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Minimally Invasive but Maximally Effective Treatment of Anterior Skull Based Tumors — The Combination of Advanced Neuroendoscopy and Intraoperative Imaging with iMRI and O-Arm

Kaveh Asadi-Moghaddam, Joseph C. Taylor and Todd W. Vitaz

Additional information is available at the end of the chapter

1. Introduction

The use of endoscopic techniques for the treatment of anterior skull based tumors has seen and exponential rise over the past 15 years. As a result of this rapid growth newer more powerful endoscopic systems with better surgical instruments have been developed which has increased the armamentarium and further broadened the scope of potentially treatable lesions [1,2]. However, even with these newer systems as well as angled surgical telescopes; visual lines of sight and normal anatomical structures can still hinder visualization. In addition, the steep learning curve associated with this type of procedure as well as the loss of the normal surgical feedback such as direct 3d visualization and tactile feedback also increase the challenges associated with such procedures. Therefore, in many cases it may be difficult to determine when the surgical goals of complete resection or safest maximal debulking have been obtained. The addition of advanced intraoperative imaging with intraoperative MRI or O-Arm (Medtronic, Minneapolis, MN) technology to some of these cases enables surgeons to obtain radiographic feedback during the procedure and thus further assess their work and adds another factor into surgical decision making [3].

2. Surgical corridors and types of lesion approaches treatable with extended endonasal approach

The treatment of both benign and malignant lesions of the anterior skull base can be performed with this approach. This technique requires a team approach with an ENT and neurosurgeon who both must be experienced in endoscopic principles, skull base anatomy and have a vast understanding of all potential treatment options[1,2,4-6]. An enormous learning curve exists not only for performing the surgical approach but also for dissection and removal of the lesion and subsequent reconstruction of the surgical defect and complication avoidance. Most authors have reported this learning curve with much higher complication rates in the earlier portions of their series[1,6-8]. We like most other teams have modified and fine-tuned our technique as we have continued to gain experience. Most authors recommend starting with straight forward midline lesions (figure 1.) and then broadening their technique to more challenging and invasive para-midline lesions as their comfort level and experience grows. In addition, the inclusion of frameless navigation systems and even more modern advanced imaging techniques such as O-Arm and intraoperative MRI also improve the safety and broaden the scope of lesions that may be amenable to such treatment approaches.
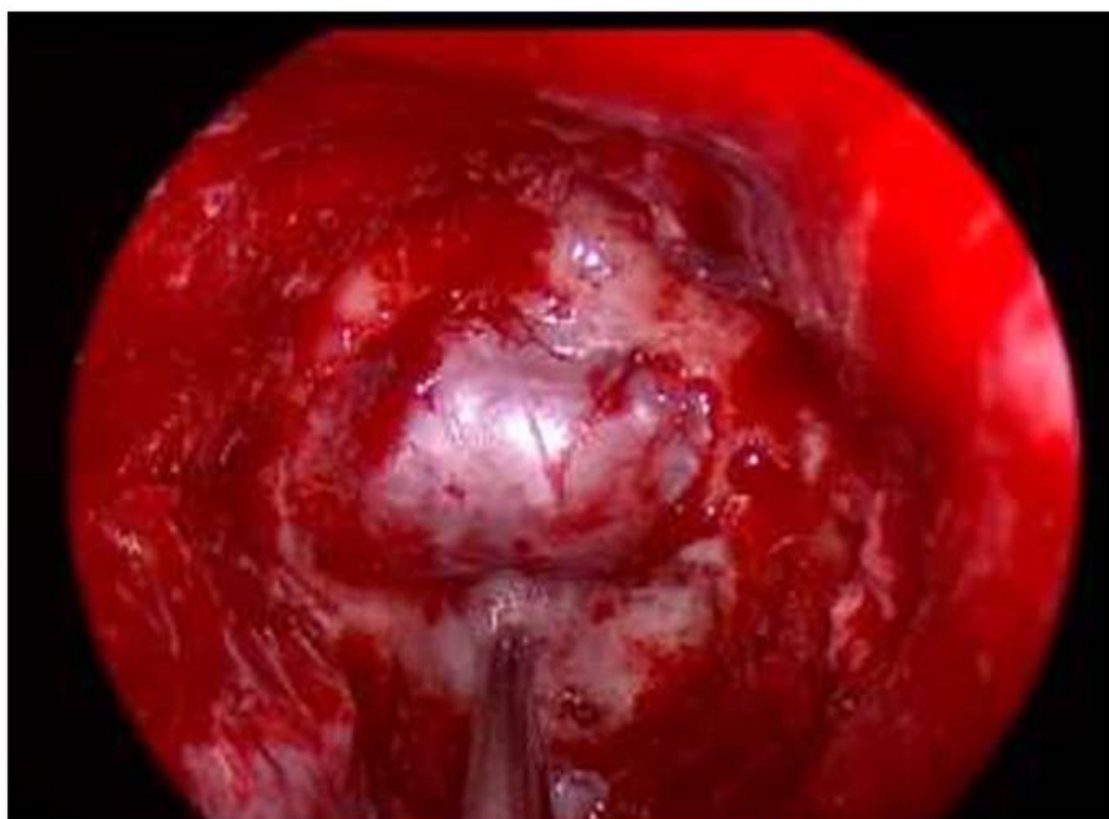

Figure 1. Intraoperative photograph from endoscopic endonasal approach to a small midline pituitary tumor, after straightforward midline approach and bone removal illustrating exposed sellar dura.

Lesions from the crista galli all the way down to the body of C2 can be treated with different variations of this approach[1,2,6,8-11]. Superiorly the medial orbits serve as a lateral limit on exposure [6]; however, more advanced techniques utilizing an oculoplastic surgeon and a small conjunctival incision can even expand this border (figure 2.). Traditionally the carotid arteries served as the lateral extent at the level of the sella [6,10]; however more advanced techniques now allow lateral exposure all the way to the infratemporal fossa [2,5].
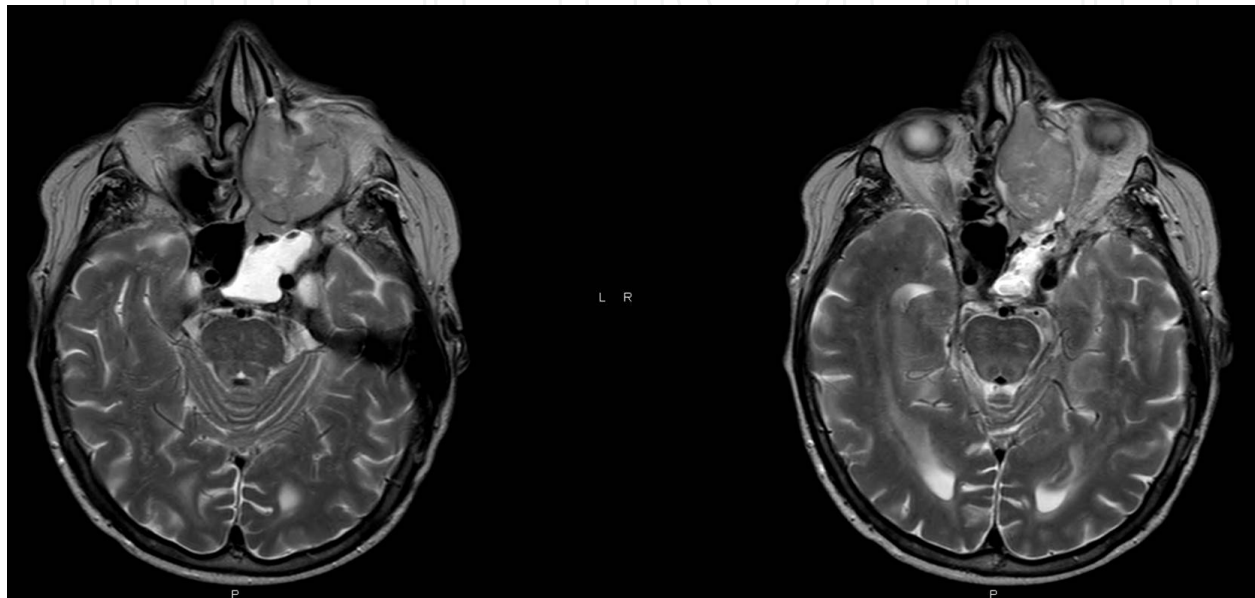

Figure 2. Preoperative axial T2-wieghted preoperative MRI showing primary sinus melanoma with left orbital compression in an 86 year old gentleman. Patient underwent endoscopic removal with aide of a small subconjunctival incision for palliative debulking of the lesion without globe removal.

Studies comparing endoscopic techniques with more traditional transcranial procedures have found either equivalent or superior results with endoscopic approaches[7,8]. However, limitations with endoscopic techniques continue to exist. These include anatomical constraints that may place major neural or vascular structures ventral to the pathology and thus increase the surgical risks and minimize utility. Limitations in visualization have been overcome with newer endoscopic lighting and camera systems. The 2 dimensional view with endoscopic techniques may create some challenges; however, experienced surgeons have learned to accommodate to these limitations. Newer 3D systems will soon become readily commercially available and as these systems evolve will likely overcome this limitation all together. Hemostasis and repair of postoperative CSF leaks have been the two most challenging aspects of these procedures [1,2,6,8,10,12]. Various commercially available products and surgical nuances can be used to overcome many of the challenges with hemostasis. In addition, vascular lesions are approached from the ventral side of dural involvement thus allowing devascularization of the lesion prior to any tumor manipulation or debulking. Control of postoperative CSF leaks deserves special mention and will be discussed below. Finally, the method of tumor removal

must be modified to safely perform these techniques. While en bloc resection may be possible for small midline lesions this is not safely feasible for the majority of tumors. This becomes especially important in the realm of malignant tumor management where the historical standard has always been en bloc resection with negative margins. Even though this may be the goal, studies have shown that this in actually only obtained in 70% of cases of "open" resections for these lesions [13,14]. There is no convincing evidence to prove that a less invasive piecemeal resection portends to a worse prognosis and studies in this area are lacking [8].

3. Complications associated with EEA

Major neurological complications following this type of procedure are rare. They are typically related to either damage to major vascular structures or perforating vessels, optic nerve and chiasm or cranial nerves [1,2,4-8]. New or worsening visual symptoms are rare and their occurrence varies considerably based on pathology. Intraoperative monitoring of cranial nerve 3, 4, 6 may minimize the risk of damage to these structures.

Unlike transcranial approaches there is no skin incision or autologous bone flap, thus the risk of wound infection is almost entirely eliminated [7]. During the early experience with this exposure the concern for operating through a contaminated nasal corridor and the associated risk of meningitis or intracranial abscess was an enormous concern; however, experience has shown that this risk is minimal and usually limited to the setting of postoperative CSF leakage. In fact most authors recommend standard perioperative gram positive antibiotic coverage (cefazolin, clindamycin, vancomycin) for 24-48 hours [1,2,4,7]. In addition, because the pathological process is approached from the ventral bone interface, brain retraction and manipulation is minimal in these procedures. Therefore the risk of postoperative seizures, cognitive or other detrimental neurological changes from brain retraction and manipulation are almost entirely eliminated.

3.1. Postoperative CSF leaks

The creation of postoperative CSF fistulas has been one of the most challenging limitations to overcome with these techniques. Direct repair with suturing is not possible because of the deep surgical corridor and limited lateral exposure. Rates of postoperative CSF leakage vary between (0%-30%)[15-19]; and most surgeons have shown a direct relationship to experience with higher rates early on in their series despite progressing to more complex and invasive modifications of this procedure as their experience grew [1,2,4,6-8].

To try to prevent the occurrence of these events numerous reconstructive procedures have been attempted. These include the use of various autologous, allogenic and synthetic sub-strates from abdominal fat, fascia lata, nasal mucosa or turbinates, temporalis muscle, peri-cardium, and synthetic dural substitutes. In addition, bone reconstruction has been attempted with various autologous and synthetic commercial substances. These implants may be inserted as inlay or onlay grafts as well as the "gasket seal" techniques [20]. The addition of biological

sealants such as Tisseal (Baxter Bioscience, Deerfield, IL) and DuraSeal (Integra, Plainsboro, NJ) are often commonly used as well.

A recent advancement has been the use of vascularized nasoseptal flaps [1,2,6,7,10,12]. These flaps which are typically developed at the beginning of the procedure prior to bone removal to reduce the risk of damage to the vascularity, have significantly decreased the risk of postoperative CSF leaks in cases where opening of the dura and arachnoid is anticipated [6]. A complete understanding of the vascular anatomy of this region is required to ensure that adequate vascularized tissue is available for reconstruction at the end of the procedure. Harvesting of such grafts lengthens surgical times only slightly but does increase postoperative nasal crusting and discomfort. Typically the septum is remucosalized by 3 months [6].

4. Combination of endoscopic techniques with advanced imaging technology

Despite the fact that endoscopic techniques may actually improve illumination and visualization over conventional microsurgical techniques there are many instances where it may be difficult to determine whether or not the surgical goals have been obtained. The use of angled (30, 45, 70 degree) telescopes can help surgeons evaluate around corners but not through objects. The surgical goals vary from case to case and depend on patient age, comorbidities, preoperative neurological status and pathology. While gross total resection may be the goal for most procedures in some lesion debulking for symptom control followed by stereotactic radiosurgery to the capsule may be the safest approach to minimize surgical morbidity (figure 3).
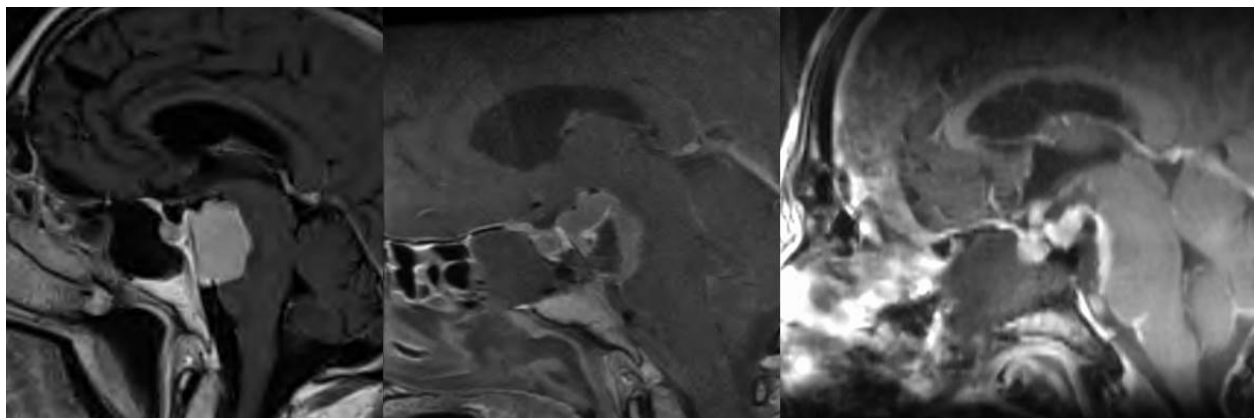

Figure 3. Sagittal T1-weighted post contrast preoperative, first intraoperative and second intraoperative MRI in 78 year old myelopathic gentleman with clival meningioma with significant brainstem compression. The surgical goal was to debulk the lesion leaving a small capsule however endoscopically it was difficult to determine how much residual tumor persisted behind the pituitary gland which is clearly seen on the middle image. On the final image the capsule can be seen falling away from the diencephalon and chiasmatic region.

O-Arm (Medtronic, Minneapolis, MN) and similar technologies may be useful in defining bone anatomy during some very complex procedures. The lack of tissue differentiation makes this technology very limiting for determining the extent of tumor removal for most cases. We have found this extremely useful in verifying adequate surgical results in cases of basilar invagination treated with the EEA. Following what is felt to be complete resection of the compressive pathology imaging can be obtained to verify the actual surgical results (figure 4). In addition, this technology can also be used in cases where more lateral temporal bone removal is required to verify actual bone removal prior to dural opening and tumor resection.
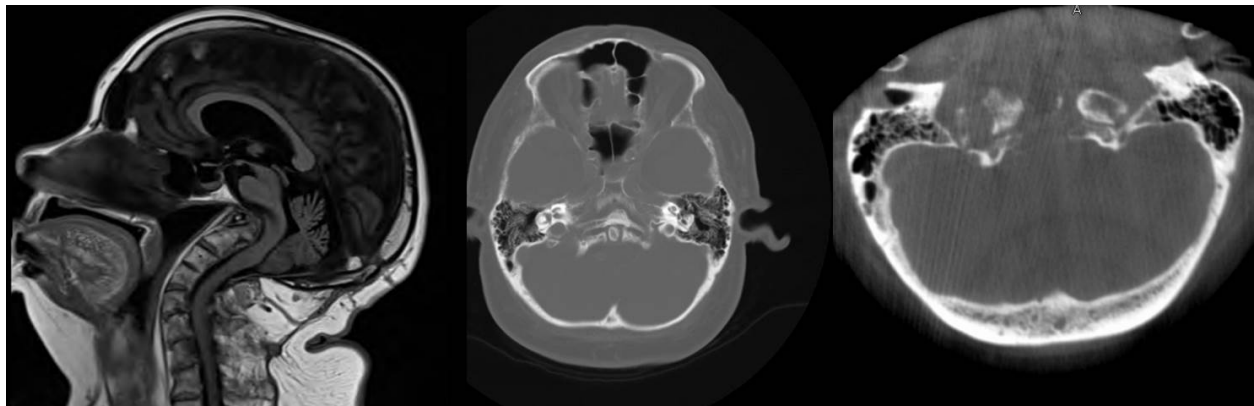

Figure 4. Preoperative Sagittal T1-weighted MRI and axial CT scan; and axial post midline decompression O-Arm image (sagittal reformatted images show complete decompression from clivus to C2/3 level) in 44 year old myelopathic female with platybasia and basilar invagination with brainstem compression, treated via endoscopic approach with O-Arm assisted navigation.

Another more common technology is the use of Intraoperative MRI. This technology has been extensively utilized for endoscopic removal of pituitary tumors for more than ten years [3,21]. We have found this exceptionally helpful in cases of giant pituitary tumors (figure 5) and other skull base cases such as meningiomas and craniopharyngiomas (figure 6). Following completion of resection imaging can be performed and then additional tumor resection can occur if significant residual is appreciated on these scans. Extreme care must be used in interpreting these results as surgical induced changes on peritumoral structures or capsule can mimic significant residual tumor in some instances.

We have found intraoperative imaging helpful in cases of large pituitary macroademonas where the capsule/diaphragm fails to prolapse into the field (figure 7). Imaging can be performed to determine the degree of residual tumor and decide whether opening the capsule and proceeding with extracapsular dissection is warranted. Finally, in cases where surgical debulking may be the primary goal intraoperative imaging can be performed to ensure that adequate results are obtained.
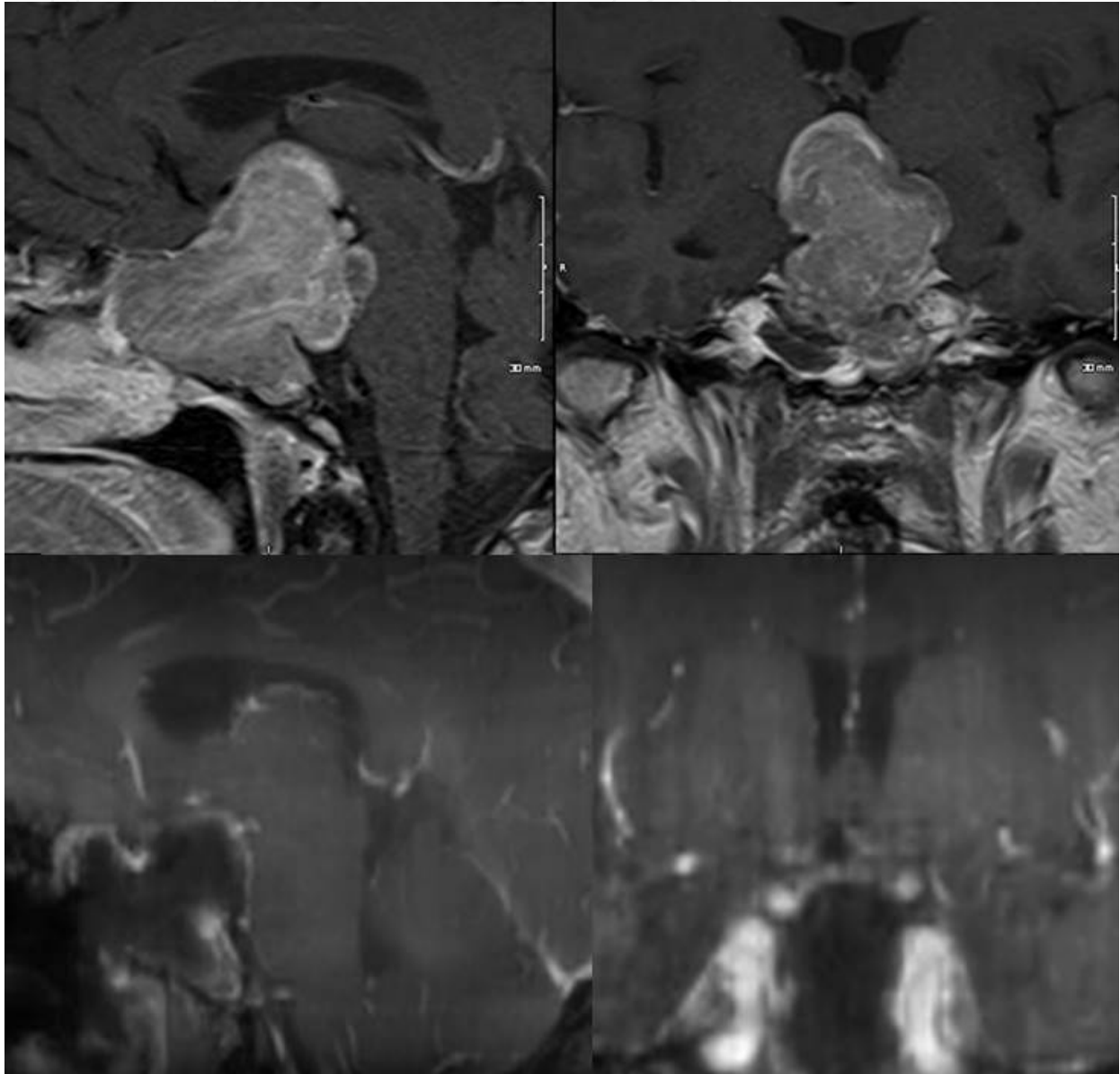
Figure 5. Post contrast T1-weighted sagittal and coronal preoperative (upper) and intraoperative (lower) images from a patient with a giant pituitary macroadenoma.
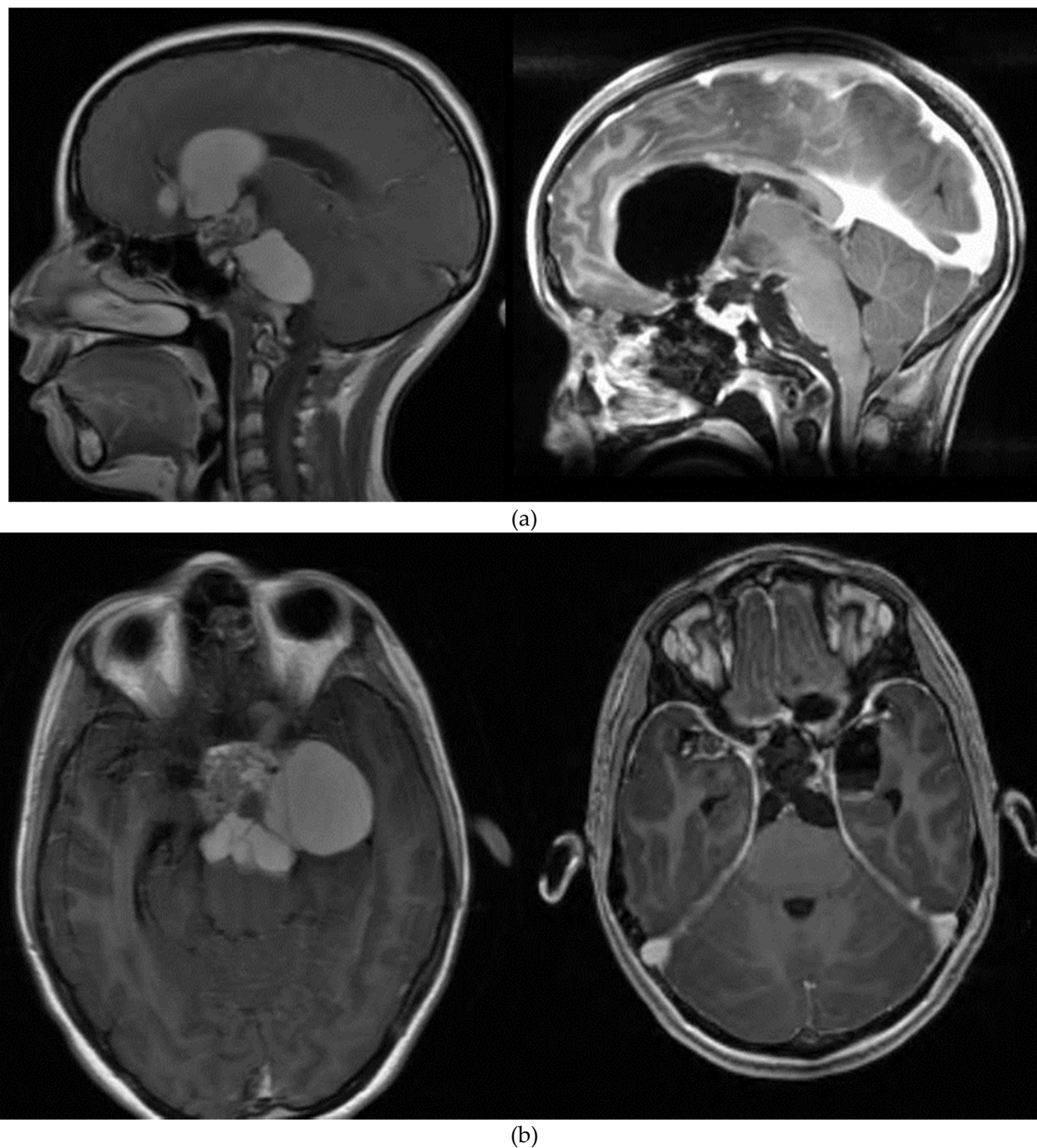
(a)

(b)

Figure 6. Post contrast T1-weighted preoperative and intraoperative Sagittal (a.) and axial (b.) images in 12 year old female with giant polycystic Craniopharyngioma with 2 cm enhancing nodule. iMRI was helpful in determining complete removal of enhancing nodule and drainage of all major cyst compartments following endoscopic midline approach from posterior ethmoids to clivus, working above and below pituitary gland, air visualized on intraoperative images was irrigated out of ventricles prior to closure.
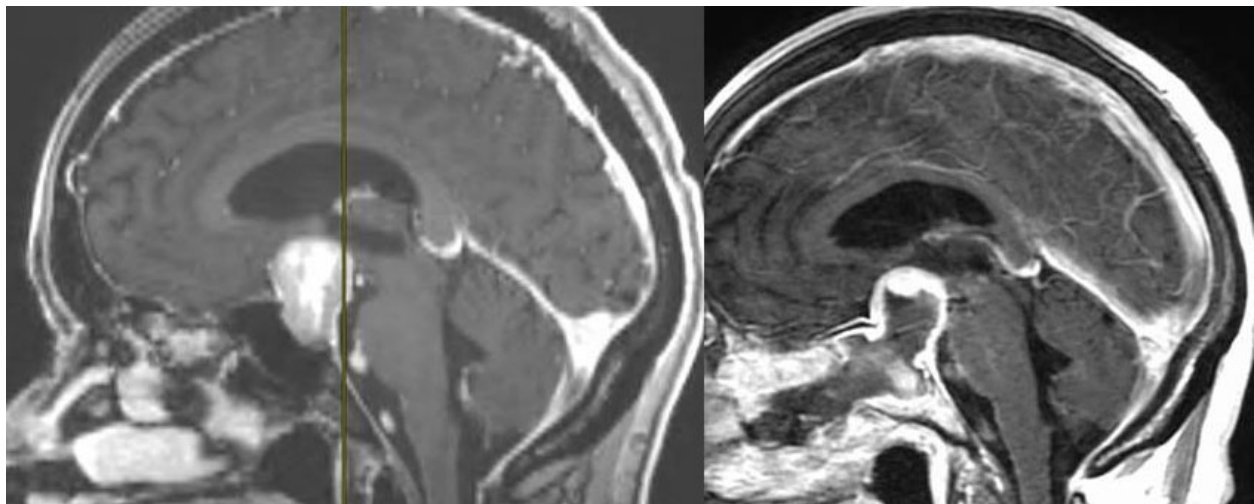
Figure 7. Post contrast sagittal preoperative and intraoperative sagittal MRI scans for a 76 year old female with a large pituitary macroadenoma, tumor capsule failed to prolapse into field during resection, visual inspection following imaging showed mostly blood products with a small amount of residual tumor along the superior aspect, given the patients age and preoperative visual status it was decided that a more aggressive resection was not in the patients best interest.

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