focuses on the possibility of a delayed malignant transformation which has been reported in 1 in 1000 cases over 5-30 years[3]. Other complications include treatment

failure (2-7%), trigeminal neuropathy (3-8%), and a communicating hydrocephalus (5%) (From protein deposition in the arachnoid granulations) which requires shunting. There is definitely a place however for radiosurgery especially in elderly patients with small to moderate size tumours.

Microsurgical removal can be achieved by translabyrinthine, retrosigmoid (suboccipital) and middle fossa approaches. All surgical approaches have associated complications. Despite advances in microsurgical techniques and intraoperative monitoring the mortality rate has been reported between 0.5-3 percent [1]. Other complications include facial nerve palsy depending on the size of tumour, meningitis 3-8%, CSF leak 10-15% and rarely lower cranial nerve palsies [1].

Translabyrinthine Approach

This is the most widely used approach for VS removal and represents the most direct route to the CPA. The advantages of this approach are a wide exposure of the CPA and the contents of the IAM, it has the highest rate of facial nerve preservation overall and there is the least amount of retraction required on the cerebellum during tumour removal. The disadvantage of this approach however is the expected total loss of hearing and balance on the operated side.

Retrosigmoid (suboccipital) Approach

This approach offers the possibility for the preservation of hearing and gives a wide exposure for tumour removal. There is however the disadvantage of cerebellar retraction, the facial nerve is not identified typically at the fundus and there is intradural drilling within the CPA.

Middle Fossa Approach

In this approach there is the potential for hearing preservation. It is useful for small tumours only as there is considerable temporal lobe retraction required at times.

Neurofibromatosis

Von Recklinghausen was first to describe this syndrome. However it was not until recently with advances in genetics that two distinct syndromes were described.

Neurofibromatosis type I (von Recklinghausen's disease) is an autosomal dominant disorder with an identifiable defect on chromosome 17q. It is characterized by café-au-lait skin lesions, skin neurofibromas, iris hamartomas (Lisch nodules), axillary or inguinal freckling, sphenoid dysplasia and optic gliomas - two or more of these signs are required for a clinical diagnosis. There is no increase in the incidence of acoustic neuromas in these patients.

Neurofibromatosis type II (NF2) is also an autosomal dominant disorder with a defect on chromosome 22q. It is characterized by either bilateral acoustic neuromas or a family history of NF2 with one of the following lesions; unilateral acoustic neuroma, meningioma, glioma, neuroma or a posterior capsular cataract. In NF2 patients develop acoustic neuromas at an early age due to defects in the tumour

suppressor gene. Two phenotypes have been described; the milder type with isolated bilateral acoustic neuromas (Gardner and Frazier) and a more aggressive type with multiple cranial nerve and spinal neuromas (Wishart).

Meningioma

Meningiomas are one of the most common benign intracranial tumours. They represent 10-15% of all intracranial tumours and 3% of all cerebellopontine angle (CPA) tumours. Meningiomas have been identified in 2.3% of autopsy studies[9]. In the CPA they commonly arise from the posterior petrous bone, tentorium cerebelli, clivus, cerebellar convexity and foramen magnum[8]. Meningiomas arising from tentorium cerebelli comprise approximately 3-6% of all intracranial meningiomas.

Histology
They are generally divided into syncytial, transitional, fibrous, angioblastic and sarcomatous types[6].

Signs/Symptoms
CPA meningiomas have a very similar presentation to acoustic neuromas. Audiovestibular symptoms include tinnitus, hearing loss and imbalance. Large meningiomas can cause trigeminal symptoms and may lead to hydrocephalus.

Investigation
Auditory investigations cannot distinguish acoustics from meningiomas. The best imaging investigation is an MRI with gadolinium enhancement.
Factors which help to distinguish meningiomas on the MRI scan from acoustic neuromas include its location (eccentric to porous), the bone/ tumour angle (obtuse angle), its attachment (broad) and shape (hemispherical). Other features include occasional hyperostosis of the adjacent bone and tumour calcification.

Management
Asymptomatic tumours can be monitored with serial MRI scans although the growth rate might change over time. The growth rate seems to be higher in younger patients[10].
Microsurgical removal is the standard treatment. Similar approaches are used for CPA meningiomas as for acoustic neuromas.

Arachnoid Cyst

An arachnoid cyst in the cerebellopontine angle may present with similar symptoms as an acoustic neuroma. They represent about 1% of all intracranial masses and seem to be 4x's as common in males. They consist of thin walled sacs filled with CSF. On MRI scanning they look very similar to epidermoids. On T1 images they are iso-intense to brain tissue and on T2, hyper-intense.

Management

There is no need for complete excision of these lesions. Symptomatic cysts can be drained via a retrolabyrinthine approach. Recurrences are not uncommon.

Primary Cholesteatomas (Epidermoids)

Primary cholesteatomas or epidermoids of the CPA are thought to originate from mixed epithelial congenital nests in the temporal bone and CPA. They are slow growing tumours and usually present late in the third or forth decade of life.

Histology

Primary epidermoids are epithelial lined sacs that enlarge with keratin production. They invade surrounding tissue in areas of least resistance and as such have an irregular surface.

Signs/Symptoms

CPA epidermoids can lead to similar audio-vestibular symptoms but they are more likely to cause facial twitching and a progressive facial palsy.

Investigations

Auditory investigations cannot distinguish these tumours from other CPA lesions. Standard investigations include CT and MRI scans. On CT scanning cholesteatoma is irregular, doesn't enhance and appears eccentric to the IAM.
On an MRI scan they have a similar signal to acoustic neuromas but do not enhance and are more irregular. In this way they can be distinguished from arachnoid cysts which have smooth surface.

Management

Microsurgical removal is the standard treatment when required.

Facial nerve Neuroma (Schwannoma)

Schwannomas of the facial nerve can arise from any part of the facial nerve including its origin in the CPA to its branches in the parotid gland. Facial nerve schwannomas represents only about 1% of all CPA tumours[11].

Histology

They are identical to vestibular schwannomas.

Signs/Symptoms

Depending on the site and size of a facial neuroma within the CPA these tumours give rise to similar audio-vestibular symptoms as an acoustic neuroma. If there is preoperative facial weakness or a history of recurrent facial paralysis then the possibility of facial neuroma must be considered and discussed with the patient. In its tympanic part it may give rise to a conductive loss while in peripheral cases it might present with a parotid mass.

Investigations

Auditory investigations cannot distinguish these tumours from other CPA lesions. The impedance test however might show an absent ipsilateral reflex. Electroneuronography (ENOG) can be useful when a preoperative suspicion exists that a facial nerve schwannoma might be present. ENOG measures the muscle response to a maximum electrical stimulation near stylomastoid foramen[13].On MRI scanning the findings are almost identical to acoustic neuromas. There might be involvement however of the labyrinthine portion or enlargement of the fallopian canal on the more distal located tumours. High resolution CT scan (1.0-1.5 mm cuts) can be used to look at the bone surrounding the labyrinthine, geniculate ganglion, tympanic and vertical segments of the nerve[12].

Management

Microsurgical removal is the standard treatment followed by primary anastomosis or cable nerve grafting. Few authors have described enucleation with fascicle preservation which supposedly provides better postoperative facial function[11].

Glomus Tumours (Paragangliomas)

Glomus tumours arise from paraganglionic cells which are derived embryologically from neural crest cells. They are typically divided into adrenal (pheochromocytomas) and extra-adrenal. For extra-adrenal tumours, the carotid body tumour appears the most common, with a higher incidence in the people living above 2000 meters[14]. Jugulotympanic and vagal paragangliomas are the next most common and can extend

into the cerebellopontine angle and erode the skull base. Extra adrenal tumours are rarely functional (i.e. producing catecholamines). Patients with headache, excessive sweating, and palpitations however should be investigated for urine nor-epinephrine metabolites (vanillylmandelic acid and metanephrine). Malignancy has been reported in paragangliomas with distance metastasis. This is very rare and more often the tumours are multicentric.

Histology

Microscopy shows a typical neoplastic collection of cells (Zellballen) with numerous eosinophilic cytoplasmic granules and uniform round nuclei, surrounded by sustentacular cells which do not contain granules[15].

Signs/Symptoms

Symptoms depend primarily on the site of the tumour. Jugulotympanic and vagal paragangliomas present with pulsatile tinnitus, a conductive hearing loss and often lower cranial nerve palsies. Tumours involving the cerebellopontine angle may give rise to similar symptoms as found in acoustic neuromas.

Investigations

A CT scan will show destruction of bone in contrast to smooth expansion of the jugular foramen in schwannomas.

The MRI scan shows a typical salt and pepper mixture of intensities on T1 and T2 sequences.

Angiography may show a Lyre's sign (splaying of carotid bifurcation) and is useful in assessing the vascular supply of the tumour should pre-operative embolization be a consideration.

Temporary balloon occlusion of the carotid artery might be useful to estimate the collateral circulation.

Management

Surgery: Small glomus tympanicum tumours with all borders visible are usually removed by a transcanal approach. If all the borders are not visible and the tumour is still not involving the jugular bulb then a combined procedure with an extended facial recess approach can be used.
Larger tumours involving the base of skull are approached by an infratemporal fossa approach. Tumours with intracranial extension require a multidisciplinary team approach for removal and reconstruction.

The key to successful surgery in these tumours is securing the facial nerve and the internal carotid artery[16]. If the lower cranial nerves have been sacrificed then early rehabilitation is very important. This might include tracheostomy, gastrostomy, eye care and phonosurgery.

Radiotherapy: There is a great debate about role of radiotherapy in the management of glomus tumours. It is generally agreed that it should not be used in the younger patients because of the potential for malignant transformation.

Cholesterol Granuloma

Cholesterol granulomas are the most common lesions of the petrous apex. Their etiology is not clear though various theories exist. The obstruction-vacuum hypothesis implies that blockage of air cells with subsequent negative pressure will lead to hyperemia and bleeding. An alternative theory proposed by Jackler and Cho suggests that the blood originates from areas of exposed marrow[17]. In either case blood products such as cholesterol, fibrin and hemosiderin will lead to a foreign body granulomatous reaction. The new blood vessels will in turn cause more bleeding with the cycle repeating itself, which results in expansion of the lesion.

Histology

Histology consists of a granulomatous reaction to the cholesterol crystals. Cholesterol clefts are surrounded by giant cells, fibrosis and hemosiderin laden macrophages[18].

Signs/Symptoms

Symptoms and signs depend on the location and size of the lesion. Retrocochlear symptoms include hearing loss, tinnitus and dizziness. Involvement of the middle fossa dura may cause headaches as well as trigeminal (V) and abducens (VI) nerve palsies. Blockage of the eustachian tube can lead to serous otitis media. Small lesions might be entirely asymptomatic.

Investigations

The CT scan usually demonstrates a punched out lesion. The CT is important especially for planning the surgical approach as it will clearly show the relation of the lesion with the major vascular structures.

The MRI scan is important to distinguish cholesterol granulomas from other petrous apex lesions i.e. cholesteatoma, chondroma, petrous apicitis, carotid aneurysm, meningioma, schwannoma and metastatic tumours[19]. Cholesterol granulomas are typically hyper intense on T1 and T2 images and do not enhance with gadolinium enhancement.

Management

Small asymptomatic tumours can be observed on serial MRI scans. Larger tumours will need active surgical drainage. The surgical approach depends on the patient's hearing. In hearing preservation procedures the tumour can be drained via infracochlear or infralabyrinthine approaches. If there is no serviceable hearing then a translabyrinthine approach would be preferable.

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