Introduction

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The surgical treatment of meningiomas located at the base of the anterior cranial fossa continues to pose a big challenge to neurosurgeons despite that over the past century, many advances have taken place in both the treatment and the biological understanding of these lesions. The introduction of the microsurgical technique and the development of skull base approaches has allowed surgeons to achieve a better treatment, a big improvement in the outcome, and a higher cure rate of these tumors and was well founded in principle and proven beneficial in practice [1].

Once again in the history of modern neurosurgery, we must thank Harvey Cushing who made significant contribution in the understanding and treatment of meningiomas in general but particularly those involving the anterior cranial base, following early reports of prominent figures such as Sir William MacEwen and Francesco Durante, who were first to perform successful operations to treat these tumors [2–5].

Meningioma's cell of origin is supposed to be the arachnoid cap cell, and these tumors are listed under the heading "Tumors of the Meninges" and the subheading "Tumors of the Meningothelial Cells" in the *WHO classification* that are classified anaplastic, papillary, and rhabdoid as Grade III meningiomas; atypical, chondroid, and clear cell types as Grade II; and all the other variants as Grade I [6].

Today, it appears that cytogenetic analysis is a very important predictor of an aggressive meningioma. A normal karyotype is associated with a lower recurrence rate and slower growth being monosomy of chromosome 22 which is a frequent finding in benign meningiomas. The deletion of chromosome 1p or 14q has been definitively associated with a higher-grade meningioma and a more aggressive biology. One more prognostic factor could be the expression of TRF1 which is heterogeneously expressed in meningiomas [7–10]. Despite these considerations and because of their easy determination on fixed specimens, a high K_i-67 labeling index, or a lack of progesterone receptors, is considered a useful indicator in determining the aggressiveness of meningiomas.

Based on the site of dural attachment, even the most recent classifications, one above all of the *Al-Mefty classifications* of meningiomas is based on the following principles: convexity, parasagittal, falx, tentorial, peritorcular, falcotentorial, olfactory groove, tuberculum sellae, lateral and middle sphenoid wing, clinoidal, cavernous sinus, sphenoorbital, cerebellar convexity, cerebellopontine angle, clival and petroclival, temporal bone, foramen magnum, lateral and fourth

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ventricles, third ventricle and pineal region, middle fossa floor [1].

Meningiomas of the anterior cranial fossa represent 12–20 % of all intracranial meningiomas. They are classified into *olfactory groove*, *planum sphenoidale*, *tuberculum sellae*, and *diaphragma sellae meningiomas*, according to the site of attachment, each of them with few distinct clinical features. However, despite that the original site of attachment may differ, we can consider this group of tumors as an unique entity that grows in an area where the brain has a high compliance, thus allowing these tumors to reach large sizes at the time of diagnosis and occupying a significant portion of the anterior cranial fossa [11, 12]. This characteristic, their slow growth, and subfrontal location give often to anterior cranial fossa meningiomas an insidious presentation. Especially for the olfactory groove and planum sphenoidale types, one of the most common symptoms is the change in personality, judgment, or motivation noted by family members or close contacts with headache, visual disturbance, or lack of smell occurring only late in the course of the disease. Working with prominent figures such as Sir William Gowers and Sir Victor Horsley at the National Hospital in Queen's Square in London, Dr. Robert Foster Kennedy made a significant contribution, recognizing a common clinical presentation of space-occupying lesions located in the frontal lobe known as "Foster Kennedy syndrome" (optic atrophy in the ipsilateral eye, papilledema in the contralateral eye, central scotoma in ipsilateral eye, anosmia, nausea and vomiting, memory loss, and emotional lability), during a time when imaging modalities were not widely available [13]. With earlier diagnosis achieved thanks to modern imaging, the Foster Kennedy syndrome is only seen in a minority of patients. Visual impairment is among the primary symptoms of patients with meningiomas of the anterior cranial fossa, especially those located in the tuberculum sellae and diaphragma. Because of the growth pattern of olfactory groove meningiomas and planum sphenoidale ones, these tumors may extend posteriorly and inferiorly compressing the optic nerves and causing an inferior visual field deficit. In contrast due to their location close to the visual pathways, tuberculum sellae meningiomas produce a bitemporal visual field defect caused by elevation and compression of the optic chiasm.

Historically, meningiomas were characterized by plain roentgenograms and conventional diagnostic angiography, but the introduction of computed tomography and the magnetic resonance imaging dramatically increased detection and accuracy of the diagnosis. Recent years have witnessed the development of advanced imaging techniques, such as MR spectroscopy, MR perfusion, indium-111-octreotide scintigraphy, and PET. Anyway, despite their usefulness in certain clinical scenarios, these newer tools remain peripheral at present and serve only as adjuncts to CT and routine MRI sequences [14].

Initially, large-sized unilateral or bilateral craniotomies were necessary to approach these deep-seated lesions. Technical advances such as the introduction of electrosurgery, the operating microscope, the cavitron ultrasound aspirator, and refined microsurgical instruments allowed neurosurgeons to perform less invasive surgical procedures with better results. Today, a wide variety of surgical strategies, including endoscopic surgery and radiosurgery, are used to treat these tumors [15].

Since the initial experience of the pioneering neurosurgeons, multiple advances have improved the safeness and the effectiveness of treatment of meningiomas. Starting with the unilateral frontal craniotomy performed by Cushing and evolved to a bifrontal craniotomy and a transbasal approach, due to the efforts of Dandy [16], we arrived to the Tonnis experience with the bifrontal approach preserving the brain tissue, which was followed later by multiple surgeons. The introduction of the operating microscope in the 1970s was a milestone in the removal of these neoplasms. The unilateral and bifrontal craniotomies have been further modified, and currently, some craniofacial approaches are used to treat tumors invading the nasal cavity and/or paranasal sinuses. The endoscope, which has been available for a long time for the treatment of other neurosurgical entities, was introduced recently in the treatment of anterior cranial fossa meningiomas and is acquiring

more advocates as supporting evidence becomes available.

Nowadays, several approaches have been described to remove anterior cranial fossa meningiomas. Large tumors are often approached with a subfrontal approach with a bilateral or monolateral craniotomy [17, 18]. The pterional approach was popularized by Yasargil and since then largely used with his variations like the fronto-orbitozygomatic one [19, 20]. With the concept of minimally invasive neurosurgery and the development of modern neuroimaging techniques, neurosurgeons gained the possibility of a proper characterization of brain tumors and their relation to surrounding structures. This characterization is helpful in presurgical planning and in the intraoperative setting and makes it possible to approach deep-seated lesions through very small openings like the supraorbital "keyhole" craniotomy described by Perneczky and colleagues or the mini-pterional approach [21–23]. The introduction of the endoscope to the realm of neurosurgery led to successful treatment of deep-seated lesions without brain retraction. To gain access to the anterior skull base, the endoscope can be used via a low route, like in the extended endonasal approach, or via a high route using a small supraorbital craniotomy [24–28]. The extended endoscopic endonasal approach for the treatment of anterior cranial fossa meningiomas is relatively new and has been increasingly reported during the last decade, with significant contributions from different groups.

In its general principles, the ideal surgical approach should provide enough exposure of the tumor, including its dural attachment, to interrupt its blood supply early in the procedure. In addition, brain retraction and manipulation of critical neurovascular structures should be minimized as much as possible to avoid procedure-related morbidity. Sufficient access to the skull base is also desirable in cases in which bone resection and subsequent cranial base reconstruction are necessary. The selection of the most appropriate approach depends on multiple factors, including surgeon's preference and experience, tumor size and location, extent of dural attachment, and relation with the surrounding neurovascular structures [29].

Since 1957 when *Simpson* published his famous article correlating the extent of resection with the subsequent recurrence risk, neurosurgery gained a useful tool to predict the prognosis after the surgery of patients with meningiomas. His scale indicates *five grades of removal*: (I) macroscopically complete removal of tumor, with excision of its dural attachment, and of any abnormal bone including resection of venous sinus if involved; (II) macroscopically complete removal of tumor and its visible extensions with coagulation of its dural attachment; (III) macroscopically complete removal of the intradural tumor, without resection or coagulation of its dural attachment or its extradural extensions; (IV) partial removal, leaving intradural tumor in situ; and (V) simple decompression, with or without biopsy [30].

Nonsurgical therapies are used for recurrent or incompletely resected anterior cranial base meningiomas. Standard or stereotactic irradiation has been used.

According to Guthrie and associates conclusions, surgical excision is the treatment of choice, and radiotherapy should be considered after surgery (1) for a malignant meningioma, (2) following an incomplete resection of a meningioma whose risk of resection of an eventual recurrence is judged to be excessive, (3) for patients with multiple recurrent tumors for whom the surgeon judges repeat surgery to be too risky, and (4) as a sole therapy of a progressively symptomatic patient with a meningioma judged by the surgeon inoperable [31].

Bibliography

1. De Monte F, Mc Dermott MW, Al-Mefty O (2011) Al Mefty's meningiomas. Thieme, New York, pp 4–11
2. Cushing H (1938) Meningiomas, their classification, regional behaviour, life history and surgical end results. Charles C Thomas, Springfield
3. Durante F (1887) Contribution to endocranial surgery. Lancet 130:654–655
4. Durante F (1902) Observations on certain cerebral localizations. Br Med J 2:1822–1825
5. Macewen W (1881) Intra-cranial lesions: illustrating some points in connection with the localization of cerebral affections and the advantages of antiseptic trephining. Lancet 2:581–583

6. Louis DN, Ohgaki H, Wiestler OD et al (2007) WHO classification of tumors of the central nervous system. In: Bosman FT, Jaffe ES, Lakhani SR et al (eds) World Health Organization classification of tumors, 4th edn. International Agency for Research on Cancer, Lyon, p 309

7. Aragona M, De Divitiis O, La Torre D, Panetta S, D'Avella D, Pontoriero A, Morelli M, La Torre I, Tomasello F (2001) Immunohistochemical TRF1 expression in human primary intracranial tumors. Anticancer Res 21(3C):2135–2139

8. La Torre D, de Divitiis O, Conti A, Angileri FF, Cardali S, Aguennouz M, Aragona M, Panetta S, d'Avella D, Vita G, La Torre F, Tomasello F (2005) Expression of telomeric repeat binding factor-1 in astroglial brain tumors. Neurosurgery 56(4):802–810

9. Kane AJ, Sughrue ME, Rutkowski MJ, Shangari G, Fang S, McDermott MW, Berger MS, Parsa AT (2011) Anatomic location is a risk factor for atypical and malignant meningiomas. Cancer 117(6):1272–1278

10. Barbera S, San Miguel T, Gil-Benso R, Muñoz-Hidalgo L, Roldan P, Gonzalez-Darder J, Cerda-Nicolas M, Lopez-Gines C (2013) Genetic changes with prognostic value in histologically benign meningiomas. Clin Neuropathol 32(4):311–317

11. Rubin G, Ben David U, Gornish M, Rappaport ZH (1994) Meningiomas of the anterior cranial fossa floor. Review of 67 cases. Acta Neurochir (Wien) 129:26–30

12. Tuna H, Bozkurt M, Ayten M, Erdogan A, Deda H (2005) Olfactory groove meningiomas. J Clin Neurosci 12:664–668

13. Kennedy F (1911) Retrobulbar neuritis as an exact diagnostic sign of certain tumors and abscesses in the frontal lobes. Am J Med Sci 142:355–368

14. Okonkwo DO, Laws ER Jr (2008) Meningiomas: historical perspective. In: Lee JH (ed) Meningiomas: diagnostic treatment and outcome. Springer, London, pp 3–14

15. Pia HW (1972) The microscope in neurosurgery—technical improvements. Acta Neurochir (Wien) 26:251–255

16. Cushing H (1927) The meningiomas arising from the olfactory groove and their removal by the aid of electro-surgery. Jackson, Wylie & Co, Glasgow

17. Nakamura M, Struck M, Roser F, Vorkapic P, Samii M (2008) Olfactory groove meningiomas: clinical outcome and recurrence rates after tumor removal through the frontolateral and bifrontal approach. Neurosurgery 62(6 Suppl 3):1224–1232

18. Persing JA, Jane JA, Levine PA, Cantrell RW (1990) The versatile frontal sinus approach to the floor of the anterior cranial fossa. Technical note. J Neurosurg 72:513–516

19. Hassler W, Zentner J (1989) Pterional approach for surgical treatment of olfactory groove meningiomas. Neurosurgery 25:942–947

20. Tomasello F, Angileri FF, Grasso G, Granata F, De Ponte FS, Alafaci C (2011) Giant olfactory groove meningiomas: extent of frontal lobes damage and long-term outcome after the pterional approach. World Neurosurg 76:311–317

21. Perneczky A, Müller-Forell W, van Lindert E, Fries G (1999) Keyhole concept in neurosurgery. Thieme Medical Publishers, Stuttgart

22. Reisch R, Perneczky A (2005) Ten-year experience with the supra-orbital subfrontal approach through an eyebrow skin incision. Neurosurgery 57(4 Suppl):242–255

23. de Divitiis E, Esposito F, Cappabianca P, Cavallo LM, de Divitiis O (2008) Tuberculum sellae meningiomas: high route or low route? A series of 51 consecutive cases. Neurosurgery 62(3):556–563, discussion 556–63

24. Gardner PA, Kassam AB, Thomas A, Snyderman CH, Carrau RL, Mintz AH et al (2008) Endoscopic endonasal resection of anterior cranial base meningiomas. Neurosurgery 63:36–54

25. Schwartz TH, Fraser JF, Brown S, Tabaee A, Kacker A, Anand VK (2008) Endoscopic cranial base surgery: classification of operative approaches. Neurosurgery 62:991–1005

26. Van Gompel JJ, Frank G, Pasquini E, Zoli M, Hoover J, Lan-zino G (2011) Expanded endonasal endoscopic resection of anterior fossa meningiomas: report of 13 cases and meta-analysis of the literature. Neurosurg Focus 30(5):E15

27. Webb-Myers R, Wormald PJ, Brophy B (2008) An endoscopic endonasal technique for resection of olfactory groove meningioma. J Clin Neurosci 15:451–455

28. Spektor S, Valarezo J, Fliss DM, Gil Z, Cohen J, Goldman J et al (2005) Olfactory groove meningiomas from neurosurgical and ear, nose, and throat perspectives: approaches, techniques, and outcomes. Neurosurgery 57(4 Suppl):268–280

29. Rachinger W, Grau S, Tonn JC (2010) Different microsurgical approaches to meningiomas of the anterior cranial base. Acta Neurochir (Wien) 152:931–939

30. Simpson D (1957) The recurrence of intracranial meningiomas after surgical treatment. J Neurol Neurosurg Psychiatry 20(1):22–39

31. Couldwell WT, Cole CD, Al-Mefty O (2007) Patterns of Skull base meningioma progression after failed radiosurgery. J Neurosurg 106(1):30–35