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Endoscopic endonasal approaches to the skull base tumors: minimally-invasive approach with achievement of radicality. Our experience

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Objective: to optimize surgical tactic of endoscopic endonasal transsphenoidal (EET) approaches in cases of tumors with intra- and extracranial extension.

Material and methods. For the period of 2013–2019, we retrospectively reviewed 39 patients with tumors of intra-extra skull base location or just extracranial extension. Tumor location and pathology: tumors in pterygopalatine fossa (paraganglioma, carcinoma, neurilemmoma, neurofibroma, chondrosarcoma) — 10 (25.6%), pituitary adenomas with sphenoid sinus and/or parasellar extension — 14 (35.9%), sphenoid sinus tumors (carcinoma, neurilemmoma, fibrous dysplasia, angiofibroma, esthesioneuroblastoma) — 8 (20.5%), petroclival tumors — 6 (15.4%): hemangiopericytoma — 1, clival tumors — 5 (chordoma), sella turcica lesion with posterior clinoid recess extension (osteoma) – 1 (2.5%). The extended EET approaches used were as follows: EET + transpterygoid approach — 22 (56.4%) (in 4 (18.1%) cases transmaxillary approach was additionally used), extended EET + transclival approach — 4 (10.2%), EET + transcavernous approach — 2 (5.1%), EET + transethmoidal approach — 11 (28.2%). In all cases, we used Karl Storz rigid 4mm 18cm with 0 and 30-degree angled optics. The extent of resection was determined based on routine postoperative CT scans performed within 24 hours after surgery. The volume of resection was evaluated using gadolinium. Gross total resection was defined as the resection of 100% of the target lesion, subtotal resection as less than 100% volumetric reduction of the lesion on postoperative CT scans. Further follow-up was done in three, six months and 1 year after surgery, then annually by MRI scanning with gadolinium.

Results. Gross total resection was achieved in 7 (77.8%) cases of tumor in pterygopalatine fossa. In cases of pituitary adenomas with Knosp 3, Knosp 4 cavernous sinus extension, gross total resection was achieved in 7 (53.8%) individuals. Sphenoid sinus tumors were totally removed in 5 (62.5%) cases. Subtotal resection was achieved in 11 (28.2%) cases. Partial resection was achieved in 8 (20.5%) cases. Postoperative complications were observed in 5 (12.1%) cases.

Conclusions Transethmoidal extended endoscopic endonasal approach is sufficient and good to access the anterior wall of the cavernous sinus improving visualization and better removing of cavernous sinus pathology extension. Transpterygoid extended endoscopic endonasal approach provides sufficient visualization of pterygopalatine fossa, petroclival region. Transmaxillary extension allows reaching the subtemporal region.

Keywords: *skull base tumors; extended endoscopic approaches*

Ендоскопічні ендоназальні доступи до пухлин основи черепа: малоінвазивність доступу та можливість радикального видалення пухлин основи черепа. Наш досвід

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Відділення ендоскопічної та краніофаціальної нейрохірургії з групою ад'ювантних методів лікування, Інститут нейрохірургії ім. акад. А.П. Ромоданова НАМН України, Київ, Україна

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Мета: оптимізувати тактику використання ендоскопічного ендоназального транссфеноїдального доступу при пухлинах із інтра- та екстракраніальним поширенням.

Матеріали і методи. Проведено ретроспективний аналіз результатів лікування 39 хворих з пухлинами основи черепа з інтра- та екстракраніальним поширенням у 2013–2019 рр. Локалізація пухлин та їх гістологічна верифікація: пухлини крилопіднебінної ямки (рак, парагангліома, нейрофіброма, невринома, хондросаркома) – 10 (25,6%), аденоми гіпофіза з поширенням у крилоподібну пазуху та/чи параселярним поширенням – 14 (35,9%), пухлини основної пазухи (рак, неврилімома, фіброзна дисплазія, ангіофіброма, естезіонейробластома) – 8 (20,5%),

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пухлини петро-клівальної ділянки – 6 (15,4%): гемангіоперицитома – 1, пухлина схилу основної кістки – 5, пухлина турецького сідла з поширенням на задній похилений паросток (остеома) – 1 (2,5%). Застосовували такі ендоскопічні ендоназальні транссфеноїдальні (ЕЕТ) доступи: ЕЕТ + трансптеригоїдальний – 22 (56,4%), у 4 (18,1%) випадках доповнений трансмаксилярним доступом), ЕЕТ+ трансклівальний – 4 (10,2%), ЕЕТ + транскавернозний – 2 (5,1%), ЕЕТ + трансетмоїдальний – 11 (28,2%). У всіх випадках використовували жорсткий ендоскоп фірми Carl Storz діаметром 4 мм завдовжки 18 см з кутовою оптикою 0 і 30°. Ступінь резекції пухлини визначали за даними мультиспіральної комп'ютерної томографії з внутрішньовенним контрастуванням, проведеної протягом 24 год після операції. Тотальним вважали 100% видалення пухлини, субтотальним – зменшення об'єму пухлини менше ніж на 100% після операції. Контрольні обстеження із застосуванням магнітно-резонансної томографії з внутрішньовенним контрастуванням проводили через 3, 6 міс та 1 рік після операції, потім – щорічно.

Результати. Тотального видалення у разі пухлини крилопіднебінної ямки досягнуто в 7 (77,8%) випадках, у разі аденоми гіпофіза з Knosp 3, Knosp 4 поширенням на кавернозний синус – у 7 (53,8%), у разі пухлини клиноподібної пазухи – у 5 (62,5%), субтотального – в 11 (28,2%), часткового – у 8 (20,5%). Післяопераційні ускладнення відзначено у 5 (12,1%) пацієнтів.

Висновки. Застосування ЕЕТ + трансетмоїдального доступу дає змогу досягти латеральної стінки кавернозного синуса, ЕЕТ + трансптеригоїдального доступу – візуалізувати пухлини, котрі поширюються на параклівальні відділи внутрішньої сонної артерії та латерально на крилопіднебінну ямку. Використання розширених ендоскопічних доступів до важкодосяжних пухлин основи черепа і збільшене поле візуалізації порівняно з мікрохірургічним трансназальним доступом дають змогу збільшити кількість хворих з радикальним видаленням пухлини, що сприяє поліпшенню онкологічної виживаності.

Ключові слова: *пухлини основи черепа; розширені ендоскопічні доступи*

Эндоскопические эндоназальные доступы к опухолям основания черепа: малоинвазивность доступа и возможность радикального удаления опухолей основания черепа. Наш опыт

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Цель: оптимизировать хирургическую тактику эндоскопического эндоназального транссфеноидального доступа при опухолях с интра- и экстракраниальным распространением.

Материалы и методы. Проведен ретроспективный анализ результатов лечения 39 больных с опухолями основания черепа с интра- и экстракраниальным распространением в 2013–2019 гг. Локализация опухолей и их гистологическая верификация: опухоли крылонебной ямки (рак, параганглиома, нейрофиброма, невринома, хондросаркома) – 10 (25,6%), аденомы гипофиза с распространением в основную пазуху и/или параселлярным распространением – 14 (35,9%), опухоли основной пазухи (рак, неврилимома, фиброзная дисплазия, ангиофиброма, эстезионейробластома) – 8 (20,5%), опухоли петро-кливальной области – 6 (15,4%): гемангиоперицитома – 1, опухоль ската основной кости – 5, опухоль турецкого седла с распространением на задний наклоненный отросток (остеома) – 1 (2,5%). Применяли такие расширенные эндоскопические эндоназальные транссфеноидальные (ЭЭТ) доступы: ЭЭТ + трансптеригоидальный – 22 (56,4%), в 4 (18,1%) случаях дополненный трансмаксиллярным доступом, ЭЭТ + трансклювальный – 4 (10,2%), ЭЭТ + транскавернозный – 2 (5,1%) 1, ЭЭТ + трансэтмоидальный – 11 (28,2%). Во всех случаях использовали ригидный эндоскоп фирмы Carl Storz диаметром 4 мм длиной 18 см с угловой оптикой 0 и 30°. Степень резекции опухоли определяли по данным мультиспиральной компьютерной томографии с внутривенным контрастированием, проведенной в течение 24 ч после операции. Тотальным считали 100% удаление опухоли, субтотальным – уменьшение объема опухоли менее чем на 100% после операции. Контрольные обследования с применением магнитно-резонансной томографии с внутривенным контрастированием проводили через 3, 6 мес и 1 год после операции, затем – ежегодно.

Результаты. Тотальное удаление в случае опухоли крылонебной ямки достигнуто в 7 (77,8%) случаях, при аденоме гипофиза с Knosp 3, Knosp 4 распространением на кавернозный синус – в 7 (53,8%), при опухоли клиновидной пазухи – в 5 (62,5%), субтотальное – в 11 (28,2%), частичное

– в 8 (20,5%). Послеоперационные осложнения отмечены у 5 (12,1%) пациентов.

Выводы. Применение ЭЭТ + трансэтмоидального доступа позволяет достичь латеральной стенки кавернозного синуса, ЭЭТ + трансптеригоидального доступа – визуализировать опухоли, которые распространяются на парапливальные отделы внутренней сонной артерии и латерально на крылонебную ямку. Использование расширенных эндоскопических доступов к труднодоступным опухолям основания черепа и увеличенное поле визуализации по сравнению с микрохирургическим трансназальным доступом позволяют увеличить количество больных с радикальным удалением опухоли, что способствует улучшению онкологической выживаемости.

Ключевые слова*: опухоли основания черепа; расширенные эндоскопические доступы.*

Introduction

Tumors with intra-extra cranial extension or with pure external extension to the skull base surface are always challenging for surgeon. Complicated anatomy and difficult access to critical structures, necessity of removal of massive bone structures could eventually make surgery difficult [1, 2]. Complete resection is challenging for invasive tumors using standard microsurgical route [2]. The first applications of the endoscope in transsphenoidal surgery were described by Apuzzo et al. [3]. Pioneers in endoscopic pituitary surgery, Jho and Carrau, reported their technique and results using endoscopic approach for tumor resection in 1997 and 1998, respectively [4]. Nowadays endoscopic endonasal transsphenoidal approach allows achieving direct approach to the sella region and widely expose parasellar region [6–8], Meckel's cave [8], pterygopalatine and infratemporal fossae [9–11]. Complete tumor resection is challenging to achieve by standard endoscopic endonasal technique [2, 7, 10, 11]. Extended endoscopic endonasal transsphenoidal (EET) approach might simplify procedure and is discussed here as a method to treat intra-, extracranial skull base tumors.

Objective: to optimize surgical tactic of endoscopic endonasal transsphenoidal approaches in cases of tumors with intra- and extracranial extension.

Material and methods

For the period of 2013–2019, we retrospectively reviewed 39 patients with tumors of intra-extra skull base location or just extracranial extension. Extended EET approach was used to remove these tumors.

Tumor location and pathology: pterygopalatine fossa tumors (paraganglionoma, carcinoma, neurilemmoma, neurofibroma, chondrosarcoma) — 10, pituitary adenomas (PA) with sphenoid sinus and/or parasellar extension — 14, sphenoid sinus tumors (carcinoma, neurilemmoma, fibrous dysplasia, angiofibroma, esthesioneuroblastoma) — 8, petroclival tumors (hemangiopericytoma — 1, clival region — 5 (chordoma), sella turcica lesion with posterior clinoid recess extension (osteoma) — 1.

We used the following extended EET approaches: EET + transpterygoid approach — 22 (56.4%), in 4 (18.1%) cases transmaxillary approach was additionally used to achieve lateral compartments of middle skull base, extended EET + transclival approach — 4 (10.2%), EET + transcavernous approach — 2 (5.1%), EET + transethmoidal approach — 11 (28.2%). In all cases, we used Karl Storz rigid 4mm 18cm with 0 and 30-degree angled optics. The extent of resection was determined based on routine postoperative CT scans performed within 24 hours after surgery. The volume of resection was evaluated using gadolinium. Gross total resection was defined as the resection of 100% of the target lesion, subtotal resection as less than 100% volumetric reduction of the lesion on postoperative CT scans. Further follow-up was done in three, six months and 1 year after surgery, then annually by MRI scans with gadolinium. Demographics, clinical-pathological data, and surgical techniques are summarized in ***Table 1***.

Table 1. Demographics, oncological, and surgical technique information

Variable	Abs	%
Gender		
• Male	17	43.6
• Female	22	56.4
Age	Mean 45.8	
Site of origin		
• sellar region	14	35.9
• pterygopalatine fossa	10	25.6
• sphenoid sinus	8	20.5
• petroclival region	7	17.9
Surgical approach		
• EET + transpterygoid (in 4 case expanded by transmaxillary approach)	22	56.4
• EET extended with transclival approach	4	10.2
• EET + transcavernous approach	2	5.1
• EET + transethmoidal approach	11	28.2

This article contains some figures that are displayed in color online but in black and white in the print edition

The study was carried out in accordance with the principles of bioethics, regulated by the World Medical Association Declaration of Helsinki and approved by the Ethics and Bioethics Commission of Romodanov Neurosurgery Institute (Minutes No. 3 of 04/05/2018).

Results

Thirty-nine patients were included in this study. Endoscopic endonasal approach at its extension was used in all cases. Extended EET transethmoidal approach was used in 11 cases, mostly in pituitary adenomas with cavernous sinus extension (10 cases.) In 1 case, EET transethmoidal approach was used to access clival chordoma with cavernous sinus extension. Extended EET transpterygoid approach was used in 18 cases: in 13 cases of lateral tumor extension into the pterygopalatine fossa, in 1 case of clival chordoma and in 4 cases of giant pituitary adenomas with infrasellar extension.

Gross total resection (GTR) was achieved in 19 cases, mostly in benign pathology. Subtotal resection was achieved in 11 cases, mostly in malignant tumors with lateral extension into the pterygopalatine fossa, which were highly vascularized, in some cases too solid. Subtotal resection was performed in pituitary adenomas with cavernous sinus extension Knosp 4 and associated with the inability to open the cavernous sinus safely. Partial resection was achieved in 8 cases of large tumors with massive extra-intracranial extension. A biopsy was performed in 1 case of a large invasive tumor with intra-extracranial extension involving the pterygopalatine fossa, sphenoid sinus, cavernous sinus, maxillary sinus and middle fossa.

Low rate of postoperative complications was achieved in 5 cases. The cerebrospinal fluid leak was observed in 1 case. Diabetes insipidus occurred in 2 cases, hemiparesis (ICA damage) in 1 case, worsening of neurological deficit in 1 case.

No postoperative mortality was observed.

Discussion

Preoperative planning helps to improve surgical results. MRI and CT scans were used to build 3D models before surgery. That helps to identify the relation between critical anatomical structures and the tumor itself. EET extended approaches are easier to perform using preoperative 3D planning. That was used mostly in all cases.

Tumors that extended into critical anatomical structures are challenging for surgery. Primary malignant tumors of the sphenoid sinus, pterygopalatine fossa, sphenoid sinus can be reached via EET route using lateral extension [2, 12]. For non-secretory pituitary adenomas, gross total resection was achieved in 71% of cases, long-term progression-free survival was 80% within 10 years [2]. The degree of the cavernous sinus invasion varies between patients and can be the determining factor in degree of tumor removal [13]. Hofstetter et al. [4] reported their experience in the management of 86 patients with functional pituitary adenomas who underwent endoscopic endonasal resection, 21% of them had cavernous sinus invasion. A rate of gross total resection was 33.3%. Ajlan et al. [13] studied a cohort of 176 total PAs treated predominately with the endoscopic approach achieving gross total resection only in 47% cases with the cavernous sinus invasion and in 86% for noninvasive tumors.

We achieved gross total resection in 6 (60%) cases of pterygopalatine fossa tumor, meanwhile in cases of pituitary adenomas with Knosp 3, Knosp 4 cavernous sinus extension, the gross total resection was achieved in 7 (53.8%) cases. Sphenoid sinus tumors were totally removed using EET approach in 5 (62.5%) cases. Surgery for the pathology located in petroclival region is complicated and depends on the tumor size, its invasion in critical anatomical structures [6]. Only in one case (16.6%), we achieved the gross total resection. This case is illustrated in the case report 1. In cases of extensive intra, extra-intra cranial tumors growth or those cases with tumors expansion on the outer cranial surface, we used extended EET approaches but even in these cases, we rely on some criteria. These criteria include vascularity, the relationship of the crucial nerves and vessels, tumor invasiveness, and surgical approach accessibility [2, 6, 9, 10]. The subtotal resection was achieved in 11 (28.2%) cases (in 4 out of them in pituitary adenomas, in 3 out of them in petroclival tumors, in the rest 4 cases different tumors located to the sphenoid sinus and pterygopalatine fossa). Partial resection was achieved in 8 (20.5%) cases, among them 2 cases with pituitary adenomas, 1 case with sphenoid sinus tumor, 1 case with posterior clinoid osteoma, 2 cases with pterygopalatine fossa tumors, 2 cases with petroclival tumors.

As a first step, a surgical corridor by EET extension was achieved with total or partial middle turbinectomy. We performed unilateral total or partial middle turbinectomy to create a corridor to the pterygopalatine fossa, lateral wall of the sphenoid sinus, subtemporal fossa. After sphenoid ostium and superior turbine identified, a wide sphenotomy is done. The sphenoid rostrum is removed till medial plate of pterygopalatine process. Frank et al. [8] argue that the goal of extended endoscopic access to the cavernous sinus is to confirm the true invasion of the cavernous sinus, to obtain histological verification and maximize tumor removal. In our series, these goals were achieved in 3 cases when we applied EET extended approach with transethmoidal or transpterygoid rout. For tumors with intra- extracranial growth (pituitary adenomas with cavernous sinus and sphenoid sinus extension), we performed both EET transethmoidal or transpterygoid approaches. But later on, we pointed out that only EET extended with transethmoidal approach alone was enough to clearly visualize the cavernous sinus, tumor extension into it. This approach (EET transethmoidal) was used in every case of tumor located in sphenoid/cavernous sinus but not beyond these structures. With this maneuver, we decrease rhinological morbidity [14]. We used EET extended transethmoidal approach in 3 cases of pituitary adenomas with Knsop 4 cavernous sinus extension. The anterior wall of the cavernous sinus was exposed by a surgical corridor created by middle turbinectomy, ethmoidectomy on the side of invasion. That was sufficient to expose lateral sphenoid sinus wall and achieve sufficient manipulations around an intracavernous segment of ICA. Laterally extended pituitary adenomas can be removed by this lateral extended approach. Intraoperative Doppler control over ICA position was crucial and provided safe tumor resection in

the cavernous sinus. That allowed us to achieve gross total resection in 2 (66.7%) cases.

Tumors of the infratemporal fossa, pterygopalatine fossa are difficult to approach with standard EET rout [10, 11, 16]. To achieve lateral exposure, EET extended transpterygoid approach was used [16]. To expose these tumors laterally, we used EET extended transpterygoid approach. We used this approach wherever a tumor was localized laterally into the pterygopalatine fossa, and on the level or below the sphenoid sinus (n = 22 (55%)). Pterygopalatine fossa tumors are not visible through a standard EET approach. With EET transpterygoid approach, the lateral and posterior aspects of the tumors located into the pterygopalatine fossa can be controlled and this gives a chance to increase a resection rate. Extended EET transpterygoid approach permits delineation of the posterior resection margin under direct control and magnified view and provides the possibility for increasing the volume of excision [12]. With EET transpterygoid approach, we achieved gross total resection in 12 (30.7%) cases. When amenable to radical excision as a cancer is involving the maxillary sinus, typically treatment starts with surgery followed by adjuvant radiotherapy with chemotherapy [2, 10, 11, 15, 16]. All our patients received radio- and chemotherapy according to the standard protocols. EET approach can be extended by transpterygoid procedures to customize in accordance with the prevalent tumor growth. The pterygopalatine fossa tumors can be removed using EET transpterygoid approach, gross total resection was achieved in 77.8% (n = 7) cases.

We applied EET extended transpterygoid approach for clival/paraclival tumors. A surgical corridor which was created with this approach can be expanded by removing the maxillary sinus medial and posterior. This selective technique is demonstrated on ***Fig. 1***.

Alberto Deganello et al. [6] highlighted the benefits of endoscopic endonasal approach extended via the maxillary sinus rout to reach malignant tumors spreading to the external skull base. Tumors of pterygopalatine fossa can be removed using EET transpterygoid approach, gross total resection was achieved in 77.8% (n = 7).

Extended endoscopic endonasal approaches take more time, require knowledge of sellar, sphenoid sinus anatomy, pterygopalatine fossa and sino-paranasal anatomy. Though the extended EET approaches are time-consuming they are effective as complication rate is low enough — 12.1% (n = 5) cases for this challenging skull base pathology. The complication rate for this pathology could be as high as 16% [15]. The cavernous segment of the ICA is most often injured and the mortality rate due to ICA injury is currently 10% [16]. In our cases, no ICA injury was observed.

Case presentation

Case 1

Patient G. 35 yrs. was hospitalized with numbness at the right sight of the face. The symptom onset was over one month. After MRI scans with gadolinium performed, right-side petroclival tumor with the cavernous sinus extension was identified ***(Fig. 2A, B)***. The extended EET transethmoidal approach was performed. Posterior ethmoid cells were removed and a paraclival segment of ICA was identified. Drilling the inferior wall of sellae turcica laterally on the right side, as well as inferior anterior wall of the cavernous sinus and lateral clivus was performed. The tumor was identified and totally removed in a few pieces. The paraclival segment of ICA was identified. Muscle graft was placed into the cavernous sinus for hemostasis. MRI scans after 6 months showed a gross total tumor resection ***(Fig. 2C, D)***. No postop radiotherapy. No complications after surgery. The numbness in the face regressed in one month after surgery.

Case 2

Patient S. 59 yrs. presented with headache, progressive visual loss and visual field deficit. The symptom onset was over one month. After MRI scans done, a giant pituitary adenoma was revealed with supra-infrasellar extension into the sphenoid sinus, extending to the cavernous sinus Knosp 4 on the right side ***(Fig. 3A,***

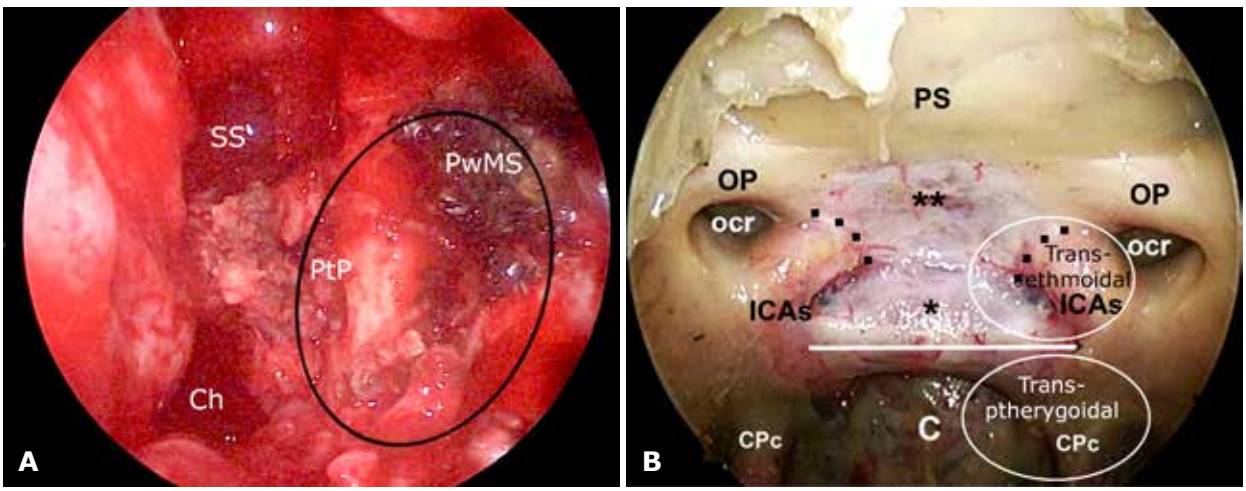

Fig. 1. A: SS — sphenoid sinus, PtP — pterygopalatine process, PwMS — posterior wall of maxillary sinus, Ch — choana, PS — planum sphenoidale; B [17]: * — pituitary gland, ** — tuberculum sellae; OCR — opto-carotid recess, OP — optic protuberance, ICAs — internal carotid arteries, CPc — paraclival segment of internal carotid artery, C — clivus

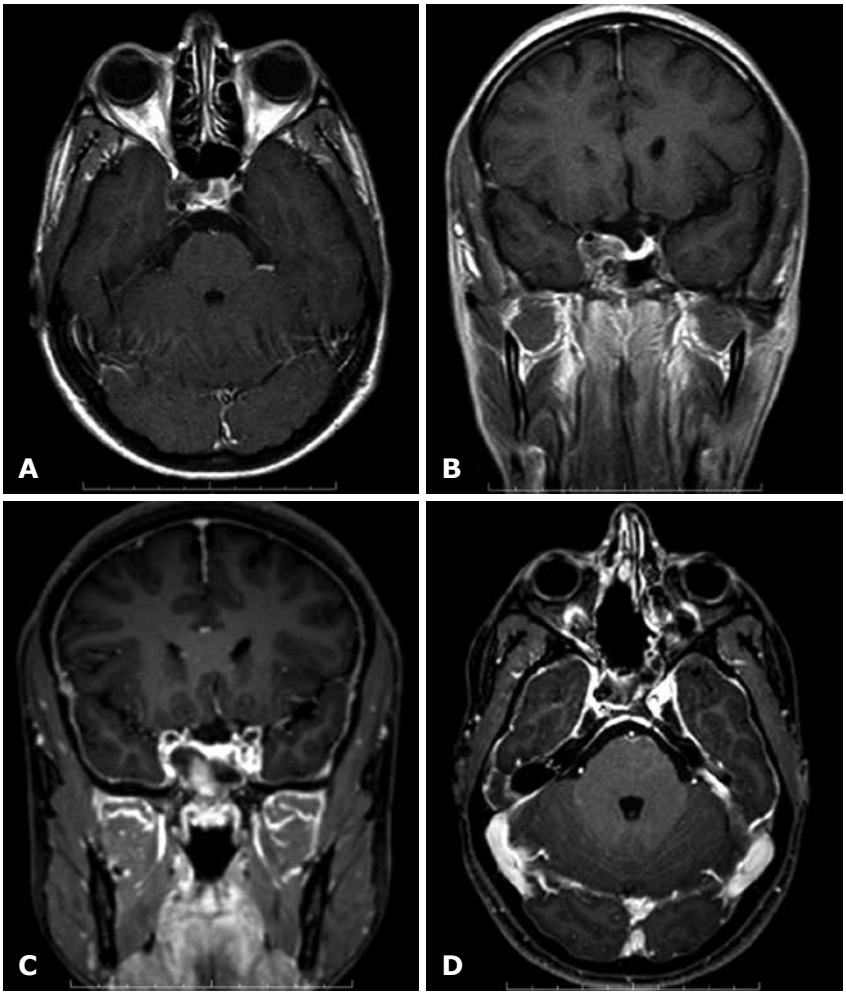

Fig. 2. MRI scans with gadolinium of a petroclival tumor with the right cavernous sinus extension. A, B — preoperative axial and coronal T1 weighted images; C, D — postoperative axial and coronal T1 weighted images

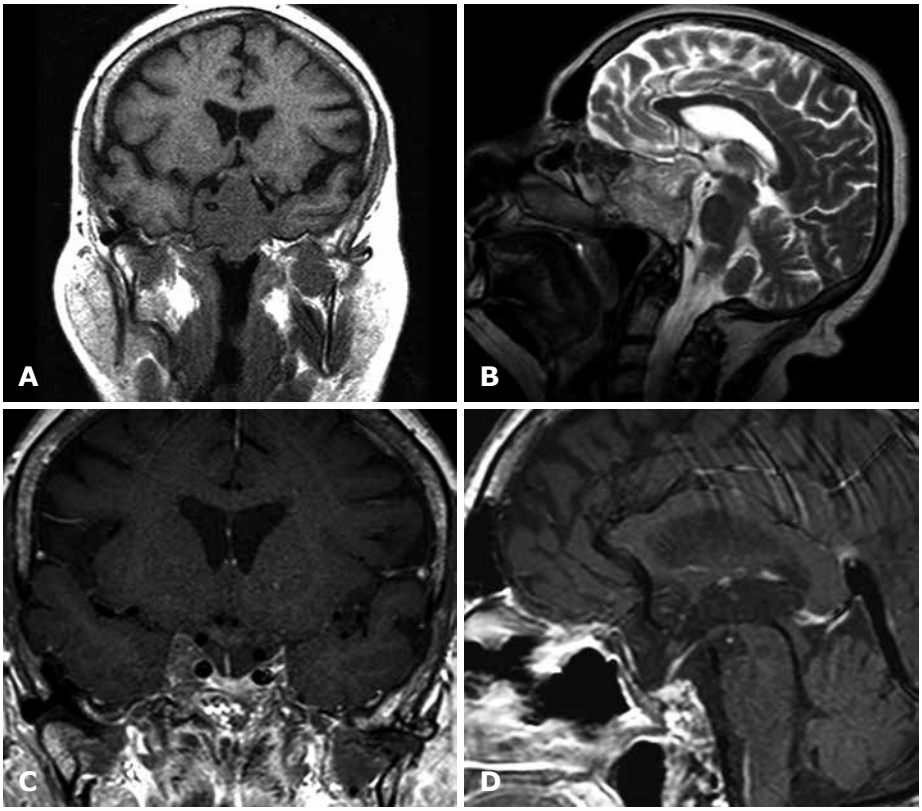

Fig. 3. MRI scans of a giant pituitary adenoma with supra-infra-parasellar extension (into the sphenoid sinus, cavernous sinus Knosp 4 on the right side). A, B — preoperative coronal T1 weighted images and sagittal T2 weighted images; C, D — postoperative coronal and sagittal T1 weighted images with gadolinium

B). Preoperative hormone levels were in normal range. Extended EET transpterygoid approach was performed. During the surgery, the anterior wall of the cavernous sinus was visualized using intraoperative Doppler probe; ICA was identified. Consistency of the cavernous sinus tumor was highly fibrous thus making it difficult to remove tumor totally. MRI scans after 3 months showed residual component in the right cavernous sinus ***(Fig. 3C, D)***. Visual field and side acuity improved after the surgery. No postoperative hormonal disorders.

Conclusions

1. Transethmoidal extended endoscopic endonasal approach is sufficient and good to access the anterior wall of the cavernous sinus improving visualization and better removing of the cavernous sinus tumor extension

2. Transpterygoid extended endoscopic endonasal approach gives good visualization of the pterygopalatine fossa, petroclival region. The endoscopic endonasal transmaxillary approach would further extend laterally into the subtemporal region.

Disclosure

Conflict of interest

The authors declare no conflict of interest.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

The written informed consent was obtained from each patient or appropriate family member before the surgery.

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