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ORIGINAL ARTICLE

Endoscopic endonasal extended transsphenoidal removal of tuberculum sellae meningioma (TSM): an experience of six cases

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Abstract

***Aims.* Tuberculum sellae meningiomas (TSMs) are usually removed through a transcranial approach. Recently, the sublabial transsphenoidal microscopic approach has been used to remove such tumours. More recently, endonasal extended transsphenoidal approach is getting popular for removal of tuberculum sellae meningioma. Here, we describe our initial experience of endonasal extended transsphenoidal approach for removal of suprasellar meningiomas in six consecutive cases. *Materials and method.* Six patients (four female and two male) who presented for headache and visual loss were investigated with MRI of brain that showed tuberculum sellae meningioma compressing visual apparatus. Average size was 3 × 3 cm in three cases and 4 × 4 cm in rest of the three. All patients underwent endoscopic endonasal extended transsphenoidal tumour removal, but in two patients with large tumour, microscopic assistance was needed. Complete tumour removal was done in all cases except one case where perforators seemed to be encased by the tumour and resulted in incomplete removal. The surgical dural and bony defects were repaired in all patients with thigh fat graft. Nasal packing was not used, but inflated balloon of Foley's catheter was used to keep fat in position. *Result.* There was mild postoperative cerebrospinal fluid (CSF) leakage in one patient on the fourth postoperative day after removal of lumbar CSF drain and stopped spontaneously on the seventh postoperative day. There were no postoperative CSF leaks or meningitis in the rest of the cases. In one patient, there was visual deterioration due to pressure on optic nerve by grafted fat and improved within 4 weeks. At 4 months after surgery, three patients had normal vision, two patients improved vision comparing with that of preoperative state but with some persisting deficit; one patient had static vision, no new endocrinopathy and no residual tumour on MRI in five cases but residual tumour in remaining case was static at the end of the ninth month. *Conclusion.* The endoscopic endonasal extended transsphenoidal approach appears to be an effective minimally invasive method for removing relatively small to medium tuberculum sellae meningiomas. With more experience of the surgeon, larger tuberculum sellae meningioma may be removed by purely endoscopic techniques in near future.**

Keywords: neuroendoscopy; operative experience; transsphenoidal removal; tuberculum sellae meningioma; endonasal endoscopic extended transsphenoidal approach

Introduction

Tuberculum sellae meningioma (TSM) is one of the challenging skull base meningioma for a neurosurgeon due to its close relationship with the surrounding vital neurovascular structures. Meningiomas of the tuberculum sellae arise from the limbus sphenoidale, chiasmatic sulcus and tuberculum sellae.[1] The transsphenoidal approach is a well-established method for the surgical removal of intrasellar pathophysiology.[2,3] Lesions situated in the suprasellar space without involvement of the sella turcica have been traditionally approached through a transcranial approach.[4–9] Recently, several authors had described modifications of the microscope-based transsphenoidal approach that extend its reach past the sella into the suprasellar region.[10–18] More recent modification to the transsphenoidal approach had been the use of the endoscope for an endonasal approach that circumvents the need for the microscope and postoperative nasal packing.[19–31] The feasibility of a endoscopic extended transsphenoidal approach to remove tuberculum sellae meningiomas had been reported previously, but the number is still small. Long term result with large number of cases is yet to be published. Here, we report our initial experience of endoscopic endonasal extended transsphenoidal approach for removal of tuberculum sellae meningiomas.

Materials and method

Six patients (four female and two male) who presented for headache and visual impairment and were investigated with MRI of brain (Figs. 1A, 2A–C, 3A and 4A–C) that showed tuberculum sellae meningioma compressing the visual

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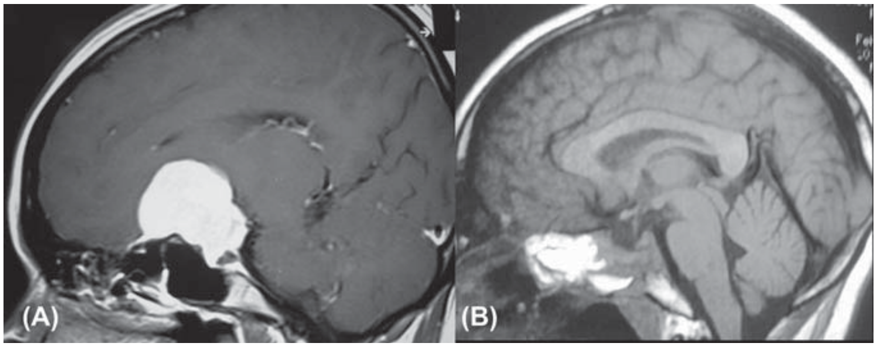

Fig. 1. MRI of brain (sagittal section). (A) Preoperative (TBM) and (B) postoperative (9 months after operation).

apparatus during the period of January 2009 to January 2010 were included in this series. Average size was 3 × 3 cm in three cases and 4 × 4 cm in rest of the cases. All patients underwent endoscopic endonasal extended transsphenoidal tumour removal but in two patients (with larger tumour), microscopic assistance was needed. Complete tumour removal was done in all cases (Figs. 1B, 2C–E, 3B and 4C–E) except one where perforators were seemed to be encased by the tumour and resulted in incomplete removal. The dural and bony defects of skull base were repaired in all patients with thigh fat followed by lumbar (CSF) drain for 3–4 days. Nasal packing was not used but inflated balloon of Foley's catheter was used to keep fat in position. Follow-up CT scan was obtained within 24 hours after surgery (Fig. 4C–E) for identification of residual tumour, postoperative hematomas, pneumocephalus, etc., postoperative follow-up MRI was performed at 3 and 9 months (Figs. 1B and 3B) after operation. All patients underwent visual acuity and visual field assessment (by clinical tests and peritmetry) preoperatively, immediate postoperatively and 3 months after operation. Complete endocrinological evaluation (pituitary, adrenal, thyroid and gonadal axis) was performed preoperatively and postoperatively, 3 months after operation.

Operative details

After introduction of general anaesthesia, the patient was given antibiotics and glucocorticosteroid. A lumbar (CSF) drain was placed. The nasal mucosa was decongested with cottonoids soaked in 0.1% Xylometazolin (topical) solution. Using a 0°, 18-cm long, 4-mm diameter rigid endoscope (Karl Storz), both nasal cavities was inspected. Under endoscopic visualisation, the middle and superior turbinates were resected on right side and retracted laterally on left side, and the sphenoid ostia were identified bilaterally. The posterior 1 cm of the nasal septum was resected using a back bite type of rongeur after fracturing and displacement of nasal septum from rostrum of sphenoid. This resection provided a panoramic view of the sphenoid sinus rostrum and the ostia bilaterally, and allowed the use of both nostrils through which 3–4 instruments could be introduced for the remaining part of the procedure. The mucosa of the sphenoid sinus was removed.

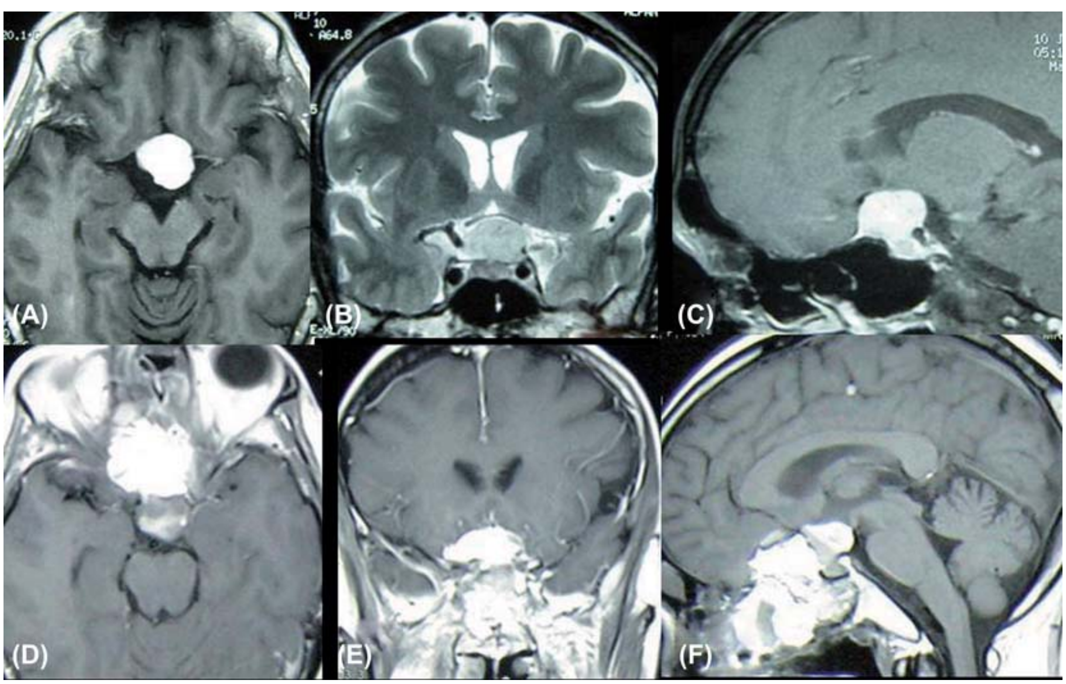

Fig. 2. Preoperative MRI of brain showing TBM; (A) axial, (B) coronal and (C) sagittal view. (D–F) Postoperative MRI of brain on 2nd postoperative day (axial, coronal and sagittal view successively) showing fat graft extending into cranial cavity.

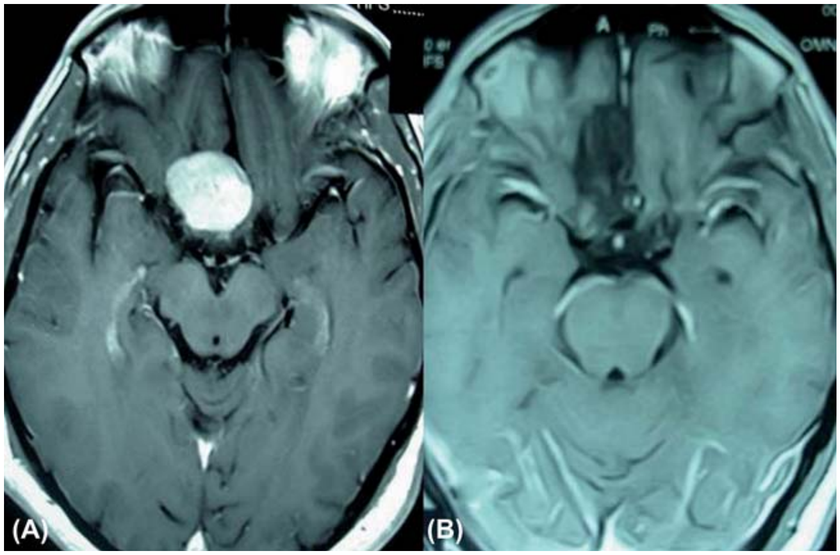

Fig. 3. MRI of brain axial section. (A) Preoperative (showing TBM) and (B) postoperative after 9 months of operation.

The intersinus sphenoid septum/s were also removed using a rongeur forceps. The posterior wall of the sphenoid sinus was thus brought into full view. Then posterior group of ethmoid sinuses were removed and seller floor, optico-carotid recesses, optic and carotid protuberances, tuberculum sellae and planum sphenoidale were clearly identified (Fig. 5A). The upper third of the seller floor, tuberculum sellae, medial part of optic protuberances and planum sphenoidale were removed by using a high-speed drill, curette and Kerrison rongeur. The base of meningioma was identified and coagulated. The dura above and below the intercavernous sinus was opened using a sickle knife, and the sinus was cauterised and transected. Meningioma was immediately visualised once the dura was opened. Internal decompression was performed using surgeon controlled suction and pituitary type micro rongeur. The tumour could be internally decompressed without having to operate around the optic nerves or carotid arteries. Once internal decompression was done, the tumour capsule could be mobilised. The Acom (anterior communicating) artery complex and perforating arteries were dissected sharply off the tumour capsule. The optic nerves and pituitary stalk were clearly seen posterior and inferior to the tumour and were easily dissected off the back of the tumour with preservation of the arachnoidal plane. The remaining capsule was removed completely (Fig. 5B). In one case, the Acom and A2 segments were encased by the tumour and a small part of the tumour was left behind. The resection bed was examined using a 45°, 18-cm long, 4-mm diameter rigid endoscope (Karl Storz) to ensure the absence of any residual tumour. Special care was taken to examine the course of the

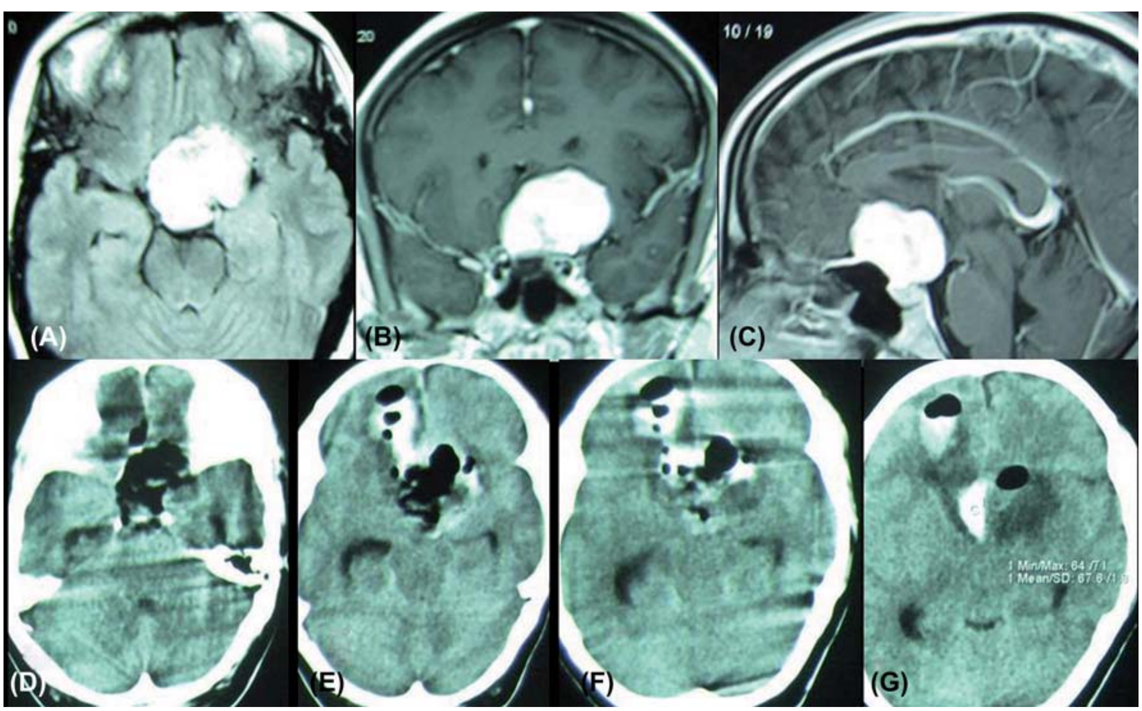

Fig. 4. Preoperative MRI of brain showing TBM; (A) axial, (B) coronal; (C) sagittal view. (D–F) Postoperative CT scan on second postoperative day.

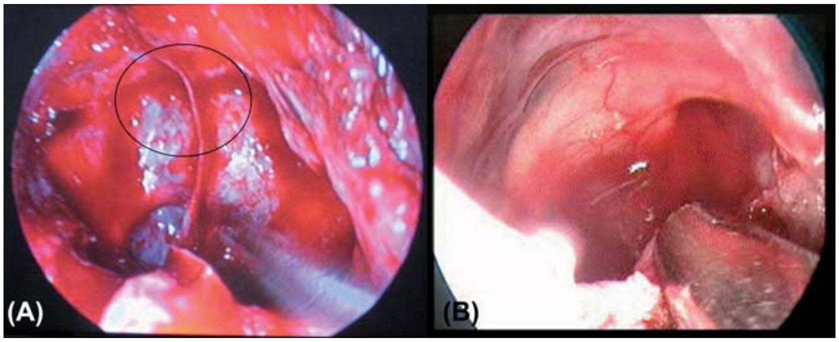

Fig. 5. (A) Preoperative endoscopic view after removal of posterior ethmoidal sinus, anterior wall and floor of sphenoidal sinus showing seller floor, optic protuberance, optico-carotid recess, tuberculum sellae, carotid protuberance and dorsum sella. (B) Peroperative view showing Acom complex and optic apparatus after removal of TBM.

optic nerve to ensure that no residual tumour remained in the optic canal. In two cases, where tumour was larger, after initial decompression and partial removal of tumour capsule, we felt difficulties to proceed further with endoscope, so we removed the residual tumour microsurgically with the help of endonasal speculum. The dural and skull base defects were repaired with thigh fat. The fat graft was larger in earlier cases and relatively smaller in later cases where we buttressed the fat graft by a fascia lata inlay graft. Inflated balloon of Foley's catheter was placed in sphenoid cavity to support the graft. Lumbar cerebrospinal fluid drain was kept for 3–4 days.

Result

The mean follow-up period was 7 months (Table I). There was mild postoperative cerebrospinal fluid leakage in one patient on fourth postoperative day after removal of lumbar drain that stopped spontaneously on seventh postoperative day. There was no postoperative cerebrospinal fluid leak or meningitis in the rest of the cases. In one patient, there was visual deterioration due to pressure on optic nerve by grafted fat as seen in the immediate postoperative CT scan and improved gradually over next 4 weeks. At the end of third month after operation, three patients had normal vision, two patients had improved vision comparing with that of preoperative state but with some persisting deficit, and one patient had static vision as that of preoperative. Two patients developed electrolytes imbalance (hyponatremia) at the end of first week of operation for which one patient became unconscious, and another patient became drowsy. The electrolytes imbalance was corrected accordingly, and patient recovered well. We faced no diabetes insipidus (DI) or new endocrinopathy. There was no residual tumour on postoperative MRI in five cases, and small residual tumour was present in the remaining case that was static in size at the end of ninth month after operation. There was no nose related complications (i.e. epistaxis or breathing difficulties).

Discussion

The history of development of transsphenoidal surgery is very long and well known. Pituitary tumour was initially removed through the transcranial approaches with high mortality and morbidity but later transcranial approaches were replaced by transsphenoidal approach after having long historical events and now many other midline skull base lesions are removing through this approach microscopically or endoscopically.[32–45]

There is a long learning curve for the use of endoscope in neurosurgery and that should be started from neuroanatomical laboratory. The endoscope can provide better illumination, magnification and visualisation than the operating microscope.[34,40,46] Meanwhile, the advantage of angled vision and a panoramic view are crucial for safety of the surgical procedure,[40] where associated complications such as arterial injury, visual deterioration, ocular falsies and dural injury to para- and suprasellar areas can be avoided using the endoscope.[46,47] Moreover, the ability of angled telescope to visualise the para- and suprasellar areas has resulted in better tumour resection.[20,34,38,40] The smaller size of the endoscopic instruments (as compared to microscopic

Table I. Details of patients information.

Case no/sex	Age (years)	Presenting symptoms	Size of lesion (cm)	Resection	Lumbar drain (days)	Dural repair	CSF leak	Other complication/s	F/U (months)
1/male	52	Visual loss, headache	4 × 4	Complete	4	T. Fat	None	Visual deterioration (pressure by fat on optic nerve), improved later	12
2/female	37	Visual loss	2 × 3	Complete	3	T. Fat	None	Hyponatremia, drowsy	10
3/female	29	Visual loss	4 × 4	Incomplete	3	T. Fat	None	None	08
4/male	33	Visual loss	2 × 3	Complete	3	T. Fat	None		06
5/female	46	Visual loss, headache	4 × 4	Complete	4	T. Fat + Fascia lata	Transient, 5th POD, stopped 7th POD	Hyponatremia, Unconscious	O4
6/female	40	Visual loss	2 × 3	Complete	3	T. Fat	None	None	02

CSF, cerebrospinal fluid; F/U, follow up, T, thigh; POD, postoperative day.

Table II. Comparison between different published series of TSM (operated through endoscopic endonasal transsphenoidal approach).

Series		No. of cases	TR/NTR/GTR/STR	Visual outcome	CSF leak	Mortality	DI/other complication
de Divitiis E et al.* (2008)[57,62,63]	1. de Divitiis et al. (2008)[62]	6	GTR-5 STR-1	Visual function normal in all cases (100%)	1(16%) (3 times re-operation needed)	1	Intraventricular hemorrhage-1
	2. de Divitiis et al. (2008)[63]	7	GTR-6 NTR-1	Full recovery in all cases (100%) (Transient worsening-3)	2(28%) (re-operated)	1	DI-1
	3.de Divitiis et al. (2008)[57]	Endonasal-7 (out of 51 TSM)	In endonasal(7)- GTR-83.3%	Improved-71.4% (among endonasal 7 cases; no worsening)	28.6% among the endonasal cases	–	–
	1 + 2 + 3.(same cases were reanalysed in 3 series)	7	GTR-6 NTR-1	Visual function normal in all alive cases (100%)	2	1	DI-1, Intraventricular hemorrhage-1
Gardner et al (2008)[59]		TSM-13 (out of 35 endonasal cases)	In TSM(13): GTR-11, NTR-1, TR-1	All improved (100%) (no deterioration)	40% (14 out of 35)-no Re-operation needed	00	DI-1 (3)%
Wang et al. (2009)[64]		7	TT-6, ST-1	Improved-6(86%), Static-1(14%)	--	--	Recurrence-1
Fatemi et al. (2009)[65]		Endonasal-12 + 2 (supraorbita l-7, both endonasal and supraorbital-2)	NTR-80% (Transnasal endoscopy + microscopy-2)	Recovery-93% Visual worsening-1 (among 14 endonasal)	4(28.5%) (out of 14 Endonasal removal cases)	--	--
Present series		6	TR-5 STR-1	Improved-5(84%) Static-1(16%) (Transient deterioration-1)	1 (16%) (transient)	00	00

TR, total removal; NTR, near total removal; GTR, gross total removal; STR, subtotal removal; DI, diabetes insipidus; endonasal, endonasal transsphenoidal removal; TSM, tuberculum sellae meningioma.
*de Divitiis et al (2008).[57,62,63] – same cases were reanalysed in three series that are integrated as 1 + 2 + 3.

equipments[38]), the ability to change the field quickly to view at the surgical site and more panoramic perspective facilitate permanent monitoring of important anatomical landmarks increase the surgeon's confident.[40]

Potential disadvantage of endoscopic surgery includes the lack of binocular viewing and lack of depth of field, but this can be resolved by visual and tactile feedback, obtained while moving the telescope slightly in and out together with palpation of structures with an instrument under endoscopic monitoring, moreover, this can be compensated by magnification and wider field of view that can be achieved by endoscope.[40,48] The main advantage of microscope over endoscope is depth assessment of surgical field with binocular vision. Another advantage of microscope is both hands of surgeon are free for holding two instruments during tumour dissection. In endoscopy, when surgeon is holding endoscope, he cannot do bimanual dissection but this is not a major problem as surgeon learns quickly dealing of dissection in single hand; when bimanual dissection becomes mandatory then either assistant can hold the endoscope or an endoscope holder can be used. The extended transsphenoidal approach expands operative exposure beyond the sella by removing the tuberculum sellae and the planum sphenoidale.[11,18] The use of this approach to purely suprasellar lesions had been described previously, but most authors reported using a microscope rather than an endoscope, often making a sublabial incision, and applying a transseptal approach.[11–13,15–18,49,50] Even in these reports, the lesions often extended into the sella. Nevertheless, authors of a few of these papers had described the extended transsphenoidal approach for lesions that were entirely suprasellar.[14,16,50] Tuberculum sellae meningioma is a purely suprasellar lesion. Skull base meningiomas (25%) are tuberculum sellae meningioma[1]; traditionally that is approached by transcranial sub frontal or pterional approaches. Nevertheless, the sub frontal route presents disadvantages, which include ligation of the most anterior portion of the longitudinal sinus and, consequentially, of tributary veins, dissection with possible injury to the olfactory nerves, risk of opening of the frontal sinus, development of cerebrospinal fluid (CSF) fistula and meningitis. Many authors prefer the pterional route, as it provides lateral access between the optic nerves (ipsilateral to the optic nerve), with preservation of the olfactory tracts, and represents a short distance to the tuberculum sellae after removal of the greater wing of the sphenoid.[51–53] With the rapid development of neuroendoscopic techniques endoscopic endonasal extended transsphenoidal approach for removal of tuberculum sellae meningiomas are becoming popular; though still only a few numbers of neurosurgeons are operating in this approach. Recently, several authors have proposed the resection of these lesions using minimally invasive ways or with the aid of a surgical microscope or endoscopically guided vision.[11,54–57] Prevedello et al.[58] reported technical notes on successful endoscopic endonasal resection of a synchronous pituitary adenoma and a tuberculum sellae meningioma in 2007.

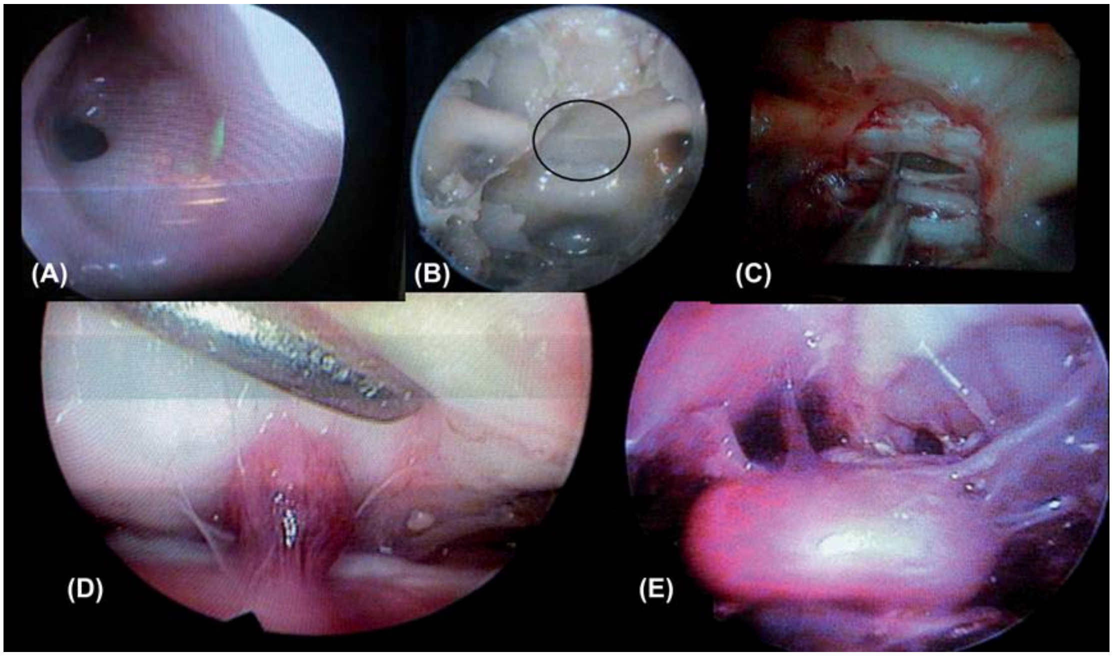

Fig. 6. Cadaveric dissection. (A) Endonasal endoscopic view of spheno-ethmoidal recess and sphenoidal ostium. (B) Endoscopic view after removal of posterior ethmoidal sinus, anterior wall and floor of sphenoidal sinus (circle indicating tuberculum sellae area). (C) Endoscopic view after removal out of anterior seller floor and tuberculum sellae. (D) Elevation of optic chaisma to show pituitary stalk and diaphragma sella and its margin. (E) Exposed pituitary gland after removal of sellar dura.

Gardner et al.[59] reported, a total of 35 patients underwent endoscopic endonasal resection of anterior cranial base meningiomas. Degree of resection by tumour location was as follows: 10 of the 12 (83%) patients with olfactory groove meningiomas underwent gross total (7 of 12) or near-total (>95%) (3 of 12) resection (67% of all 15 olfactory tumours); 12 of 13 patients (92%) with tuberculum meningiomas underwent gross (11 of 13) or near (>95%) (1 of 13) total resection; five patients diagnosed with petroclival meningiomas had successful resection of the parasellar portion of their tumours with relief of visual symptoms; two giant petroclival meningiomas were debulked. All patients experienced resolution or improvement of visual symptoms. Only one (3%) patient developed postoperative permanent pituitary deficit, diabetes insipidus. The postoperative cerebrospinal fluid leak rate was 40% (14 of 35) and varied by tumour location. All leaks were resolved without craniotomy. There was no operative or perioperative death.

Couldwell[11] operated on a series of 105 patients with pituitary tumours, craniopharyngiomas, chordomas and TSMs, among others, using the extended transsphenoidal approach. This author reported a 6% incidence of CSF leakage and four cases of bleeding in the ICA that resulted in one case of cervical carotid ligation. Kabil and Shahinian[55] reported on a series of 28 patients with different pathologies of the sellar region, including craniopharyngiomas, meningiomas and pituitary adenomas. These authors achieved total removal in all but one case in which a small amount of tumour adherent to the optic nerve remained. Kitano et al.[56] reported on 28 patients with TSMs; 12 patients were operated on using the transcranial route, and 16 patients were operated on using the extended transsphenoidal route. CSF leakage was observed in two patients, anosmia was present in two patients and infarct from injury in perforating arteries was observed in two cases. These authors developed a technique in which the fascia graft was placed subdurally to cover the defect, and in some cases, they managed to suture the fascia to close the dural defect. de Divitiis et al.[57] operated on seven patients with TSMs using the transsphenoidal route under endoscopic vision; two (28.6%) patients developed CSF fistula, both requiring re-operation to occlude the fistula.

The advantages of the extended transsphenoidal approach (for tuberculum sellae meningioma) over a classical transcranial approaches are the avoidance of frontal or temporal lobe retraction or sylvian fissure dissection and the possible cerebral injury. In extended transsphenoidal microscopic approach, visualisation is limited by long, narrow retractors due to light source and lens are long away from the operating field.[16] The endoscope overcomes this problem by bringing the light source and lens closer to the surgical lesion along with panoramic view of pathology and surrounding structures. Microscope-based removal of purely suprasellar craniopharyngiomas and meningiomas has been associated with a 20–33% rate of CSF leakage and a gross-total resection rate of only 22–46%.[60,61] Visualisation provided by endoscope is outstanding, and this advantage can minimise the risk of morbidity to vital neurovascular structures and also decrease the risk of CSF leakage because of secure closure aided by improved visualisation. In addition, because of the lens and light source are at the tip of the endoscope, the endonasal approach does not limit visibility in the lateral dimension, as occurs with the microscope. Thus, even extended approaches can be performed with the same minimally invasive, mucosa-sparing endonasal approach, as opposed to the microscope-based approaches that require a sublabial incision and sub mucosal dissection.[16,50] In Table II comparison of results was done between our series and other published series.[59,62–65]

In our small experience, visualisation provided by the endoscope was very good for the extended approach to small and medium size tuberculum sellae meningioma, and we faced some difficulties to proceed further with endoscope in larger TSM where we took assistance of microscope. So for the benefit of patients, where needed, endoscopic surgeon should take assistance of other available facilities (e.g. microscope, navigation, Doppler study, etc.). We believe that the development of the tumour in the midline and the absence of vascular encasement rather than the size of tumour are the main factors for consideration of TSM removal through transsphenoidal route. When a para median development is present or if major arteries are encased in the tumour, a transcranial approach is the better choice for radical removal of the lesion. It is emphasised that extended endoscopic transsphenoidal procedures are not without risk and should be performed only by surgeons with significant experience in both transsphenoidal microscopic and endoscopic surgery, preferably after practising on adequate cadaveric specimens (Fig. 6A–E).

Conclusions

Endoscopic endonasal approaches are being increasingly used for the treatment of pathologies in the anterior skull base including TBMs. The endoscopic endonasal extended transsphenoidal approach appears to be an effective minimally invasive method with less complication for removing relatively small to medium TBMs but positive long term outcome with less mortality and morbidity in large number of patients treated for TBMs in this approach can establish the approach as an ultimate approach for TBMs. We hope that with more experience of the surgeon, all TBMs including larger TBMs can be removed by purely endoscopic endonasal techniques in near future.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

1. DeMonte F. Surgical treatment of anterior cranial base meningiomas. *J Neurooncol* 1996;29:239–48.
2. Jane JA Jr, Thapar K, Kaptain GJ, Maartens N, Laws ER Jr. Pituitary surgery: transsphenoidal approach. *Neurosurgery* 2002;51:435–4.
3. Liu JK, Das K, Weiss MH, Laws ER Jr, Couldwell WT. The history and evolution of transsphenoidal surgery. *J Neurosurg* 2001;95:1083–96.
4. Barrow DL, Spector RH, Takei Y, Tindall GT. Symptomatic Rathke's cleft cysts located entirely in the suprasellar region: review of diagnosis, management, and pathogenesis. *Neurosurgery* 1985;16:766–72.
5. Ciric IS, Cozzens JW. Craniopharyngiomas: transsphenoidal method of approach—for the virtuoso only? *Clin Neurosurg* 1980;27: 169–187.
6. Dyer EH, Civit T, Abecassis JP, Derome PJ. Functioning ectopic supradiaphragmatic pituitary adenomas. *Neurosurgery* 1994;34:529–32.
7. Laws ER Jr. Transsphenoidal microsurgery in the management of craniopharyngioma. *J Neurosurg* 1980;52:661–6.
8. Ross DA, Norman D, Wilson CB. Radiologic characteristics and results of surgical management of Rathke's cysts in 43 patients. *Neurosurgery* 1992;30:173–9.
9. Shillito J Jr. Craniopharyngiomas: the subfrontal approach, or none at all? *Clin Neurosurg* 1980;27:188–205.
10. Cook SW, Smith Z, Kelly DF. Endonasal transsphenoidal removal of tuberculum sellae meningiomas: technical note. *Neurosurgery* 2004;55:239–46.
11. Couldwell WT, Weiss MH, Rabb C, Liu JK, Apfelbaum RI, Fukushima T. Variations on the standard transsphenoidal approach to the sellar region, with emphasis on the extended approaches and parasellar approaches: surgical experience in 105 cases. *Neurosurgery* 2004;55:539–50.
12. Jane JA Jr, Thapar K, Kaptain GJ, Laws ER Jr. The transsphenoidal transtuberculum sellae approach for suprasellar and midline anterior cranial fossa tumors. *Oper Techn Neurosurg* 2002;5:226–30.
13. Kaptain GJ, Vincent DA, Sheehan JP, Laws ER Jr. Transsphenoidal approaches for the extracapsular resection of midline suprasellar and anterior cranial base lesions. *Neurosurgery* 2001;49:94–101.
14. Kato T, Sawamura Y, Abe H, Nagashima M. Transsphenoidal-transtuberculum sellae approach for supradiaphragmatic tumors: technical note. *Acta Neurochir (Wien)* 1998;140:715–9.
15. Kim J, Choe I, Bak K, Kim C, Kim N, Jang Y. Transsphenoidal supradiaphragmatic intradural approach: technical note. *Minim Invasive Neurosurg* 2000;43:33–37.
16. Kouri JG, Chen MY, Watson JC, Oldfield EH. Resection of suprasellar tumors by using a modified transsphenoidal approach. Report of four cases. *J Neurosurg* 2000;92:1028–35.
17. Mason RB, Nieman LK, Doppman JL, Oldfield EH: Selective excision of adenomas originating in or extending into the pituitary stalk with preservation of pituitary function. *J Neurosurg*. 1997; 87: 343–351.
18. Weiss M. Transnasal transsphenoidal approach. In Apuzzo MLJ, ed. *Surgery of the third ventricle*. Baltimore: Williams & Wilkins, 1987:476–94.
19. Cappabianca P, Alfieri A, de Divitiis E. Endoscopic endonasal transsphenoidal approach to the sella: towards functional endoscopic pituitary surgery (FEPS). *Minim Invasive Neurosurg* 1998;41:66–73.
20. Cappabianca P, Cavallo LM, Colao A, de Divitiis E. Surgical complications associated with the endoscopic endonasal transsphenoidal approach for pituitary adenomas. *J Neurosurg* 2002;97:293–8.
21. Carrau RL, Jho HD, Ko Y. Transnasal-transsphenoidal endoscopic surgery of the pituitary gland. *Laryngoscope* 1996;106:914–8.
22. Cooke RS, Jones RA. Experience with the direct transnasal transsphenoidal approach to the pituitary fossa. *Br J Neurosurg* 1994;8:193–6.
23. Frank G, Sciarretta V, Mazzatenta D, Farneti G, Modugno GC, Pasquini E. Transsphenoidal endoscopic approach in the treatment of Rathke's cleft cyst. *Neurosurgery* 2005;56:124–9.
24. Gamea A, Fathi M, el-Guindy A. The use of the rigid endoscope in trans sphenoidal pituitary surgery. *J Laryngol Otol* 1994;108: 19–22.
25. Heilman CB, Shucart WA, Rebeiz EE. Endoscopic sphenoidotomy approach to the sellae. *Neurosurgery* 1997;41:602–7.
26. Jankowski R, Auque J, Simon C, Marchal JC, Hepner H, Wayoff M. Endoscopic pituitary tumor surgery. *Laryngoscope* 1992;102: 198–202.
27. Jho HD, Carrau RL. Endoscopic endonasal transsphenoidal surgery: experience with 50 patients. *J Neurosurg* 1997;87:44–51.
28. Jho HD, Carrau RL, Ko Y, Daly MA. Endoscopic pituitary surgery: an early experience. *Surg Neurol* 1997;47:213–23.
29. Rodziewicz GS, Kelley RT, Kellman RM, Smith MV. Transnasal endoscopic surgery of the pituitary gland: technical note. *Neurosurgery* 1996;39:189–93.
30. Shikani AH, Kelly JH. Endoscopic debulking of a pituitary tumor. *Am J Otolaryngol* 1993;14:254–6.
31. Wurster CF, Smith DE. The endoscopic approach to the pituitary gland. *Arch Otolaryngol Head Neck Surg* 1994;120:674.
32. Giuseppe L, Laws ER. Pioneers in the development of transsphenoid surgery; the Odor Koch, Oskar Hirsh, and Norman Dott. *J Neurosurg* 2001;95:1097–103.
33. Liu JK, Das K, Weiss MH, Laws ER Jr, Couldwell WT. The history and evolution of transsphenoidal surgery. *J Neurosurg* 2001;95:1083–96.
34. Gopal HV. Endoscopic transnasal transsphenoid pituitary surgery. *Curr Opin Otolaryngol Head Neck Surg* 2000;3:43–8.
35. Dew LA, Haller JR, Major S. Transnasal transsphenoidal hypophysectomy; choice of approach for otolaryngologist. *Otolaryngol Head Neck Surg* 1999: 824–7.

36. Ciric IS, Tarkington J. Transsphenoid neurosurgery. *Surg Neurol* 1997;2:207.
37. Marks Steven C. *Nasal and sinus surgery*. Saunders 2001:399–407.
38. Moses RL, Keane WM. Endoscopic transseptal transsphenoid hypophysectomy with 3-D intraoperative localization technology. *Laryngoscope* 1999;109:509–12.
39. Herman P, Lot G, Guichard JP, Marianowski R, Assayag M, Tran Ba Huy P. Mucocele of the sphenoid sinus: a late complication of transsphenoid pituitary surgery. *Ann Otol Rhinol Laryngol* 1998;170:765.
40. Sethi DS, Pillay PK. Endoscopic management of lesions of the sella turcica. J Laryngol Otol 1995;109:956–62.
41. Alfieri A. Endoscopic endonasal transsphenoidal approach to the sellar region: technical evolution of the methodology and refinement of a dedicated instrumentation. *J Nerosurg Sci* 1999;43:85–92.
42. Carrau RL, Jho HD, Ko Y. Transnasal-transsphenoidal endoscopic surgery of pituitary gland. *Laryngoscope* 1996;106:914–8.
43. Cappabianca P, Alfieri A, Thermes S, Buonamassa S, de Divitiis E. Instruments of endoscopic transsphenoidal surgery. *Neurusurgery* 1999;45:392–6.
44. Grifith HB, Veerapen R. A direct transnasal approach to the sphenoid sinus (technical note). *J Neurosurg* 1987;66:104–12.
45. Yaniv E, Rappaport ZH. Endoscopic transseptal transsphenoidal surgery for pituitary tumors. *Neurosurgery* 1997;40:944–6.
46. Kennedy DW, Bolger WE, Zinreich SJ. *Disease of the sinuses*. BC Decker Inc., 213–15, 230–231.
47. Black PM. Zervas NT, Candia GL. Incidence and management of complications of transsphenoid operation of pituitary adenoma. *Neurosurgery* 1997;20:920–4.
48. Koren I, Hadar T, Rappaport ZH, Yaniv E. Endoscopic transnasal transsphenoid microsurgery versus the sublabial approach for the treatment of pituitary tumors. *Laryngoscope* 1999;109:1838–40.
49. Jane JA Jr, Dumont AS, Vance ML, Laws ER Jr. The transsphenoidal transtuberculum sella approach for suprasellar meningiomas. *Semin Neurosurg* 2003;14:211–8.
50. Kitano M, Taneda M. Extended transsphenoidal approach with submucosal posterior ethmoidectomy for parasellar tumors. Technical note. *J Neurosurg* 2001; 94:999–1004.
51. Fahlbusch R, Schott W. Pterional surgery of meningiomas of the tuberculum sellae and planum sphenoidale: surgical results with special considerations of ophthalmological and endocrinological outcomes. *J Neurosurg* 2002;96:235–43.
52. Jallo GI, Benjamin V. Tuberculum sellae meningiomas: microsurgical anatomy and surgical technique. *Neurosurgery* 2002;51:1432–40.
53. Nakamura M, Roser F, Struck M, Vorkapic P, Samii M. Tuberculum sellae meningiomas: clinical outcome considering different surgical approaches. *Neurosurgery* 2006;59:1019–29.
54. Kabil MS, Shahinian HK. Application of the supraorbital endoscopic approach to tumors of the anterior cranial base. *J Craniofac Surg* 2005;16:1070–5.
55. Kitano M, Taneda M, Nakao Y. Postoperative improvement in visual function in patients with tuberculum sellae meningiomas: results of the extended transsphenoidal and transcranial approaches. *J Neurosurg* 2007;107:337–46.
56. Cappabianca P, Cavallo LM, Esposito F, De Divitiis O, Messina A, De Divitiis E. Extended endoscopic endonasal approach to the midline skull base: the evolving role of transsphenoidal surgery. *Adv Tech Stand Neurosurg* 2008;33:151–99.
57. de Divitiis E, Esposito F, Cappabianca P, Cavallo LM, de Diviitis O. Tuberculum sellae meningiomas: high route or low route? A series of 51 consecutive cases. *Neurosurgery* 2008;62:556–63.
58. Prevedello DM, Thomas A, Gardner P, Snyderman CH, Carrau RL, Kassam AB. Endoscopic endonasal resection of a synchronous pituitary adenoma and a tuberculum sellae meningioma: technical case report. *Neurosurgery* 2007;60 (4 Suppl 2):E401.
59. Gardner PA, Kassam AB, Thomas A, Snyderman CH, Carrau RL, Mintz AH, Prevedello DM. Endoscopic endonasal resection of anterior cranial base meningiomas. *Neurosurgery* 2008;63: 36–54.
60. Maira G, Anile C, Albanese A, Cabezas D, Pardi F, Vignati A. The role of transsphenoidal surgery in the treatment of craniopharyngiomas. *J Neurosurg* 2004;100:445–51.
61. Dusick JR, Esposito F, Kelly DF, *et al*. The extended direct endonasal transsphenoidal approach; Dyer EH, Civit T, Abecassis JP, Derome PJ: Functioning ectopic supradiaphragmatic pituitary adenomas. *Neurosurgery* 1994;34:529–532.
62. de Divitiis E, Cavallo LM, Esposito F, Stella L, Messina A. Extended endoscopic transsphenoidal approach for tuberculum sellae meningiomas. *Neurosurgery* 2008;62(6 Suppl 3):1192–201.
63. de Divitiis E, Esposito F, Cappabianca P, Cavallo LM, de Divitiis O, Esposito I. Endoscopic transnasal resection of anterior cranial fossa meningiomas. *Neurosurg Focus* 2008;25:E8.
64. Wang Q, Lu XJ, Li B, Ji WY, Chen KL. Extended endoscopic endonasal transsphenoidal removal of tuberculum sellae meningiomas: a preliminary report. *J Clin Neurosci* 2009;16:889–93.
65. Fatemi N, Dusick JR, Neto MADP, Malkasian D, Kelly DF. Endonasal versus supraorbital keyhole removal of craniopharyngiomas and tuberculum sellae meningiomas. *Neurosurgery* 2009;64(5 Suppl 2):269-84.