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Review Article

Anterior fossa meningiomas: a review of the clinical features and management

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Abstract

Anterior cranial fossa meningiomas constitute an important subset of skull base tumors, frequently presenting late due to their indolent growth and the capacity of the frontal lobes to accommodate large masses before neurological symptoms emerge. This review synthesizes current evidence regarding epidemiology, molecular biology, clinical features, diagnostic considerations, and modern management strategies for olfactory groove, planum sphenoidale, and tuberculum sellae meningiomas. We examine more than 150 published studies, integrating contemporary molecular insights—including NF2 and non-NF2 mutations (TRAF7, AKT1, KLF4, PIK3CA, SMO)—with evolving surgical approaches such as endoscopic endonasal surgery, keyhole craniotomies, and extended skull base techniques. We further evaluate visual and neurocognitive outcomes, complication profiles, recurrence predictors, and long-term prognosis. Anterior cranial fossa meningiomas, although often benign, present unique operative challenges due to involvement of the optic apparatus, olfactory structures, and major vascular systems. Gross total resection remains the standard of care but is increasingly complemented by tailored approaches based on radiological anatomy, tumor consistency, vascular encasement, and patient comorbidities. This review aims to provide neurosurgeons, skull base surgeons, and trainees with a comprehensive, evidence-based reference for best practices in managing anterior fossa meningiomas.

Introduction

Meningiomas are the most common intracranial tumor, accounting for about 32% of all intracranial neoplasms. These tumors can be found in all age groups; however, they are rare in childhood, accounting for 1% of all childhood intracranial tumors. They are more commonly seen in females than males, with a ratio of 2:1. The reason for this distribution is poorly understood but has been associated with progesterone promoting the growth of the tumors (1).

Meningiomas were in the past believed to arise from the dura mater; however, pathological studies challenged this theory. Meningiomas arise from arachnoid cap cells embedded in the arachnoid villi (1,2). This means that meningiomas can be seen in any location with arachnoid cells, including the ventricles.

Meningioma risk and number of lesions have been associated with genetic abnormalities. Yuzawa et al. looked at the genetics of meningiomas and found that NF2 aberration was observed in 55 % of meningiomas. However, this is a classic and well-established relationship in neurosurgery. In the study Yuzawa et al. mutations of TRAF7, AKT1, KLF4, PIK3CA, and SMO were identified in 20, 9, 9, 4.5, and 3 % of cases, respectively.

And they found that Clinicopathologically, tumors with mutations in TRAF7/AKT1 and SMO shared specific features: they were located in the anterior fossa, median middle fossa, or anterior calvarium, and most of them were meningothelial or transitional meningiomas (2).

Anterior fossa meningiomas are classified according to their attachment. According to the site of attachment, the most common meningiomas of the anterior cranial fossa are classified into olfactory groove, planum sphenoidale, and tuberculum sellae meningiomas (3). In clinical practice these tumors are considered as a continuum with unclear boundaries (4).

Clinical features

The anterior cranial fossa meningiomas usually grow to very large sizes prior to diagnosis and may occupy a large portion of the anterior fossa. This is especially seen in the anteriorly located tumors (olfactory groove and planum sphenoidale) (4). In a study of 99 cases by Pallini et al., overall, the mean tumor size was 5.4 cm. Meningioma size was small (3 cm) in 15 of 99 cases (15.2%), medium (3-6 cm) in 33 of 99 (33.3%), and large (6 cm) in 51 of 99 (51.5%) of cases (5). These tumors are slow growing. They maybe asymptomatic or cause slowly progressive worsening of symptoms. This leads to a delay in diagnosis and large size of these lesions at diagnosis.

In 1911, Dr. Foster Kennedy described a clinical syndrome which, when present, is almost diagnostic: “a speedy reduction in ipsilateral acuity of vision due to ipsilateral compression neuritis of the optic nerve lying below the frontal lobe, coincident with papilledema and normal vision of the opposite eye. From compression of the olfactory tract there is usually under these circumstances’ anosmia on the same side on which retrobulbar neuritis and the primary optic atrophy have occurred.” (6)

This syndrome has also been described in cases of other subfrontal masses such as craniopharyngioma, pituitary adenoma, and similar lesions (7). Cases of pseudo–Foster Kennedy syndrome have also been reported, in which optic atrophy and contralateral papilledema occur without an intracranial mass (8). Foster Kennedy syndrome has been reported in approximately 1% to 5% of cases (4,7).

Given the higher functions of the frontal lobe, it is not uncommon to see psychiatric and personality changes associated with frontal lobe lesions. Mental changes are the primary presenting features of these tumors in about 20-70% (4). The psychiatric signs and symptoms seen can range from mood symptoms, psychosis, memory issues, personality changes, anxiety to anorexia nervosa (9, 4). Tumor location is a major determinant in the presenting signs and symptoms. A tumor in the dorsolateral prefrontal region typically leads to deficits in executive function and a tumor in the orbitofrontal region leads to disinhibition. Similarly, a medial-frontal region tumor may lead to apathy or abulia and temporal-limbic tumors may present with psychosis (10). Some authors have suggested that failure of response of medical treatment in a patient presenting in the psychiatric department should prompt radiological investigations to look for an anterior fossa lesion (11). In cases of large tumors, secondary parkinsonism has been reported due to compression on the basal ganglia (12)

Refaat et al. found that headache is the most common presenting feature (70%) followed by visual symptoms (60%) (13). Preoperative visual symptoms are very common especially meningiomas of the planum sphenoidale and tuberculum sella region. The close proximity of the optic nerves and chiasm in this region makes them prone to compression producing a variety of visual deficits.

Other symptoms associated with anterior fossa meningiomas include anosmia, seizures (seen in about 10-20% of patients) (13, 5) and rarely hormonal abnormalities. The intimate relationship between large midline anterior fossa meningiomas and the olfactory tract may lead to anosmia due to direct compression. Anosmia may also present as a result of damage to the olfactory tract intraoperatively. In a study by Pallini et al anosmia was the most common symptom in 59.6%. (5)

Management and complications

Direct surgical excision of the tumor is the only treatment for these tumors. These tumors are intimately associated with the surrounding structures like the olfactory tracts with olfactory groove meningiomas and the carotid artery, anterior cerebral artery and its branches, optic nerves and chiasm with the tuberculum sella and planum sphenoidale tumors. Hence the main goal of surgical management of the tumors is maximal possible resection with the least risk to the neural structures and minimal morbidity. With recent advances in surgical technology such as preoperative imaging, neuro-monitoring, and microsurgical instruments and techniques, the surgical resectability of intracranial meningioma has increased markedly over the last two decades (15). This has led to improved outcomes. The surgical method is dependent on the size of the tumor, location and extension (13). As a preoperative MRI, CT and angiography are invaluable in choosing the approach (3). Commonly used techniques for the management of anterior fossa meningiomas include bifrontal, frontotemporal (pterional), supraorbital and more recently, endoscopic methods (4, 3). The reported gross total resection rates in literature are around 90% for each approach (15). These approaches have been compared by various authors.

Transnasal

The extended transnasal approach is a newer method to manage these tumors once thought to be manageable only transcranially. This method is useful for midline lesions especially those involving the sella region. The Enrico et al. looked at the endonasal approach and concluded that the technique offers a minimally invasive

route to the midline anterior skull base, avoids brain retraction and injury, and reduces manipulation of main vessels and hemorrhagic events. This method allows for early decompression of the optic nerves and chiasm and reduces manipulation and injury to the optic apparatus (16). However, this approach is associated with a high risk of cerebrospinal fluid leak and has been reported in about 40% of patients by some authors (16, 3, 17). This technique is not recommended for tumors >40mm in diameter, calcifications and absence of cortical vascular cuff (15).

Supraorbital

The supraorbital approach is also known as the eyebrow approach. The skin incision is made in the lateral two thirds of the eyebrow. This is a minimally invasive approach as the incision is very small and in selected cases it minimizes the need for excessive brain retraction while offering acceptable total resection rates. Reisch and Perneczky used this method to manage 93 anterior fossa meningiomas with 80.2% resulting in complete resection in a piecemeal fashion regardless of their size (18, 19). This result is similar to resection rates seen with other approaches. This method is not recommended for large tumors more than 5cm or in cases of severe frontal lobe edema. As long as the frontal air sinus is not violated, the risk of postoperative cerebrospinal fluid leak is almost none. In cases of violated sinus, it has to be meticulously repaired. In the event of ethmoid bone erosion and sinus penetration, the supraorbital approach is not recommended as reconstruction is very challenging. Damage to the supraorbital nerve and temporal branch of the facial nerve has been reported as a common complication especially in cases of incorrect skin incision and excessive traction of the skin.

Sub-frontal

Sub-frontal approaches are commonly used for more anteriorly located lesions. This includes the unilateral and bifrontal craniotomy. Bifrontal craniotomy is considered by some authors as the "work horse" of anterior fossa meningiomas. The technique is relatively straight forward and many neurosurgeons are familiar with the intraoperative view. The bifrontal craniotomy is used with lesions crossing the midline, large lesions and when there is need for anterior fossa floor repair. This method has the least risk of excessive brain retraction due to the generous exposure. This approach allows for early devascularization the meningiomas as the feeding arteries which in these tumors commonly include the anterior and posterior ethmoidal arteries are visualized early. However, the main disadvantage of this method is that the important distally located structures like optic nerves, chiasm and carotid arteries are visualized late. The wide opening of the air frontal sinuses bilaterally increases the risk of cerebrospinal fluid leak (4, 3). The risk described in literature ranges from about 5 to 15% (20, 21, 22). For lesions more prominent unilaterally, the unilateral frontal craniotomy can be performed. This spares the superior sagittal sinus but the risk of cerebrospinal spinal leak associated with opening the frontal air sinus is not different from the bifrontal craniotomy. For large tumors, it is associated with high risk of brain retraction. The effects of excessive brain retraction have been described (23). Modifications have been made to the sub-frontal approaches to minimize excessive retraction to the brain.

Pterional

The pterional approach is one of the most commonly used approaches in neurosurgery. It is known as the work horse of neurosurgery. Its importance in the management of anterior fossa meningiomas cannot be overemphasized. Unless

the tumor is predominantly protruding to the left or encasing the left ICA the right side is usually approached. This approach offers the shortest distance to the tumor and parasellar region while allowing the surgeon early visualization of the important structures in this region like the carotid artery and its branches (4, 3). This is a very important step in the resection of anterior fossa meningiomas as it reduces the risk of damage to these structures reducing the morbidity and mortality. Another added advantage to using this approach is the early opening of the cerebrospinal fluid cisterns. This allows for brain relaxation which is an invaluable step especially when dealing with very large tumors in the anterior fossa. This will in turn reduce the need for excessive brain manipulation and retraction minimizing the associated brain injury (4). The risk of cerebrospinal leak in the pterional approach is very low as the frontal air sinuses are not violated (3). Although the pterional approach offers a lot of advantages, it has its own limitations. The working angle is narrow as compared to other approaches. This may reduce the visibility of high riding olfactory groove meningiomas where the superior part of the tumor may not be visible. In these cases, there is risk of excessive retraction on the frontal lobes. In cases involving a meningioma crossing the midline to affect the contralateral side as commonly seen with midline tumors, the operative corridor maybe long via the pterional approach. A study by Andrej et al concluded that the pterional approach is comparable and may actually be superior to the sub-frontal approaches for olfactory groove meningiomas (24).

Modifications have been made to the pterional approach to include removal of the supraorbital rim, part of the roof, and lateral wall of the orbit as well as a portion of the zygoma. This fronto-orbito-zygomatic approach is useful for more basal exposure when needed.

Conclusion

Anterior cranial fossa meningiomas represent a surgically demanding group of skull base tumors due to their proximity to critical neurovascular structures and the need to preserve olfaction and visual pathways. Advances in skull base anatomy, microsurgical techniques, endoscopy, and neuro-navigation have improved gross total resection rates while minimizing morbidity. Contemporary management requires a personalized approach integrating tumor biology, molecular markers, anatomical complexity, patient comorbidities, and surgeon expertise. Continued evolution in minimally invasive techniques and molecular-targeted therapies promises to further improve outcomes.

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