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Endoscopic Endonasal Transsphenoidal Exposure of Circle of Willis (CW); Can It be Applied in Vascular Neurosurgery in the Near Future? A Cadaveric Study of 26 Cases

Willis Poligonuna Endoskopik Endonasal Transsfenoidal Yaklaşım; Bu Yaklaşım Vasküler Beyin Cerrahisinde Yakın Bir Gelecekte Uygulanabilir mi? 26 Olguluk Kadavra Çalışması

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ABSTRACT

AIM: Endonasal transsphenoidal approaches are getting rapidly popular in removing many midline skullbase lesions from crista galli to foramen magnum. For safe removal of these lesions, familiarity with endoscopic endonasal anatomy of circle of Willis is very important. Furthermore, for safe development of this approach in vascular neurosurgery in the near future, endoscopic endonasal exposure of circle of Willis is a fundamental step. The goals in this study were to dissect the circle of Willis completely through the endoscopic endonasal approach and to become more familiar with the views and skills associated with the technique by using fresh cadaveric specimens.

MATERIAL and METHODS: After obtaining ethical clearance, 26 fresh cadaver heads were used without any preparation. Using a neuroendoscope, complete exposure of the circle of Willis was done endonasaly, and various observations including relation of circle of Willis was recorded.

RESULTS: Complete exposure of the circle of Willis was made through an endonasal approach in all cases without injuring surrounding structures.

CONCLUSION: Endoscopic endonasal extended transsphenoidal exposure of CW can make the surgeon more efficient in removing midline skullbase lesions with safe handling of different parts of circle of Willis and it may help in development of endonasal endoscopic vascular neurosurgery in the near future.

KEYWORDS: Endoscpic endonasal transsphenoidal, Circle of Willis, Exposure

ÖZ

AMAÇ: Kafa kaidesinde, krista gali ile foramen magnum arasına yerleşmiş orta hat lezyonlarının çıkarılması için endonazal transsfenoidal yaklaşım giderek artan bir popülarite kazanmaktadır. Güvenli bir yaklaşım için bu bölgede Willis poligonunun anatomisinin iyi bilinmesi gereklidir. Bunun yanında bu bölgede endonasal transsfenoidal yaklaşım ile yapılacak Vasküler girişimlerde Willis poligonunun anatomisinin bilinmesi temel bir adım olacaktır. Taze kadavralarda yapılan bu çalışma ile; endonasal transsfenoidal yaklaşımla bu bölge anatomisinin daha iyi anlaşılması ve daha iyi bir teknik geliştirilmesine yardımcı olacaktır.

YÖNTEM ve GEREÇ: Etik inceleme izni sonrası, taze kadavradan elde olunan 26 kafa herhangi bir işleme tabi tutulmadan incelemeye alındı. Nöroendoskop kullanılarak, transnasal olarak Willis poligonuna ekspozür sağlandı ve Willis poligonunun değişik ilişkileri ortaya kondu.

BULGULAR: Tüm vakalarda çevre dokulara zarar vermeden endonazal yaklaşımla Willis poligonu tam olarak ortaya çıkarıldı.

SONUÇ: Genişletilmiş endoskopik endonazal yol ile Willis poligonuna ulaşılması ile hem kafa kaidesi orta hat lezyonları daha güvenli olarak çıkarılabilecek, hem de ilerisi için endonasal vasküler yaklaşımlar için gelişim sağlanacaktır.

ANAHTAR SÖZCÜKLER: Endoskopik endonazal transsfenoidal, Willis halkası, Yaklaşım

INTRODUCTION

In 1962, Thomas Willis was the first scientist to describe the circulus arteriosus, the major blood supply to the brain (45). The circle of Willis has an important role in maintaining a stable and constant blood flow to the cerebral hemisphere (29). The circle of Willis (CW) plays an important role in cerebral hemodynamics as a collateral anastomotic channel, and presence of an intact CW should be more effective in facilitating cross flow compared to situations where there are deficiencies in the CW. There is a close correlation between a low capacity CW and an increased risk of stroke, (4,5,19,23) Collateral ability of the CW is best used when an emergency supervenes, depending on the presence and the size of the luminal caliber of its component vessels (42,43,49). A wide range anatomical variations have been reported on different branches forming the circle of Willis by various authors pertaining to the formation, development and size of the principal arteries (29,44,46,50). The vessels that take part in the formation of the CW are the anterior cerebral, posterior cerebral, anterior and posterior communicating arteries. Endonasal transsphenoidal approaches are getting rapidly popular in removing many midline skullbase lesions from crista galli to foramen magnum. For safe removal of these lesions, familiarity with endoscopic endonasal anatomy of the circle of Willis is very important. Furthermore, for the safe development of this approach in vascular neurosurgery in the near future, endoscopic endonasal exposure of the circle of Willis is a fundamental step. To the best of our knowledge, no study has been conducted to expose the CW bilaterally at the same time by keeping the brain in situ through a transnasal transsphenoidal approach. We therefore conducted this study to see the feasibility of the endonasal endoscopic transsphenoidal approach to expose the CW completely and to study the related observations.

MATERIALS and METHODS

After obtaining ethical clearance, 26 fresh cadaver heads were used without any preparation. Using a neuroendoscope, endonasal extended transsphenoidal complete exposure of circle of Willis was done and different observations including relation of circle of Willis with other neurostructure was recorded.

Details of dissection:

The cadaver head was fixed on the dissecting table with the micropore in slight neck flexion and the face turned to the right. Both nasal cavities were first cleaned by washing with normal saline. Using a 0°, 18-cm long, 4-mm diameter rigid endoscope (Karl Storz), both nasal cavities were inspected. Under endoscopic visualization, the middle and superior turbinates were resected on the right side and retracted laterally on the left side and the sphenoid ostia (Figure1A) were identified bilaterally. The posterior 1 cm of the nasal septum adjacent to the vomer bone was resected using

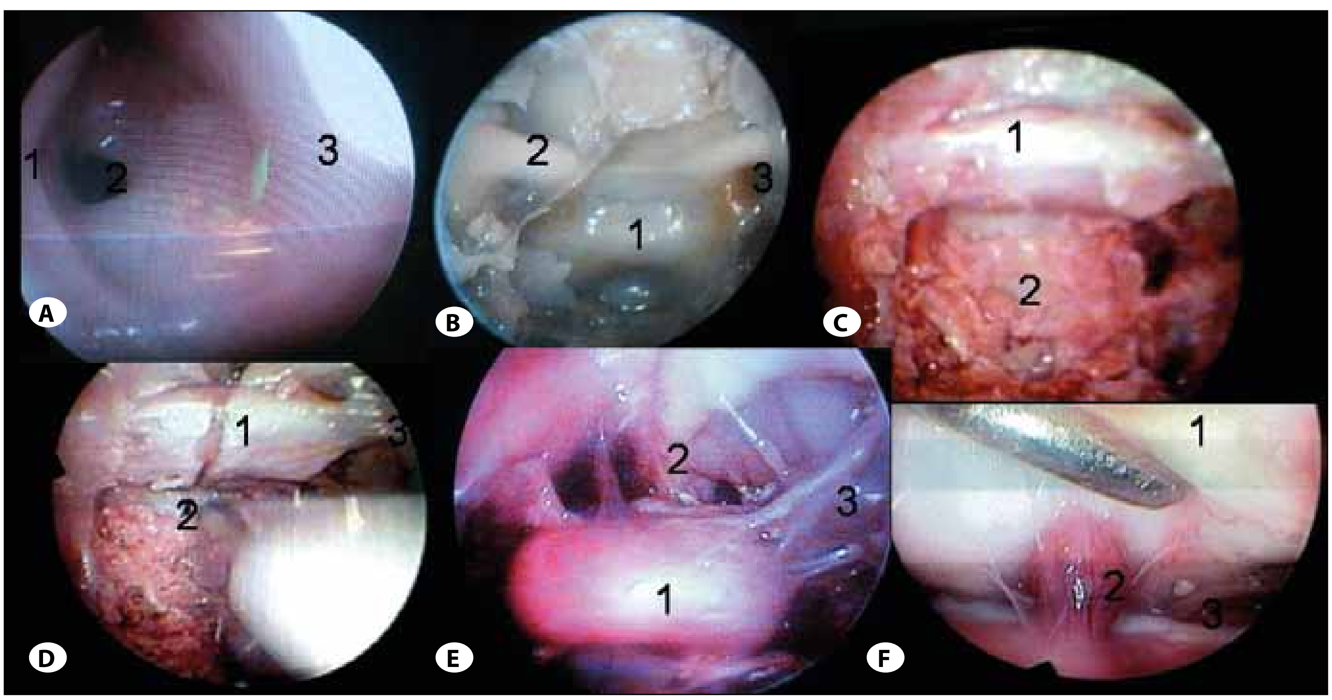

Figure 1: A) Endonasal endoscopic view of spheno-ethmoidal recess.1-sphenoidal ostium, 2-superior turbinate and 3-posterior nasal septum. **B)** Endoscopic view after removal of posterior ethmoidal sinus, anterior wall and floor of sphenoidal sinus. 1-sellar floor, 2-optic protuberance & 3-optico-carotid recess. **C)** Endoscopic view after drilling out of sellar floor, tuberculum sellae and dorsum sellae. 1-pituitary gland inside the dura, 2-upper clival dura. **D)** incision over sellar dura.1-pituitary gland, 2-upper clival dura & 3-cavernous sinus area. **E)** Exposed pituitary gland after removal of sellar dura. 1-pituitary gland, 2-pituitary stalk & 3-carotid artery (cavernous segment). **F)** Elevation of optic chaisma. 1-optic chaisma, 2- pituitary stalk & 3-Diaphragma sellae and its margin.

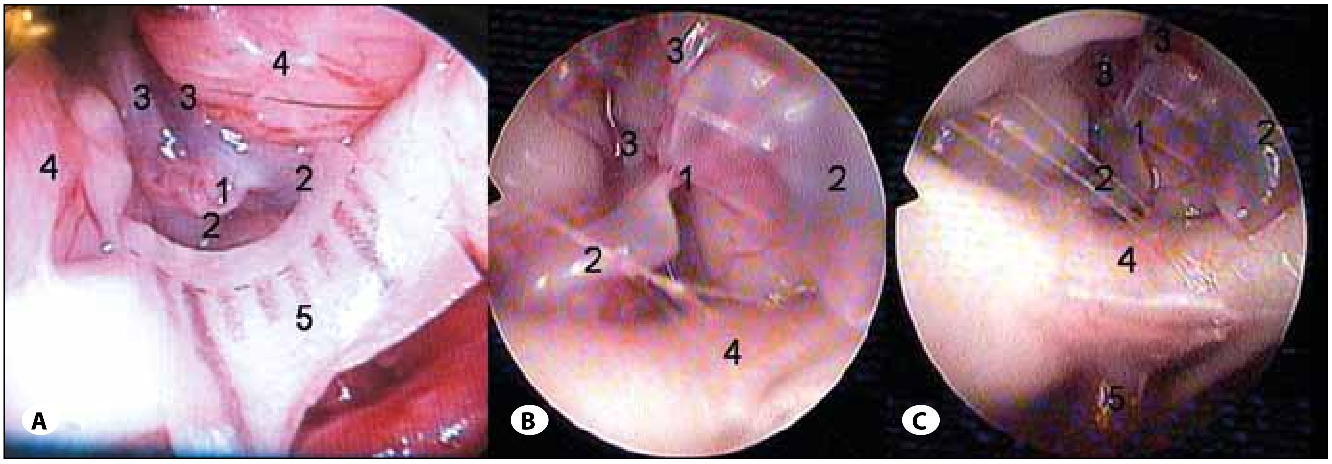

Figure 2: Endoscopic view of anterior communicating (A com) artery complex. **A)**1- A Com, 2-A1, 3-A2, 4-gyrus ractus & 5-paper scale. **B)** 1- A Com, 2-A1, 3-A2, 4-optic chiasma. **C)** 1- A Com, 2-A1, 3-A2, 4-optic chiasma & 5-pituitary stalk.

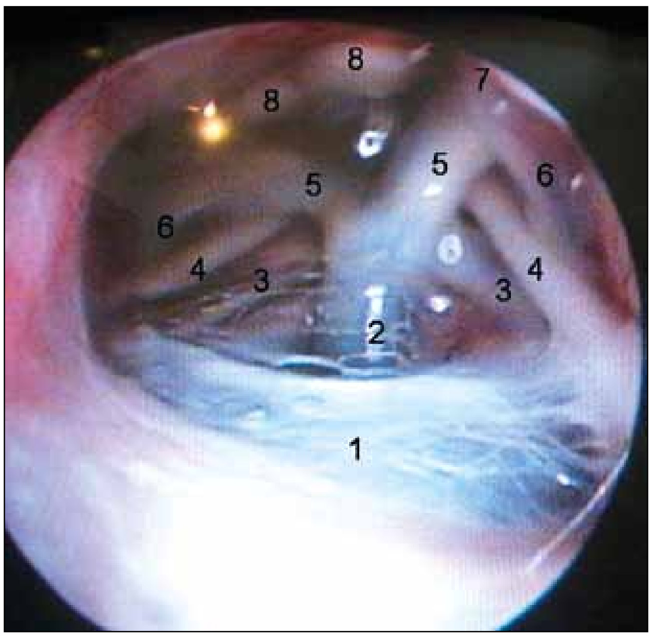

Figure 3: Endoscopic view of posterior part of CW showing a number of anatomnical variations. 1-Liliequist membrane, 2-basilar trunk, 3-SCA (left>right), 4-oculomotor nerve, 5-P1 (left>right), 6-P2 (left>right), 7-fetal type of Pcom & 8-mamillary body. Note-left SCA>P2 and right P2>SCA.

a back bite type of rongeur after displacement of nasal septum from rostrum of sphenoid. This resection provides a panoramic view of the sphenoid sinus rostrum and the ostia bilaterally and allows the use of both nostrils through which three to four instruments can be introduced for the remaining part of the procedure. The mucosa of the sphenoid sinus was removed and the intersinus sphenoid septum/s was removed using a rongeur forceps. The posterior wall of the sphenoid sinus was thus brought into full view. Then the posterior group of ethmoid sinuses were removed. Sellar floor, optico-carotid recesses, optic & carotid protuberances, tuberculum sellae and planum sphenoidale were clearly identified (Figure1B)). The sellar floor, tuberculum sellae, medial part of optic protuberances and planum sphenoidale were removed by using a high-speed drill, curette and Kerrison rongeur. Then the posterior wall of the sphenoidal sinus (upper clivus) and dorsum sellae were removed with the high speed drill and Kerrison punch taking care not to open and damage dura, diaphragma and the carotid arteries in cavernous sinus (Figure1C). The dura above and below the intercavernous sinus was opened using a sickle knife and then the two openings were connected by transecting the superior intercavernous sinus (Figure1D). So dura was opened in 'H' fashion. When the endoscope was introduced intraduraly, anteriorly both optic nerves, optic chiasma were clearly visualized. The pituitary stalk, diaphragma sellae and its aperture including hypophyseal vessels were visualized under the optic chiasma (Figure1E, F).Then looking above the optic chiasma after removing supra and prechiasmatic arachnoid A com artery, right and left part of A1 (distal part), A2 (Proximal part) and sometimes including perforators were clearly visualized and were examined for presence of any anatomical variation (Figure 2A-C). Lamina terminalis was identified below the A com artery with slight elevation of gyrus rectus. Lamina terminalis was incised longitudinally to enter into the third ventricle. Now the endoscope was introduced into the interpeduncular cistern below the optic chiasma, lateral to the pituitary stalk and above the diaphragma sella. Liliequist membrane was then seen below and basilar artery bifurcation and its branches were clearly seen when the basilar bifurcation was above the dorsum sellae (Figure 3). Now under close endoscopic vision the pituitary gland and stalk were freed by dissecting sharply on both lateral side and cutting of attachments of diaphragma taking care not to damage cavernous sinus, pituitary gland & stalk and other neurovascular structures. Pituitary gland and stalk were put in the prechiasmatic area or on one side (cavernous sinus area) to forward the endoscope into retroinfundibular area (Figure 4A-D). Mamillary bodies were seen on each side of midline behind the median eminence and tuber cinereum. Basilar trunk, superior cerebeller arteries (SCA), basilar bifurcation, P1, P2 (proximal part), posterior part of P com, 3rd nerves, pontine belly, crus cerebri were clearly visualized through the arachnoid membrane. Both 3rd nerves were seen emerging from midbrain medial to crus cerebri and passes anterolateraly between SCA and P1, then below and lateral to P com and medial to medial temporal lobe to enter into cavernous sinus through its roof (Figure 4, 5, 6). From the junction of P1 and P2 P com was followed anteriorly up to its entrance in intracranial intradural internal carotid artery (ICA) (Figure 5). Perforators of P Com were seen to go up and medially after originating at its superior-medial surface. The superior hypophyseal artery and ophthalmic artery were seen in only 4 cases with much difficulty. The distal carotid ring was seen as ICA was followed further anteriorly and laterally. When ICA was followed distal to the P com attachment (after retracting medial temporal lobe), the anterior choroidal artery was seen entering into the choroids fissure by passing up, lateral and posteriorly above the P Com. ICA was then further followed to the ICA bifurcation just lateral to the optic nerve, from where M1 started and passed laterally. Only the initial portion of M1 was seen with the endoscope. From the bifurcation, A1 was seen to pass anterior, medial and up. From here the proximal portion of A1 was seen (Figure 5). The middle portion of A1 is very difficult to see with the 0^{o} endoscope due to obstruction of vision by optic nerve. The opposite side was also explored using the same techniques to expose the whole Circle of Willis. Then incompleteness of CW, any asymmetry or anatomical variation was looked for.

RESULTS and OBSERVATIONS

Complete exposure of circle of Willis was made through endonasal endoscopic extended transsphenoidal approach in all cases without injuring pituitary gland and stalk, other vessels, nerves and brain parenchyma in 19 cases. In 3 cases where sphenoid sinus were less pneumatized, removal of the posterior wall of the sinus was time consuming and seemed to be difficult and in two cases the posterior cavernous sinus was exposed without damaging the intracavernous carotid. In 4 cases where dorsum sellae was too high, removal of dorsum sellae seemed difficult and dural tearing occurred in 3 cases without injuring arachnoid. During mobilization of pituitary gland no injury taken place in gland or in stalk in any case. Basilar bifurcation above the dorsum sellae seen in 5 cases, at the level of dorsum sella in 17 cases and below the dorsum sellae in 4 cases. CW was found complete in all cases.

Unilateral P1 hypoplasia seen in 1 case. Unilateral hypoplasia of P1 with persistent fetal P Com in 1 case, Unilateral hypoplasia of PCA with hyperplasia of SCA on that side with hyperplasia of PCA and hypoplasia of SCA on the opposite side in one case. Diameter of pituitary stalk and diameter of basilar artery were seem to be equal in all cases except 4 cases where pituitary stalk seemed to be larger than basilar artery in these case carotid diameter was larger than usual. Observed P com and ACA& A com arteries variations were showed in Table I and Table II respectively.

DISCUSSION

Schloffer reported the first successful transnasal approach to sella in 1906 (20,38). Though Cushing used sublabial transseptal transsphenoidal approach from 1910 to 1925 for pituitary tumor, due to poor illumination, surgical site complication and infection he abandoned this approach in favor of subfrontal transcranial approach (38). Due to Cushing dominancy in that period transnasal approach declined profundly (38,41) Norman Dott, Gerrard Guiot and Hardy brought this approach back to life by means of fluroscopy and microscopes.

During the last two decades the role of endoscopes has been firmly established in the diagnosis and treatment of nasal and sinuses as well as developing surgeons expertise made the use of endoscope, beyond the paranasal sinuses such as sella turcica, seem a logical progression (1,7,10,17,21,27,28,38,48). Busch and Halves reported first use of endoscope for pituitary in the mid 1990s (22,38).

Yaniv and Rappaport described a combined approach in which endoscope is used for initial exposure of sphenoid sinus followed by conversion to standard transsphenoidal microsurgical approach for the tumor resection (52).

The endoscope can provide better illumination, magnification and visualization than the operating microscope (21,32,48). Meanwhile the advantage of angled vision and a panoramic

Table I: P Com Artery Variation (26 cases=52 arteries)

Hypoplasia		Hyperplasia		Persistent fetal P Com		Perforator(relative) free zone of P Com (52 arteries)		
unilateral	bilateral	unilateral	Bilateral	Unilateral	Bilateral	Anterior third	Middle third	Posterior third
4	10	2	0	1 case	x	22	4	26

Table II: Variations of Anterior Cerebral Artery (ACA) and A Com (26 cases=52 ACA &26 A Com)

Variations of ACA				Variations of A Com		
Hypoplasia (A1)	Hyperplasia (A1 &A2)	Unilateral fenestrated A1	Bilateral fenestrated A1	Aplasia/ Fenestrated/ double	hypoplasia	hyperplasia
4	2	1	1	1(double)	10	4

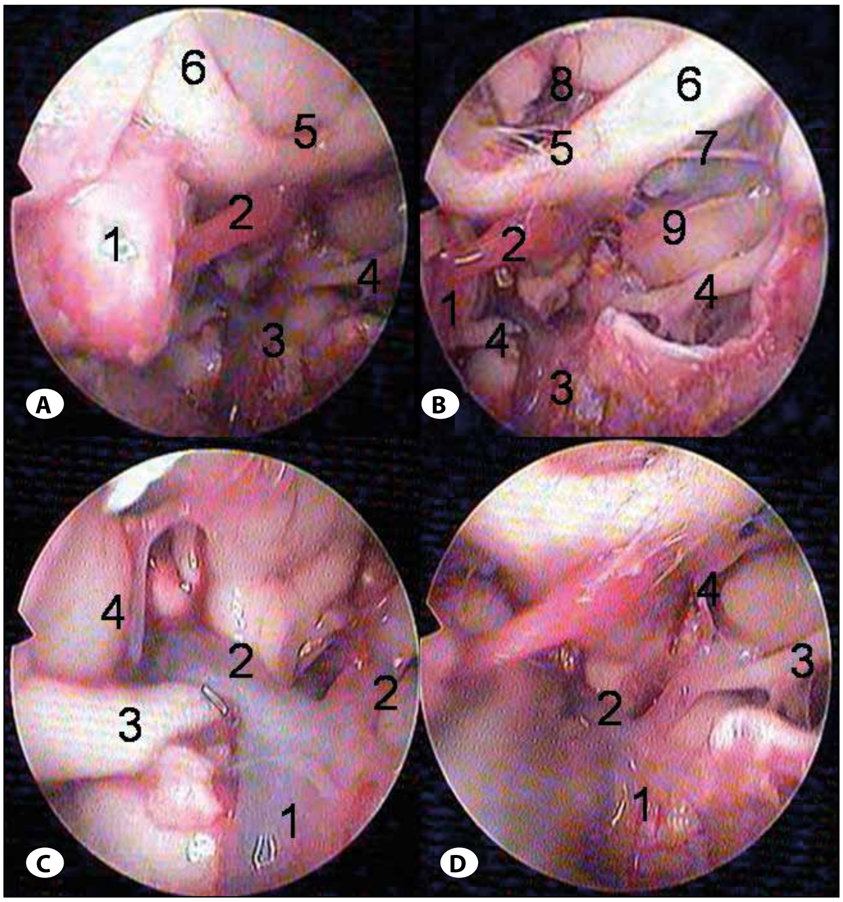

Figure 4: Endoscopic view of interpeducular fossa and posterior part of CW after mobilization of pituitary gland to right cavernous sinus area. **A)** 1-pituitary gland (mobilized), 2-pituitary stalk. 3-Basilar artery, 4-oculomotor nerve, 5-optic chiasma & 6-optic nerve. **B)** 1-pituitary gland (mobilized), 2-pituitary stalk. 3-Basilar artery, 4-oculomotor nerve, 5-optic chiasma, 6-optic nerve, 7-proximal A1 and internal carotid artery, 8-Acom complex, & 9-medial temporal lobe. **C)** 1-Basilar artery, 2-P1, 3-oculomotor nerve, & 4- medial temporal lobe. **D)** 1-Basilar artery, 2-P1, 3-oculomotor nerve & 4-Posterior communicating artery (Pcom)).

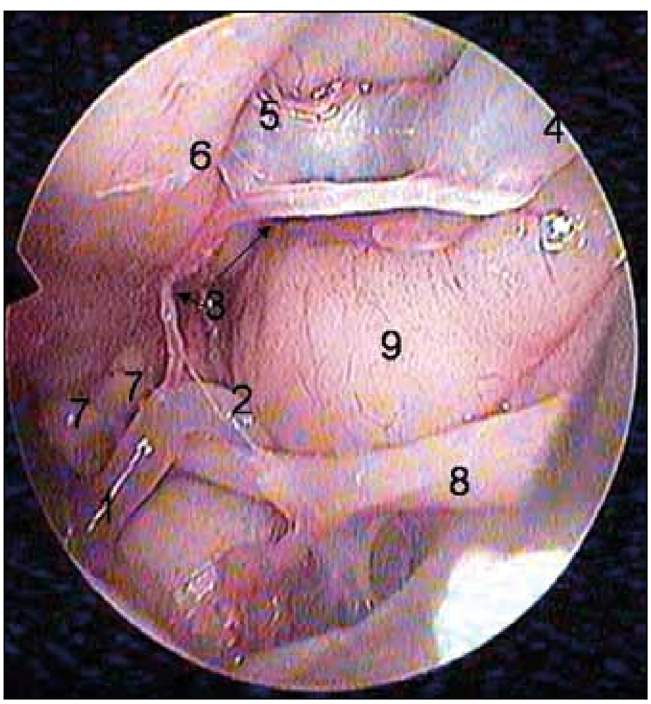

Figure 5: Endoscopic view of left sided of CW. 1-P1, 2-P2, 3-Pcom(arrows), 4-Internal carotid artery (ICA), 5-Proximal A1, 6-optic chiasma, 7-mamillary body, 8-oculomotor nerve & 9-Medial temporal lobe.

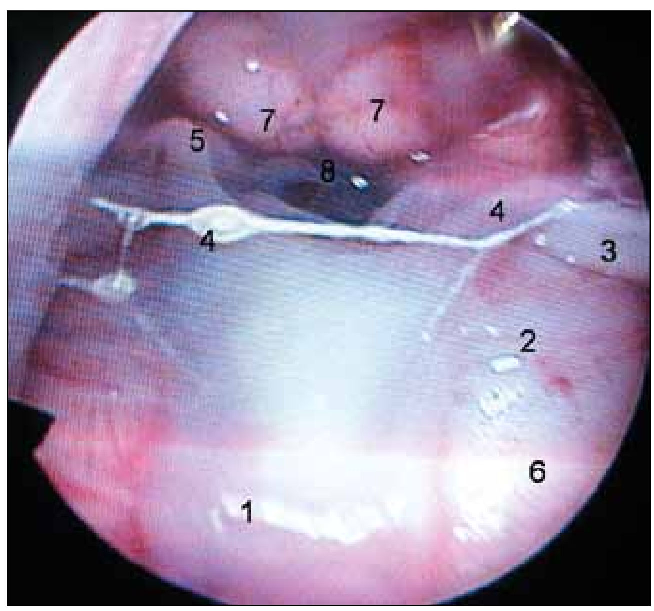

Figure 6: Endoscopic view of interpeduncular fossa and posterior part of CW. 1-Basilar trunk, 2-superior cerebellar artery (SCA), 3-oculomotor nerve, 4-P1, 5-Pcom, 6-basilar pons, 7- mamillary body & 8-Thalamoperforators.

view are crucial for safety of the surgical procedure (48), where associated complications such as arterial injury, visual deterioration, ocular falsies and dural injury to para and supraseller areas can be avoided using the endoscope (6,32). Moreover, the ability of angled telescope to visualize the para and suprasellar areas has resulted in better tumor resection (8,21,40,48). The smaller size of the endoscopic instruments (as compared to microscopic equipments (40)) and the ability to quickly change the field to view at the surgical site and more panoramic perspective facilitate permanent monitoring of important anatomical landmarks increasing the surgeon's confident (48).

Potential disadvantage of endoscopic surgeries include the lack of biocular 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 (35,48).

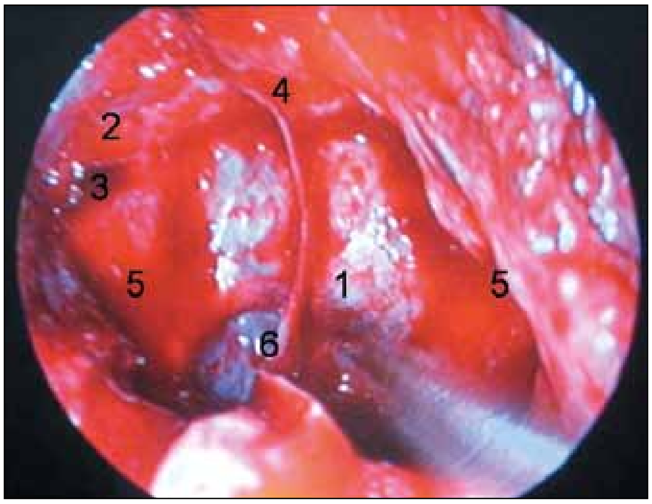

Figure 7: Peroperative endoscopic view after removal of posterior ethmoidal sinus, anterior wall and floor of sphenoidal sinus.1-sellar floor, 2-optic protuberance & 3-optico-carotid recess, 4-tuberculum sellae, 5-carotid protuberance & 6- dorsum sellae.

The main advantage of microscope over endoscope is depth assessment of surgical field with biocular vision. Another advantage of microscope is, both hands of surgeon is free for holding two instruments during tumor dissection. In endoscopy when surgeon is holding endoscope, he can not 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, the planum sphenoidale (13,51) and dorsum sellae. The use of this approach to purely suprasellar lesions has been described previously, but most authors report using a microscope rather than an endoscope, often making a sublabial incision, and applying a transseptal approach (13,25,26,30,33,36,37,39,51) Nevertheless, authors of a few of these papers described the extended transsphenoidal approach for lesions that were entirely suprasellar (31,33,37). Couldwell (13) operated on a series of 105 patients with pituitary tumors, craniopharyngiomas, chordomas, and tuberculum sellae meningiomas, 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 (34) reported on a series of 28 patients with different pathologies of the sellar region, including craniopharingiomas, meningiomas, and pituitary adenomas.

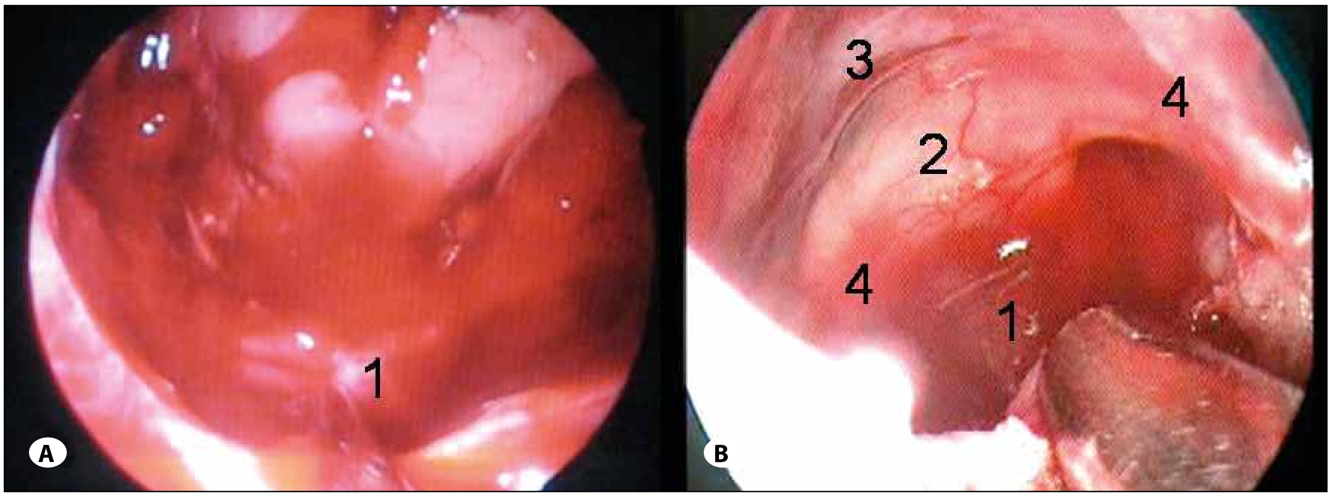

Figure 8: A) peroperative endoscopic view of interpeduncular fossa after endoscopic transsphenoidal removal of craniopharyngima.1-basilar bifurcation **B)** Endoscopic view after endonasal endoscopic removal of tuberculum sellae meningioma.1-pituitary stalk, 2-optic chiasma, 3-Acom complex & 4-optic nerve.

These authors achieved total removal in all but one case, in which a small amount of tumor adherent to the optic nerve remained. Kitano et al. (9) reported on 28 patients with tuberculam sellae meningiomas; 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.

More recently, modifications of the transsphenoidal approach that allow additional exposure of the suprasellar, parasellar, and retroclival spaces have been used for various cranial base lesions (14,15,17). In contrast to traditional cranial base surgical approaches, the endonasal technique offers a direct and minimally invasive approach that allows excellent midline access to and visibility of the suprasellar, retrosellar, and retroclival spaces, while obviating brain retraction (12,15,16).

Recent anatomical studies and clinical reports have detailed the anatomy encountered in the endoscopic endonasal approach (2,3,11,13). Full access to the skull base and the cisternal spaces it encloses is possible with this route, which can extend from the crista galli to the spinomedullary junction, yielding complete visualization of the carotid and vertebrobasilar arterial systems and of all 12 cranial nerves. The technique does require a large opening of the dura mater over the tuberculum sellae and posterior planum sphenoidale, or the retroclival space, and typically results in large intraoperative CSF leaks. This necessitates precise and effective dural closure to prevent a postoperative CSF fistula, with its potential for tension pneumocephalus and meningitis.

Endonasal extended transsphenoidal complete exposure of CW with brain in situ made opportunity to observe the circle for variations and asymmetry. Variation in CW is very common. Hypoplasia of the component arteries of the CW has been reported in anatomic studies ranging from 0.7 % (18) to 80.6%, (47) Variation is most common in A Com and ACA complex, followed by P Com and PCA.

Nowadays endonasal extended transsphenoidal approach is increasingly used for removal of midline skullbase lesions. So during removal of these lesions through this approach dealings of different parts of CW is common (Figure 7, 8A,B). During tumor dissection inappropriate dealing of CW can result injury to a major vessels or injury to perforators of CW that can result unacceptable mortality and morbidity. Orientation with endonasal transsphenoidal view of circle of Willis and its branches is a fundamental step in the learning curve of endoskullbase surgeries, usually that should started from neuroanatomical laboratory. Though there are sporadic reports of endonasal transsphenoidal clipping of aneurysm of CW, but most of them were done due to incidental finding of aneurysm during transsphenoidal surgery due to other pathologies. Scheduled aneurysm surgery are not done through this approach due to difficulty in proximal control of arteries, difficulty in retraction of surrounding brain for safe exposure of aneurysm neck for application of clip, severe difficulties in dealing preoperative rupture of aneurysm, less freedom in handling aneurysm clip and clip applicators, risk of post operative infection and CSF leakage. To use this approach for aneurysm surgery routinely the above mentioned problem must be addressed and overcome properly. In future neurosurgeons may succeed to apply this approach for vascular neurosurgery as endoskullbase techniques are rapidly improving day by day.

CONCLUSION

Endoscopic endonasal extended transsphenoidal exposure of CW can make surgeon more efficient in removing midline skullbase lesions with safe dealing of different parts of circle of Willis and it may help in development of endonasal endoscopic vascular neurosurgery in future but for that tremendous development in techniques is mandatory.

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