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ORIGINAL ARTICLE

Shaping the curve from the microscopic transsphenoidal to the endoscopic endonasal approach for the sellar region

Dando forma a la curva desde el abordaje transesfenoidal microscópico al endonasal endoscópico para la región selar

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Abstract

Objective: *This study aimed to investigate the limitations, barriers, and complications in the early transition from the microscopic transsphenoidal approach (MTA) to the endonasal endoscopic approach (EEA) to the skull base in our institution.* **Methods:** *Technical challenges, as well as clinical features and complications, were compared between MTA, EEA, and mixed cases during the early surgical curve.* **Results:** *The period from the early learning curve was 1 year until the EEA protocol was used routinely. A total of 34 patients registered a resection using a transsphenoidal approach. Eighteen patients underwent EEA, 11 underwent MTA, and five underwent a mixed endonasal and microscopic approach. Non-significant differences were found in endocrine outcomes between the three groups. Patients with unchanged or improved visual function were higher in the EEA group (p = 0.147). Non-significant differences were found in terms of the extent of resection (EOR) between groups (p = 0.369). Only 1 (2.9%) patient in the whole series developed a post-operative CSF leaking that resolved with medical management, belonging to the EEA group (5.5%).* **Conclusions:** *The early phase of the learning curve did not affect our series significantly in terms of the EOR, endocrine status, and visual outcomes.*

Keywords: *Skull base. Endoscopic surgery. Pituitary gland. Middle-income country.*

Resumen

Objetivo: *Investigar las limitaciones, las barreras y las complicaciones en la transición del abordaje transesfenoidal microscópico (ATM) al abordaje endonasal endoscópico (AEE) para la base del cráneo en nuestra institución.* **Método:** *Se compararon las características clínicas y las complicaciones entre ATM, AEE y casos mixtos durante la curva quirúrgica temprana.* **Resultados:** *El periodo desde la curva de aprendizaje inicial fue de 1 año hasta que se utilizó el protocolo AEE de forma sistemática. Un total de 34 pacientes tuvieron una resección por vía transesfenoidal. A 18 pacientes se les realizó AEE, a 11 ATM y a 5 abordaje mixto endonasal y microscópico. Se encontraron diferencias no significativas en los resultados endocrinos entre los tres grupos. Los pacientes con función visual sin cambios o mejorada fueron más en el grupo AEE (p = 0.147). No se encontraron diferencias significativas respecto a la extensión de la resección (p = 0.369). Solo 1 (2.9%) paciente desarrolló una fístula de líquido cefalorraquídeo que se resolvió con manejo médico, perteneciente al grupo AEE (5.5%).*

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Conclusiones: *La fase inicial de la curva de aprendizaje no afectó significativamente a nuestra serie en términos de extensión de la resección, estado endocrino y resultados visuales.*

***Palabras clave*:** *Base del cráneo. Cirugía endoscópica. Glándula pituitaria. País de medianos ingresos.*

Introduction

In 1907, Schloffer described the first case of a transsphenoidal approach for the resection of a pituitary tumor[1]. Initially, Harvey Cushing popularized this approach, modifying the original Schloffer's technique[2,3]. Regardless, its popularity decreased in the following decades, due to the limited light penetration in the narrow surgical corridor and Cushing's complete conversion to transcranial procedures[4]. Despite this trend, some surgeons including Norman Dott and many otolaryngologists continued to use the endonasal path, particularly in Europe. Afterward, Guiot introduced the fluoroscope for intraoperative guidance, which was further complemented with the surgical microscope by Hardy and Wisger[5], contributing to the rebirth of this approach during the 1960s[5,6]. Likewise, Guiot also registered the first transsphenoidal surgery with the use of an endoscope in 1962[1]. In the mid-1960s, Storz and Hopkins created the Storz-Hopkins endoscope, which contributed to the development of endoscopic technology, bringing optical improvements, better visualization, and improved illumination[7]. In the late 1970s Apuzzo et al.[8], in the USA, as well as Bushe and Halves[9], in Germany, started the description of combined microsurgical and endoscopic techniques for better visualization of skull base anatomical landmarks. Later on, Jho and Carrau described their one-nasal fossa technique without the use of a nasal speculum, achieving a purely endonasal endoscopic approach (EEA)[10,11]. Finally, during the late 1900s and early 2000s, former endoscopic schools started to arise, mainly in Italy and the USA, where several groups of neurosurgeons and otorhinolaryngologists started investigating the surgical features, advantages, and limitations of this approach[10-17].

Many features of EEA, including the imaging magnification, increased visualization of bone and neurovascular landmarks with different angles, without having to retract the brain, and decreasing manipulation of different neurovascular structures, have allowed a global trend to be toward performing purely endonasal endoscopic procedures for the treatment of many skull base lesions[14]. The wide access to endoscopes and instruments for endoscopic surgery has allowed the implementation of these procedures worldwide[18-21]. Other instruments including the neuronavigation system and intraoperative vascular micro-Doppler have empowered these approaches to allow surgeons to achieve a maximal safe resection of these lesions[18,22]. Trends moving forward to EEA have demonstrated the importance of the availability of adequate instruments and surgical experience to achieve satisfactory results. Unfortunately, many socioeconomic limitations slow down the capacity to develop education and perfection of these techniques in low- and middle-income countries (LMICs). This study aims to describe the learning curve and the experience of the transition between the traditional microscopic transsphenoidal approach (MTA) and the EEA for the resection of sellar lesions with suprasellar extension in a middle-income country center.

Materials and methods

Clinical features and study design

This is a cross-sectional study that reviews a prospective acquired case series that included patients surgically treated with endonasal transsphenoidal approaches at our institution between January 2018 and January 2019. Despite we have been using EEA for 6 years now, only a small group of cases were carefully selected based on detailing the dates of use of the MTA in our institution and the start of using the endoscope for the resection of sellar tumors up to the standardization of purely endoscopic resection of these lesions, as those cases going further in time (retrospectively with MTA and prospectively with EEA) will analyze different data like expertise and challenges of treating more complex cases over the tailored surgical curve. The analysis of this study is focused on the transition curve rather than comparing two different techniques. This analysis implies the selection of only a few cases. Patients scheduled for elective surgery and those who presented directly to the emergency department were included in the study. Patients over 18 years old with sellar lesions, with or without suprasellar extension that underwent endonasal transsphenoidal surgery were selected. These patients were divided into three groups: the MTA group, the EEA group, and a group of patients where a combination of both techniques was used in the same procedure. Patients who received medical management for sellar or suprasellar lesions (e.g., prolactinomas that responded to medical treatment with cabergoline) or patients in whom transcranial approaches were performed, were excluded accordingly. Authorization by our Institutional Ethics Board as well as by our Institutional Review Board was obtained. This research was performed in accordance with the Declaration of Helsinki. Clinical data were retrospectively collected from medical records including visual outcomes, endocrine function, and complications. Non-parametric tests including two-tailed Student's t test, X^2 analysis, or Fisher's exact test were performed, as appropriate. Tests were considered significant with $p < 0.05$.

Pre-operative protocol

After the neurological assessment, including a visual field testing, a non-enhanced CT of the head/paranasal sinuses, as well as an enhanced MRI of the brain and the sella were performed. In addition, all patients had a preoperative evaluation by the otolaryngology, ophthalmology, and endocrinology teams. All patients were assessed preoperatively with computerized visual fields. The endocrine evaluation consisted of a complete pre- and post-operative work-up, including cortisol, adrenocorticotropic hormone, thyroid function tests (thyroid-stimulating hormone, total, and free T4, total and free T3, when available), growth hormone, insulin-like growth factor 1, prolactin, and gonadal function, including the follicle-stimulating hormone, luteinizing hormone, estradiol, or free and total testosterone according to gender. The diagnosis of diabetes insipidus (DI) was based preoperatively on the patient's symptoms and postoperatively on the patient's last follow-up if he/she was on 1-deamino-8-d-arginine vasopressin replacement. The interpretation of endocrine test results was based on the medical records of the endocrinologist. After finishing the hormonal assessment, and by the thyroid and corticotropic axes, the surgical treatment was further performed. The techniques used for the surgical procedure were either microscopic or endoscopic according to the experience and individual consideration of the neurosurgeon. All surgical procedures were performed by a senior neurosurgeon, a young neurosurgeon, and a senior otolaryngologist. The senior neurosurgeon had significant experience on MTA and the young neurosurgeon as well as the otolaryngologist were trained on EEA. Criteria to decide which approach would be performed were based on attending neurosurgeon's preference. The decision for conversion from EEA to MTA was based on intraoperative recommendation of the senior neurosurgeon if the perception of lack of stereoscopic view or the extent of resection (EOR) was considered not satisfactory.

Microscopic technique

An enhanced CT and/or an enhanced MRI of the head (depending on the pre-operative access to an MRI scanner) are always performed before the procedure. Patients surgically treated with MTA are draped in a usual fashion and operated under general anesthesia. The patient is positioned supine, and the head is slightly rotated and extended for the placement of the nasal speculum. The initial part of the approach is mainly performed by the otolaryngologist and is, in most cases, trans-septal without harvesting any flap. A posterior septostomy and sphenoidotomy are performed. The opening of the sella is done under direct visualization with the use of a chisel or diamond drill until a proper entry to the sella is achieved. Tumor resection is performed using the traditional technique of using different-sized ring curettes and micro pituitary rongeurs (Fig. 1). Resection is continued until the surgeon feels that a reasonable neurovascular decompression is achieved, and a maximal safe resection is completed. Depending on the intraoperative cerebrospinal fluid (CSF) leaking, closure is done with either autologous fat grafting, repositioning of a piece of septal bone/cartilage, and/or the use of fibrin sealant.

Endoscopic technique

The day before surgery an enhanced CT and/or an enhanced MRI of the head (according to the availability and access to the MRI scanner) is performed to use it for neuronavigation. The navigation system equipment used for each case varied according to the insurance company's approval (NDI Polaris system [NDI, Canada] or Fusion [Medtronic, USA]). In contrary to MTA, neuronavigation system was used according to the new availability of new equipment at our institution when this approach was introduced. A Mayfield skull clamp is used for fixation. The initial approach performed by the otolaryngologist consisted of the

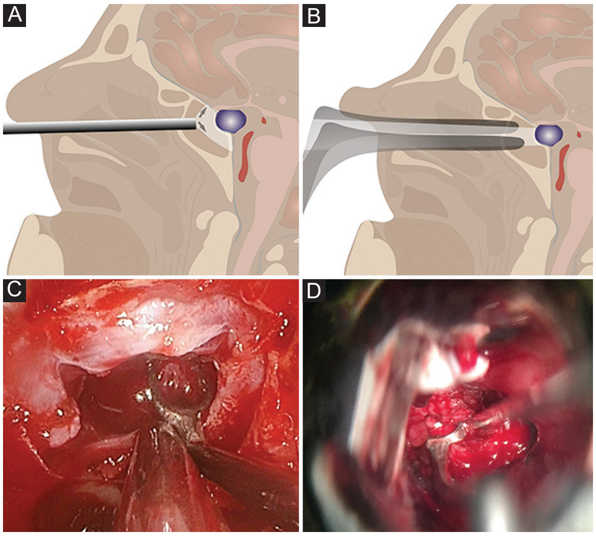

Figure 1. *Microscopic and endoscopic views of the sella.* **A:** *the illumination of the sella with an endoscope is illustrated. Inverted funnel-shaped lighting is observed.* **B:** *an illustration of a microscopic transsphenoidal approach using a nasal speculum is shown. A funnel-shaped illumination of the nasal cavity and sphenoid sinus is illustrated.* **C:** *an endoscopic and a* **D:** *microscopic view of a tumor resection using a ring curette and suction are demonstrated.* Copyright: Édgar G. Ordóñez-Rubiano.

lateralization of the superior and middle turbinate. The nasal septum is infiltrated and a pedicled nasoseptal flap is harvested. At this point of the procedure, the neurosurgeon starts drilling the sphenoidal septum until clear visualization of both opticocarotid recesses, the tuberculum sellae, and the floor of the sella is achieved. A diamond drill and Kerrison forceps are used for adequate bone removal. The dura is usually opened in a wide “X” shape fashion. Resection is performed using micropituitary rongeurs and ring curettes. After resection is done, Floseal or Surgiflo are used for hemostasis if needed. Then, the nasoseptal flap is rotated for adequate closure and covered with a fibrin sealant. Finally, verification of hemostasis in both nasal fossae up to the choana is done, performing a final closure with nasal packing with Surgicel, which is usually removed 2 days after the procedure.

Results

Demographic and clinical characteristics

Thirty-nine patients registered a resection using a transsphenoidal approach in the 1-year period selected for analysis. Five cases were excluded due to a history of a prior transcranial or endonasal resection. Eighteen patients underwent EEA, 11 MTA, and five mixed approaches using both techniques. The demographic and clinical data are presented in table 1. 32 (94.1%) patients had pituitary adenomas and 2 (5.9%) had sellar arachnoid cysts. Non-significant differences were found in terms of the EOR between groups ($p \geq 0.05$). The sellar arachnoid cysts were not included for this analysis. Both cysts underwent marsupialization and cystic volume decreased postoperatively. Only 1 (2.9%) patient in the whole series developed a persistent post-operative CSF leaking that resolved with medical management, belonging to the EEA group (5.5%). Regarding the endoscopic group, 1 (5.5%) patient developed postoperative epistaxis that was treated with anterior nasal packing, 1 (5.5%) patient developed a postoperative hematoma that required evacuation with transcranial drainage, and 1 (5.5%) patient developed a postoperative hematoma with subarachnoid and ventricular draining that resolved spontaneously. From the MTA group, 1 (9%) patient developed seizures due to post-operative cerebral edema and required anticonvulsants and corticoids for seizure control. All endoscopic cases presented crusts during the first 3 months of follow-up. Only one patient persisted after 6 months of follow-up. No patient presented loss of olfaction in this series. Despite trends in an increased length of stay in the endoscopic group given the presence of associated complications, these differences were not statistically significant. Illustrative endoscopic cases are presented in figure 2.

Endocrine and visual outcomes

When evaluating the post-operative endocrine outcomes regarding the anterior pituitary axis in the EEA group, 2 (11.1%) patients developed new-onset hypocortisolism, 2 (11.1%) patients presented with hypogonadism, and only 1 patient (5.5%) had new-onset DI. In the MTA group, 3 (27.3%) patients presented with new-onset hypocortisolism, 1 (9.1%) hypothyroidism, 1 (9.1%) hypogonadism, and 1 (9.1%) had a new-onset DI. No patients presented with a new endocrine deficit in the mixed approach group. Regarding visual outcome, in the endoscopic group, there were 16 (88.9%) patients who improved or had no changes in visual function, and only 2 (11.1%) had a visual function decline. In the MTA group, 8 (72.8%) patients improved or remained with no changes in their visual function, and 3 (27.3%) worsened their function, while in the mixed group, 4 patients (80%) improved or presented no

Table 1. Demographic and clinical information

Variable	MTA (n = 11)	EEA (n = 18)	Mixed (n = 5)	Total (n = 34)	p-value
Gender (no.)					0.099
Female	8 (72.7%)	9 (50%)	2 (40%)	19 (56%)	
Male	3 (27.3%)	9 (50%)	3 (60%)	15 (44%)	
Age (Mean ± ED)	52.3 ± 15.1	50.2 ± 10.1	40.6 ± 16.1		ns
Pathology (no.)					
Functional adenoma	1 (9.1%)	8 (44.4%)	3 (60%)	12 (35.3%)	0.016
Non-functional adenoma	9 (81.8%)	10 (55.6%)	1 (20%)	20 (58.8%)	ns
Other	1 (9.1%)	0	1 (20%)	2 (5.9%)	ns
Tumor volume in cc (Mean ± ED)	2.1 ± 1	9.6 ± 9.2	21.4 ± 27.9		
Extent of resection					ns
Gross total resection	6 (54.5%)	11 (61.1%)	3 (60%)	20 (58.8%)	
Subtotal resection	5 (45.5%)	7 (38.9%)	2 (40%)	14 (31.2%)	
Presenting symptom (no.) Visual disturbances	10 (90.9%)	11 (61.1%)	5 (100%)	26 (76.5%)	ns
Headache	6 (54.5%)	9 (50%)	3 (60%)	18 (52.9%)	
Seizures	0	0	1 (20%)	1 (2.9%)	
Vomit	1 (9.1%)	7 (38.9%)	0	8 (23.5%)	
Hypothalamic/Endocrine	6 (54.5%)	6 (33.3%)	4 (8%)	16 (47%)	ns
Memory loss	0	1 (5.6%)	0	1 (2.9%)	
Amenorrhea	1 (9.1%)	2 (11.1%)	0	3 (8.8%)	
Polyuria/Polydipsia	2 (18.2%)	0	0	2 (5.8%)	

ns: not significant.

changes in their visual function, and 1 patient (20%) worsened (Table 2). However, between approaches, no statistically significant differences were found in visual outcomes (p = 0.147).

Discussion

In our institution, traditional MTA had been used for almost four decades after the introduction of micro neurosurgery in Colombia[23,24]. Previously to the integration of the microscope to the surgical technique, the initial cases were performed using a sublabial approach. However, microscopic amplification exposure allowed to a magnified vision with lower rates of mucosal damage and a progressive transition was done between the two techniques in our institution in the 1980s. Many aspects including the generational change and the progressive socioeconomic development of the region, as well as the introduction of new technologies, have allowed the development of different skull base surgery techniques in Latin America[25,26]. This study describes the clinical, surgical, and endocrine features of the transition from the traditional MTA approach to the EEA. We included cases that were in a frame of time that was dependent of the caseload in the time of transition between both techniques. This may limit an adequate comparison between them in respect to the surgeon's experience based on the number of cases per year. Despite the use of MTA was the gold standard in our institution, there were many cases where the transcranial approach was still used. To allow all cases to be done endonasal, the respective approach transition was performed. We did not compare the results of both large series of patients operated with both techniques in the past 40 years, as this was not the goal of the study, and the analysis would focus only on comparing two different techniques for the same purpose. In the pure introduction of the endoscope (described as a mixed approach), a total of 5 (14.7%) patients required both the microscope and the

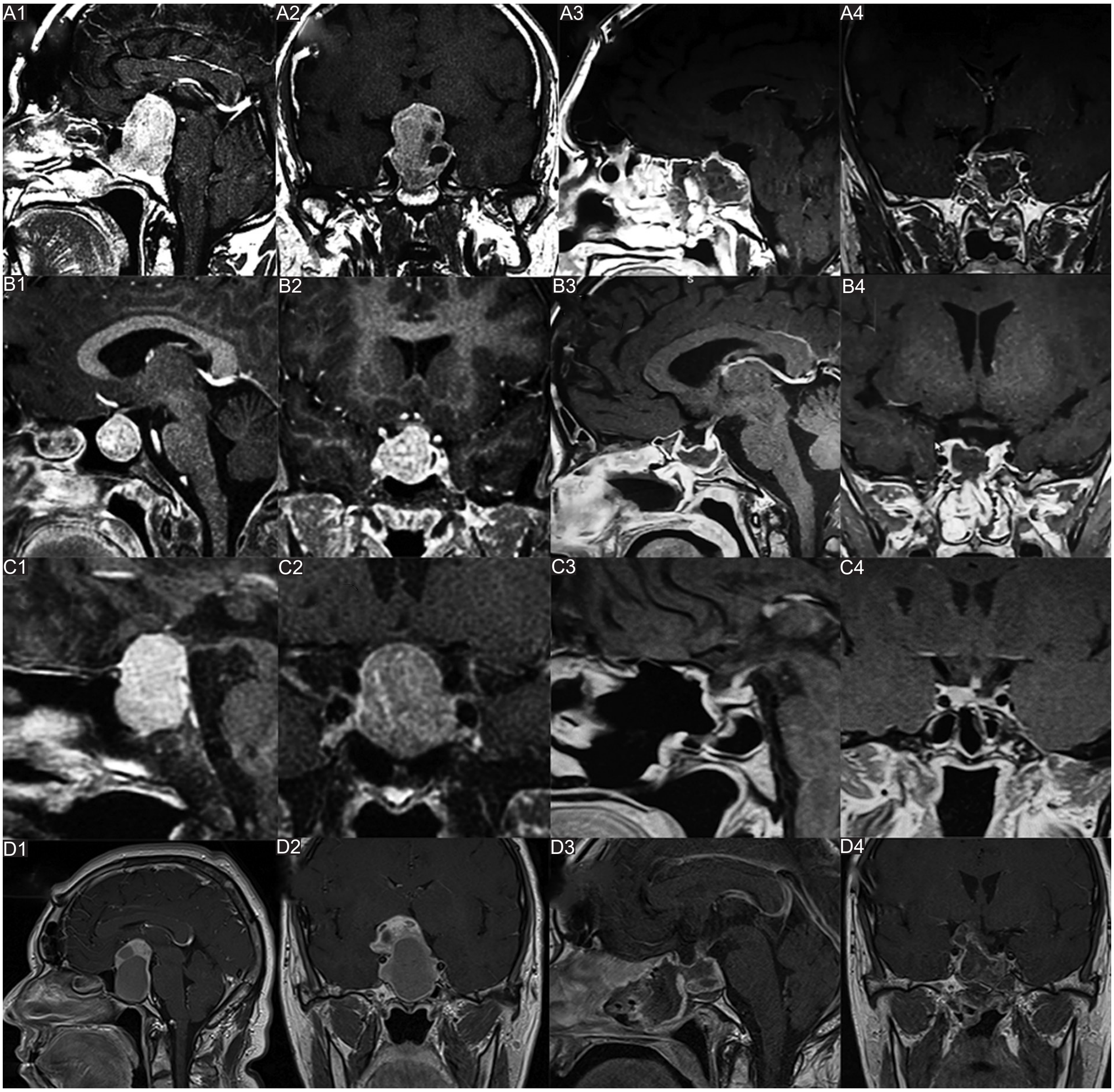

Figure 2. *Pre- and post-operative MRIs of endoscopic resection of pituitary adenomas.* **A:** *case 1: pre- and post-operative-enhanced MRIs demonstrating a near-total resection of a large macroadenoma with extension to the suprasellar space and distorting the floor of the third ventricle. Post-operative images demonstrate the preservation of the pituitary gland and the pituitary stalk.* **B:** *case 2: a rounded macroadenoma is shown. Immediate post-operative images demonstrate a satisfactory tumor resection with preservation of the gland and the stalk.* **C:** *case 3: a macroadenoma compressing the optic apparatus is observed.* **D:** *case 4: a mixed solid and cystic macroadenoma is illustrated. The suprasellar component of the tumor distortions the floor of third ventricle. Post-operative images demonstrate resection of the tumor with satisfactory decompression of the chiasm.*

endoscope for resection. This was a consequence of one or more of the following aspects: (1) the senior neurosurgeon was not satisfied with the EOR due to the lack of stereoscopic view of the endoscope or (2) because surgery time prolongation was imminent due to bleeding or technical difficulties with the endoscope such as the perception of poor lighting. In consequence, the final steps of resection were performed under the microscope. Despite one of the main advantages of the endoscopic technique is the magnified exposure and the better lighting, the perception of lighting was affected by the constant obscuration of the scope with clots in the mucosa of the septum and lateral boundaries of the surgical corridor. This leads to a constant need of cleaning of the endoscope, which may explain the uncomfortable perception of the

Table 2. Visual outcomes and surgical complications

Variable	MTA (n = 11)	EEA (n = 18)	Mixed (n = 5)	Total (n = 50)	p-value
Visual outcome					ns
Improved or nor changes	8 (72.8%)	16 (88.9%)	4 (80%)		
Deteriorated	3 (27.2%)	2 (11.1%)	1 (20%)		
Surgical complications					N/A
Hematoma	-	2 (11.1%)	-		
Nasal bleeding	-	1 (5.5%)	-		
Infection	-	-	-		
CSF leaking	1 (9.1%)	1 (5.5%)	-		
Mortality	-	-	-		
Others	-	1 (5.5%)	-		

ns: not significant; N/A: not applicable.

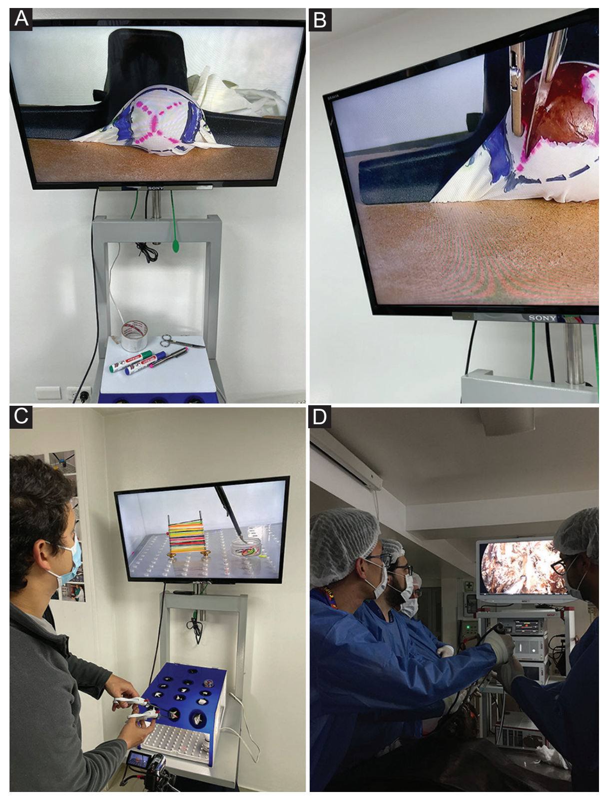

Figure 3. *Endoscopic laboratory practice with biological and non-biological exercises.* **A and B:** *a grape is wrapped with a glove, painting both cavernous sinuses and the site for "dura opening". The instruments are used for cutting both the glove and the skin of the grape for further debulking, using a single port of entry to the practice box.* **C:** *different exercises used for laparoscopic training are used through a single port for two-hand practice.* **D:** *a cadaveric laboratory practice is performed by training the 4-hand technique.*

neurosurgeon, generating the preference to finish the procedure using the microscope. Contrary to the usual learning curve, where the surgeries became endoscopic-assisted, the conversion in our series was more in a microscopic-assisted fashion, as the rest of the procedures were done under the endoscope. This allowed for a better understanding of the complete technique and a faster adaption to the 2D view. To improve assimilation to the endoscopic view and manipulation of the instruments, different strategies were implemented. The activities included: (1) cadaveric drilling and (2) non-biological practice. For non-biological practice, the simulation stations for laparoscopic training were used. For example, some exercises such as using a grape wrapped with a glove were used to resemble the dissection and resection of a macroadenoma (Fig. 3). The cadaveric training was done with a donation of an endoscope and the use of complete cadavers, which were not amenable for injection but were useful for bony anatomy dissection. Unfortunately, the use of heads in Colombia, even for academic and scientific purposes, is prohibited as the law restricts the amputation of cadaveric specimens. Despite this, the biological (with complete cadavers) and non-biological simulation exercises are still used for resident training in our institution. All strategies aim to improve the familiarization of surgeons and residents with the endoscope.

On the other hand, regarding the surgical learning curve, some authors have defined it as "the time taken and/or the number of procedures an average surgeon needs to be able to perform a procedure independently with a reasonable outcome"[27]. When plotting a learning curve, 6 different stages have been described: (1) the commencement of training, (2) a rapidly ascending curve, (3) a point when the procedure can be performed independently and competently, (4) a step where additional experience improves outcomes by small amounts until a (4) plateau is reached, and, finally, (5) there is a fall in the level of performance[28].

For endoscopic skull base surgery (ESBS), the pioneers in the field described their first experience, showing the limitations they had 2 decades ago when endoscopes and other instruments were under important development[29-31]. More recently, Younus et al. described the curve's plateau of ESBS, integrating data of 1000 cases[32]. They described an ESBS learning curve consisting of three phases: (1) the slow ascending curve, (2) the rapidly ascending curve, and (3) a variable plateau. The three different possibilities for the ESBS learning curve's plateau they propose are (1) a "slow ascending" plateau with a persistent acquisition of complex skills, (2) a "flat" plateau with mastery (classic), and 3) a "slow descending" curve if attempting more difficult cases. This was based on the premise that the plateau may last for several years depending on the complexity of the endpoints considered. In terms of the length of the phases of the curve, the exact length of phases I and II cannot be exactly determined[32]. However, 200 cases are the upper limit of most studies of the surgical learning curve[33]. It is important to note that this should be generalized for all scenarios. However, the need for a fast adaption of new technologies is paramount, especially if the caseload is not as high as it is for some reference centers in high-income countries[31,32,34]. Hence, the learning curve for a skull base surgeon in any center with a low- or intermediate load of cases will be likely even slower, and the complexity of cases performed will be limited in the first phases of the learning curve (Fig. 4). In other specialties like robot-assisted laparoscopic surgery, there has been proposed that 30-40 cases are needed to carry out the procedure safely[35]. Here, we also propose that for ESBS~40 cases are needed to reach the safe threshold and complete the phases I and II proposed by Younus et al.[32] The time to perform these 40 cases may vary among centers, as the caseload will determine the number of patients amenable for ESBS. At the early beginning of this curve, we did not perform any extended EEA, as we strongly believe that reconstruction techniques should be mastered before opening the skull base in a wide manner. In our study, in all endoscopic and mixed cases, we performed a nasoseptal flap. We considered at the beginning of our curve that the risk of CSF leaking and/or neuroinfection outweighed the inherent risks associated to the considerable manipulation of the nasal mucosa (e.g., crusts). In addition, we consider that the length of stay as well as the impact in costs in the scenario of a reoperation due to a CSF leak would be appreciated, especially in a middle-economy health-care system, where the resources are scares and should be optimized. We consider that the use of a nasoseptal flap would be a reasonable option in this early phase of the learning curve. In terms of complications, we highlight that risks were considerable higher in the endoscopic group. This is remarkable and need to be considered when starting performing ESBS. Many aspects including manipulation of the endoscope and the instruments, as well as the lack of experience, would impact directly on surgical outcomes. We suggest to make all efforts as possible to avoid resection of large tumors in this transition, given the need of aggressive resections that may lead to avoidable complications.

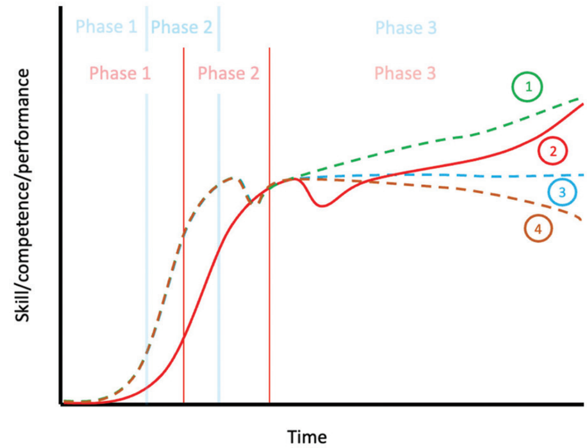

Figure 4. *The surgical learning curve for endoscopic skull base surgery. Phase 1 corresponds to the slow ascending curve, Phase 2 to the rapidly ascending curve, and Phase 3 to a variable plateau. These phases are prolonged in time for low-caseload centers (phases illustrated in red) compared to those for high-caseload centers (phases illustrated in blue). The three different possibilities of the curve's plateau proposed by Younus et al. are presented as a "slow ascending" plateau with a persistent acquisition of complex skills (green-1), a "flat" plateau with mastery-"classic" (blue-3), and a "slow descending" curve if attempting more difficult cases (brown-4). An additional curve is proposed for low-caseload neurosurgical centers (red-2), which corresponds to a slower curve. By the end, the tail of the curve would get to the same as curve 1, as the probable scenario in any center would be to perform more challenging cases over time. This final ascending curve would be related to expanded approaches in the sagittal and coronal planes.*

Our study represents an important description of overcoming barriers to trespassing the threshold of performing ESBS with reasonable outcomes. In general, in LMICs, there is a lack of high-caseload centers. Although some specific exceptions can be found, there is an urgent need to improve outcomes for ESBS in LMICs. Not only the training and the surgeon's expertise are necessary; a multidisciplinary approach including post-operative ICU care and the endocrine approach is fundamental for good results. Unfortunately, in LMICS, the health-care systems, the socioeconomic factors[36], as well as the personal interests of neurosurgeons remain to impact the advancement of the specialty in our region.

In our series, for the transition between the two approaches, the conversion of 21% of cases was needed, as well as the constant training of ENTs and neurosurgeons. Over time, we have been able to decrease the operative time by improving surgical techniques. Special cases in which a microscopic technique is ideal for the patient still exist; some examples are surgeon's comfort and experience, extensive nasal bleeding, atypical airway, or technical problems with the endoscope[37]. Furthermore, for the first cases, we decided to have the microscope prepared in case that it was required by the surgeon. It is important to highlight that all technological aids represent a change not only for the surgeon but also for the surgical team as well, and they represent a way to maximize EOR and minimize the risk of injuring neurovascular structures[13,14]. Our study found a visual function improvement or without changes in 32% of the cases in the entire series, which is a percentage similar to what has been reported in the literature, reporting rates from 16.8% to 79%[38-40]. From an endocrine point of view, both groups had similar outcomes. Published series vary according to different variables including the pathology, intervention as a 1st-time surgery, or re-intervention for recurrent tumors[13,14,40,41]. In this study, anterior and posterior endocrine deficits were no higher than 10%, which is reasonable with those reported in other series as well.

Finally, traditional microscopic transsphenoidal surgery remains trustworthy, fast, and effective. Many neurosurgeons have published excellent results with this technique. It has low complication rates and patient satisfaction is high[41,42]. However, the transition to an endoscopic approach has been growing due to the panoramic view with clear visualization of surgical corridors, bony landmarks, and neurovascular structures, increasing neurosurgeons' confidence to perform ESBS safely[37]. Some series that have compared both approaches since 2015 are presented in table 3. Visual outcomes, EOR, and endocrine outcomes vary among studies. Despite trends in ESBS for improving EOR, there is not sufficient data to support significant variations among both techniques. Unfortunately, different aspects including socioeconomic barriers, caseload, and surgical team expertise will continue to shape surgical results.

Table 3. Studies reporting microscopic versus endoscopic endonasal approaches for sellar and suprasellar lesions after 2015

Authors	Year of publication	Type of country	Period time of the study (years.)	Total cases	EEA cases	MTA cases	Mixed cases	Type of lesions	GTR (%)		Improvement or no changes in visual function (%)		New-onset endocrine deficit (%)		Phases of learning curve assessed
									EEA	MTA	EEA	MTA	EEA	MTA	
Guo-Dong et al.[43]	2016	HIC	7	247	100	147	-	Adenoma	60	58	58[a]	88[a]	21	22	1, 2, 3
Akbari et al[44]	2018	LMIC	3	35	16	19	-	Large (≥3 cm) adenomas	81	16	NR[b]	NR[b]	31	37	1, 2
Prajapati et al[45]	2018	LMIC	NR	30	17	13	-	Adenoma	65	46	100	100	12	27	1, 2
Trevisi et al.[46]	2019	HIC	15	55	27[c]	28	-	Adenoma with parasellar extension	70	29	NR	NR	NR	NR	1, 2, 3
Phogat et al.[47]	2020	LMIC	6	198	119	79	-	Adenoma	70	48	100	98	32	28	1, 2, 3
Møller et al.[48]	2020	HIC	10	240	45	195	-	Adenoma	39	22	37[d]	35[d]	3	34	1, 2, 3
Shimony et al.[49]	2021	HIC	11	87	39	48	-	Adenoma	87	79	36[a]	42[a]	36	27	1, 2, 3
Trimpou et al.[50]	2022	HIC	15	40	26	14	-	Adenoma (Cushing's disease)	62	92	NR	NR	23	36	1, 2

[a]Reported as visual improvement. [b]Visual field improvement was comparable in both groups: 50% of the patients showed improvement in the visual fields 6 months after surgery. [c]Microsurgical sublabial transsphenoidal resection. [d]Reported as normalization of visual function.
EEA: endonasal endoscopic approach; GTR: gross total resection; HIC: high income country; LMIC: low-to-middle income country; MTA: microscopic transsphenoidal approach; NR: not reported.

Study limitations

The main limitation of this study is its retrospective nature. Second, the recurrence rate or tumor progression rate was not evaluated. Cost-effectiveness and quality of life were not addressed either. However, trends of increased costs were noted in the endoscopic group given the rent of the neuronavigation system. This information could have been useful considering the budget limitations in the health-care systems in our region and further research is necessary to contrast this remarkable aspect. No analysis of re-intervention rates due to tumor regrowth was done on follow-up. This study did not measure skill improvement in terms of surgical time but demonstrates the number of cases to feel comfortable to perform purely endoscopic approaches. It is necessary to evaluate the importance of technological help required for these cases since a vascular injury, a new-onset neurologic deficit, or a severe endocrine decline related to these procedures constitute irreparable damage.

Conclusion

The transition between MTA and EEA depends on multiple factors that include training of the surgical personnel as well as the confidence or lack thereof generated by the surgeon's change in position during the procedure, the lack of stereoscopic view of the two-dimensional images of the endoscope, and the lack of security to maximize the EOR. This is most remarkable for neurosurgeons that have prior experience using MTA in a daily manner. The use of either approach will always be based on the experience and consideration of the surgical team. Finally, the early phase of the learning curve did not affect our series significantly in terms of EOR, endocrine status, and visual outcomes.

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Conflicts of interest

The authors declare no conflicts of interest.

Ethical disclosures

Protection of humans and animals. The authors declare that the procedures followed conformed to the ethical standards of the responsible human experimentation committee and in accordance with the World Medical Association and the Declaration of Helsinki.

Confidentiality of data. The authors declare that they have followed their center's protocols on the publication of patient data.

Right to privacy and informed consent. Right to privacy and informed consent. The authors have obtained approval from the Ethics Committee for the analysis and publication of routinely obtained clinical data. The informed consent of the patients was not required because this was a retrospective observational study.

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