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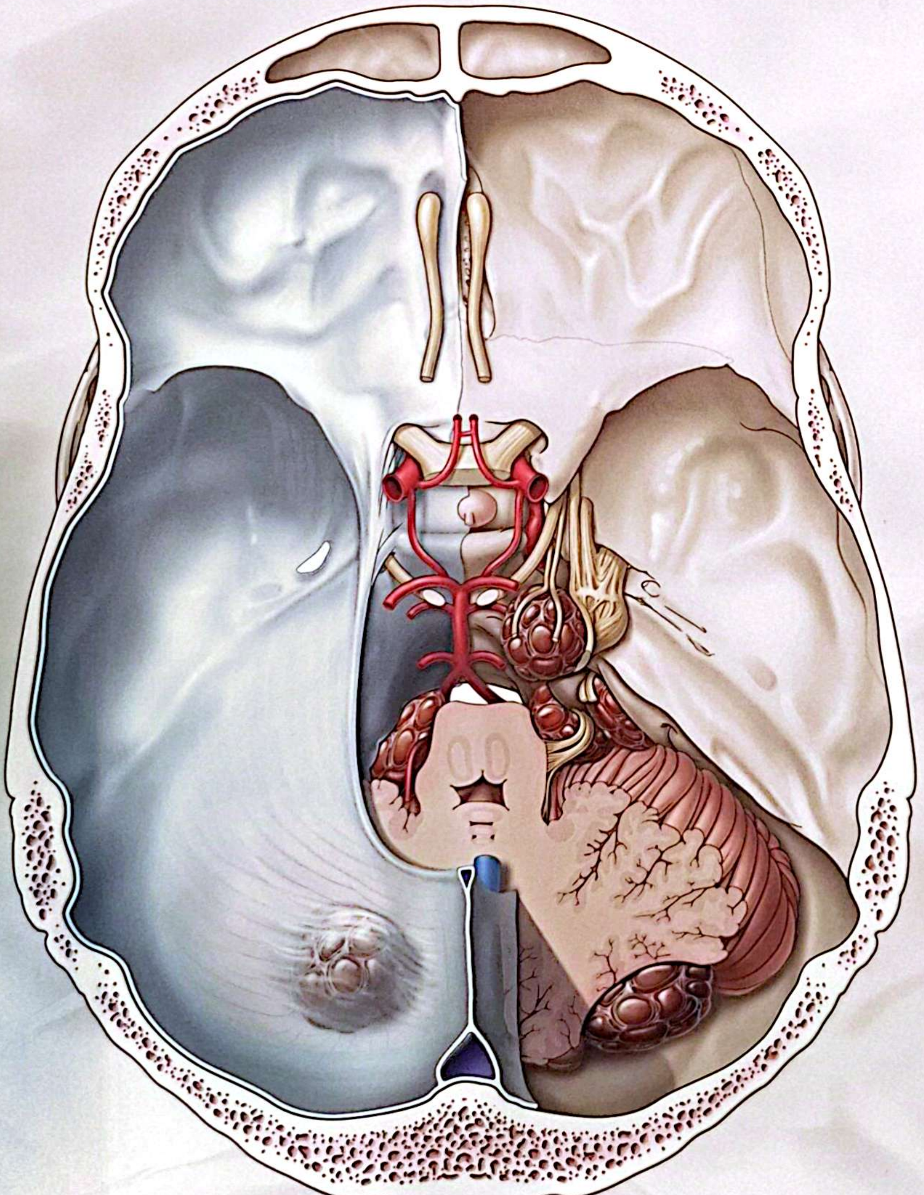
POSTERIOR FOSSA MENINGIOMAS
70 years later



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Edoardo Agosti, Marco M. Fontanella, Pier P. Panciani

NEURONAVIGATION

Introduction

In contemporary neurosurgery, the integration of advanced technologies has revolutionized the approach to tumor resection.[1] Among these innovations, neuronavigation plays a pivotal role, offering real-time guidance and precision in intracranial surgeries. This scientific discourse delves into the application of neuronavigation in meningioma surgery, emphasizing its distinctive advantages in addressing posterior cranial fossa meningiomas (PFMs).[1,2]

The inception of neuronavigation dates back to the mid-20th century, with stereotactic frame systems. However, their limited utility due to suboptimal neuroimaging spurred further developments. The advent of frameless stereotactic neurosurgery in the 1990s, facilitated by advanced imaging modalities and three-dimensional digitalization, marked a paradigm shift.[3] Neuronavigation, or frameless image-guided surgery (IGS), emerged as a transformative tool for enhancing surgical precision.[1,4]

Application to PFMs surgery

In meningioma surgery, the primary objective is to achieve safe resection while preserving adjacent neurovascular structures.[2] Neuronavigation proves invaluable by providing real-time, three-dimensional orientation based on preoperative imaging. This aids surgeons in meticulous planning and execution, contributing to optimal outcomes. The advantages of neuronavigation are particularly noteworthy in addressing the complexities associated with meningiomas.[1,3]

Convexity meningiomas

Neuronavigation offers a precise estimation of surgical risk concerning the vascular structures. By optimizing craniotomy size and location, it enhances the safety and efficacy of resection. For convexity meningiomas, risk assessment related to surrounding functional cortex and cortical vasculature is crucial. Neuronavigation facilitates a tailored approach, minimizing neurologic and wound complications.[3]

Tentorial meningiomas

In tentorial meningiomas, neuronavigation aids in identifying the transverse sinus for craniotomy planning. It provides critical insights into posterior temporal venous anatomy, such as the vein of Labbè, and guides the route to the posterior portion of the superior sagittal sinus. This information is pivotal for minimizing risks during surgery.[3]

Skull base meningiomas

Skull base meningiomas pose challenges due to intricate anatomy. Neuronavigation assists in planning tailored approaches, identifying skull base landmarks, and determining the extent of bone resection. The combination of CT and MRI modalities enhances understanding, contributing to improved surgical outcomes.[2, 3]

Neuronavigation to identify cranial nerves position when hidden by the tumor

Recently, there has been growing clinical interest in generating tractography of the cranial nerves. This can be very helpful when the nerve, for example facial or acoustic nerve, is hidden inside the capsule of the tumor.

Readout-segmented diffusion-weighted imaging and color tissue mapping has been proved to provide 1-2 mm spatially accurate imaging of the facial-vestibulocochlear nerve complex, enabling accurate preoperative localization of the facial nerve.[5]

The use of an intraoperative tractography-integrated neuronavigation system can greatly improve the identification of the nerves and their preservation.

This means to have an augmented reality system, that allows to "inject" through the microscope in the surgical field the image of the tractography and to recognize the nerve hidden by the tumor.

Conclusions

Neuronavigation stands as a transformative ally in PFMs surgery, offering unparalleled precision and guidance. Its advantages, ranging from tailored surgical planning to real-time intraoperative assistance, make it indispensable in addressing the nuances of various meningioma subtypes. As technology continues to advance, neuronavigation is poised to further refine the landscape of meningioma surgery, fostering improved patient outcomes and minimizing surgical complications.

ULTRASOUND

Introduction

In recent years, intraoperative ultrasound (ioUS) has emerged as a valuable adjunct in meningioma surgery, offering real-time imaging and aiding in the achievement of optimal resection outcomes. Meningiomas, accounting for a substantial portion of intracranial tumors, often necessitate surgical intervention for definitive management.[6, 7] The posterior cranial fossa, housing critical structures such as the brainstem and cerebellum, poses unique challenges for surgeons dealing with meningiomas in this region.[7] In this context, ioUS has emerged as a dynamic tool, providing real-time visualization and enhancing surgical precision.

Technical overview

Intraoperative ultrasound involves the use of high-frequency sound waves to create real-time images of the surgical field. This technique provides immediate feedback to surgeons, aiding in decision-making during the procedure.[6] Intraoperative ultrasound is often integrated with neuronavigation systems, combining the benefits of real-time imaging with preoperative anatomical data.[7] This fusion facilitates accurate localization and navigation, especially crucial in the delicate posterior cranial fossa.[8, 9]

Advantages of ioUS in PFMs surgery

Real-time visualization

Intraoperative ultrasound provides instantaneous imaging during surgery, allowing surgeons to visualize the meningioma and surrounding structures in real-time. This is particularly beneficial in PFMs, where the proximity to critical structures demands precision.

Dynamic adaptation

Surgery of PFMs may induce brain shift and alterations in anatomy. Intraoperative ultrasound enables dynamic adaptation, compensating for these changes and ensuring that the surgical plan aligns with the real-time configuration of the intracranial structures.[8]

Assessment of tumor consistency

Meningiomas exhibit variable consistency, and the ability to assess this intraoperatively is crucial. Intraoperative ultrasound aids in distinguishing tumor characteristics, helping surgeons tailor their approach based on the specific properties of the meningioma.

Venous sinus evaluation

The PFMs often involve major venous sinuses, and preservation of venous structures is paramount. Intraoperative ultrasound assists in assessing the relationship between the tumor and venous sinuses, guiding surgeons in making decisions to preserve venous structures and minimize complications.[8, 9]

Enhanced resection guidance

Real-time imaging guides the surgeon during the resection, ensuring a balance between achieving maximal tumor removal and preserving adjacent critical structures. This is especially crucial in PFMs, where precision is essential to avoid damage to the brainstem and associated structures.[9]

Multimodal imaging integration

In conjunction with other imaging modalities, such as Doppler ultrasound and elastosonography, ioUS provides a comprehensive view of the meningioma and its surroundings. This multimodal approach enhances the surgeon's ability to make informed decisions during surgery.[7]

Challenges and future directions

While intraoperative ultrasound has demonstrated significant advantages, challenges persist. Image resolution and the learning curve associated with its use are areas of ongoing refinement. Additionally, further research is needed to establish standardized protocols for its optimal integration into meningioma surgeries.[8, 9]

Conclusions

Intraoperative ultrasound has become an indispensable tool in meningioma surgery, offering real-time visualization, adaptability to dynamic changes, and enhanced precision. Its applications are particularly noteworthy in the challenging realm of PFMs, where the intricate anatomy demands meticulous surgical planning. As technology continues to evolve and refine, ioUS is poised to play an increasingly pivotal role in improving surgical outcomes and ensuring the optimal management of meningiomas, especially those situated in the posterior cranial fossa.

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