

ORIGINAL COMMUNICATION

Endoscopic Anatomy of Sphenoid Sinus for Pituitary Surgery

A. UNLU,^{1*} C. MECO,^{2,3} H.C. UGUR,¹ A. COMERT,⁴ M. OZDEMIR,¹ AND A. ELHAN⁴

¹Department of Neurosurgery, Faculty of Medicine, Ankara University, Ankara, Turkey

²Department of Otorhinolaryngology-Head and Neck Surgery, Faculty of Medicine, Ankara University, Ankara, Turkey

³Department of Otorhinolaryngology-Head and Neck Surgery, Salzburg Paracelsus University Medical School, Salzburg, Austria

⁴Department of Anatomy, Faculty of Medicine, Ankara University, Ankara, Turkey

Endoscopic endonasal transsphenoidal approach to the sellar region yields an alternative to classical microsurgical approaches. Endoscopes provide images that differ from microscopic view. This study aimed to highlight surgical landmarks and their anatomical relationships for pituitary surgery through endoscopic perspective. Ten sides of five adult cadaveric heads with red-colored latex injected arteries were evaluated. Endoscopic dissections were performed and measurements were done in the sphenoid sinuses before and after the removal of bony structures in all the aspects. Endoscopic vision of the sellar region enabled a wide panoramic perspective and detailed inspection. The measurements, in general, indicated the variations in the bony structures and soft tissues. The width of the pituitary, which is the distance between the medial margins of the carotid prominences, was measured as 21 ± 2.5 mm and the distance between the medial margin of the carotid prominences at the lower margin of the pituitary was 18 ± 3.1 mm. After the bony structures were removed, further measurements were done. The width of the pituitary, which is the distance between the medial margins of the anterior curvature of the ICA, was measured as 23.2 ± 3 mm, while the distance between the posterior curvature of the ICA was 19.7 ± 4.9 mm. Endoscopic view provided superior detailed visualization of the close relationships between pituitary gland, internal carotid arteries, and optic nerves. This facilitated exact evaluation for variations, which could result in more effective and safe surgery. However, these variations again emphasize the necessity of preoperative radiological evaluation in each case. Clin. Anat. 21:627–632, 2008. © 2008 Wiley-Liss, Inc.

Key words: sphenoid sinus; pituitary adenoma; anatomy; endoscopy; endoscopic endonasal surgery

INTRODUCTION

Since the beginning of 19th century, transsphenoidal approach has become the most commonly used procedure in surgical treatment of pituitary tumors. Transseptal, sublabial, and direct transnasal approaches have been applied to directly see the sellar region through a tunnel vision via a nasal speculum (Hardy, 1969).

*Correspondence to: Agahan Unlu, Department of Neurosurgery, Faculty of Medicine, Ankara University, 06100, Sıhhiye, Ankara, Turkey. E-mail: agahan@hotmail.com

Received 11 January 2008; Revised 17 May 2008; Accepted 2 August 2008

Published online 23 September 2008 in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/ca.20707

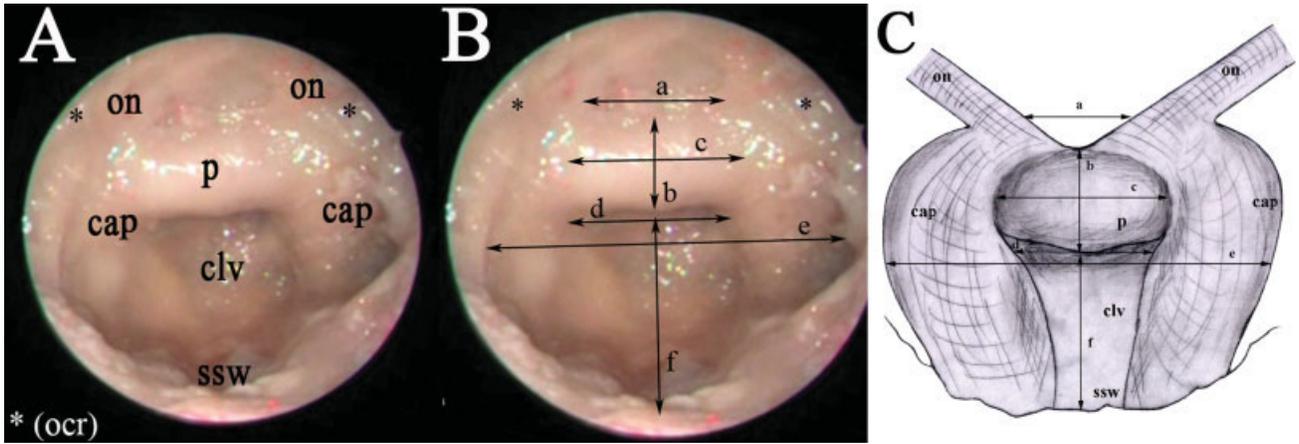


Fig. 1

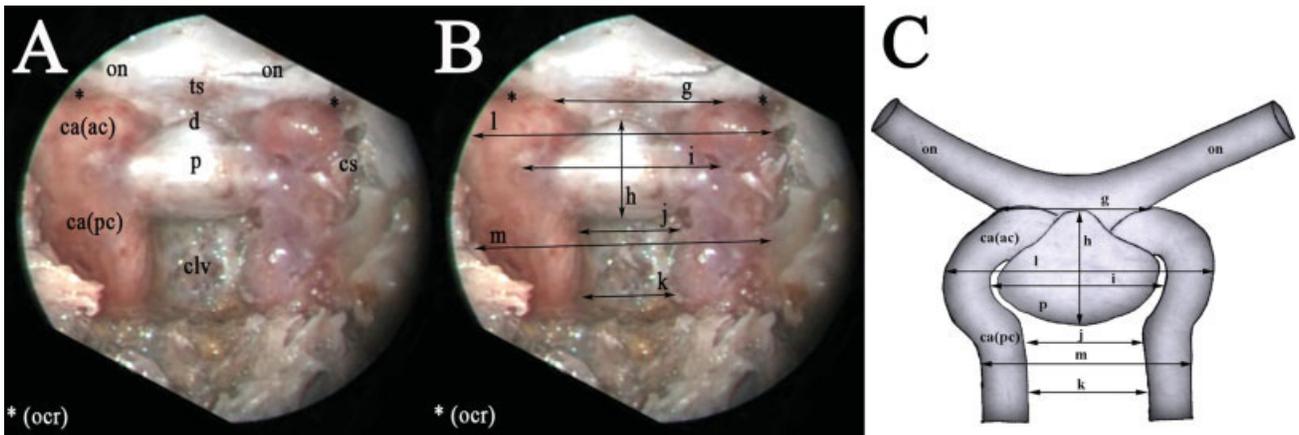


Fig. 2

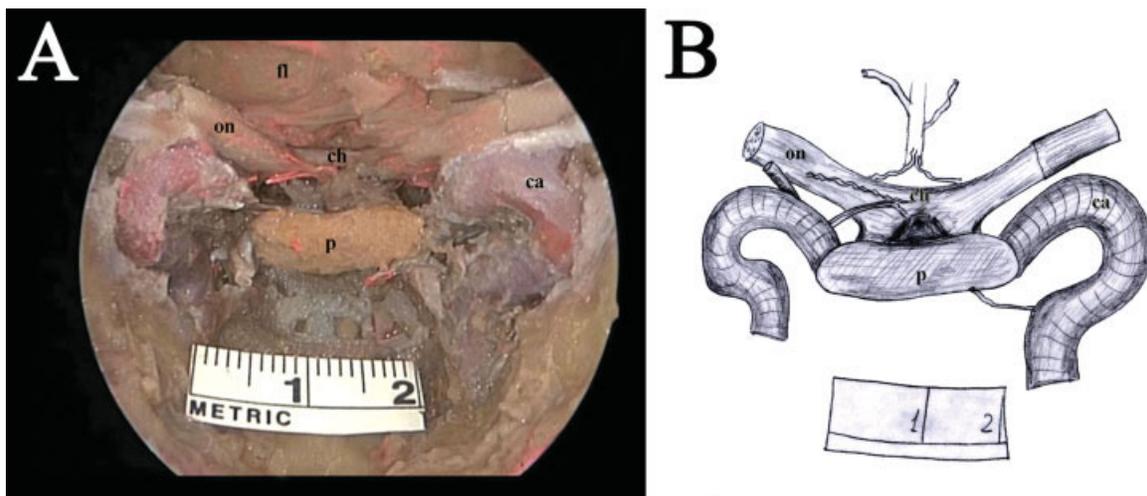


Fig. 3. **A:** Endoscopic view of the frontal basal area. on, optic nerve; ch, chiasm; fl, frontal lobe; p, pituitary gland; ca, carotid artery. **B:** Schematic view of A.

In the early eighties, endoscopes were introduced for nasal and paranasal sinus surgery, which in a very short time revolutionized the management of sinonasal pathologies and became a powerful tool in the hands of otorhinolaryngologists (Stammberger, 1986). Endoscopes, in conjunction with the presentation of computed tomography (CT), allowed a much better understanding of the paranasal sinus anatomy and its relationships to vital structures. Furthermore, advances in instrumentation and confidence gained in endoscopic techniques encouraged surgeons of different disciplines to merge their evolving skills to address various other pathologies including pituitary tumors (Kassam et al., 2005; Lauffer et al., 2007).

First reported around the mid nineties by otorhinolaryngologists, Jankowski et al. (1992) and then by Carrau et al. (1996), endoscopic endonasal transsphenoidal approach to the sellar region tumors has continuously evolved in the last decade as a surgical modality, and thus become a good alternative to the widely used classical microsurgical approaches. Endoscopes provide a widespread and detailed view of anatomical structures, which differ from the microscopic view (Batay et al., 2002; Catapano et al., 2006). Already being used by several centers around the world for its distinct advantages, this approach still signifies an entirely new field for most neurosurgeons. In the learning curve of this endoscopic operative procedure, sphenoid sinus anatomy plays the utmost important role as its bony walls cover several important structures like internal carotid arteries (ICA), optic nerves, and skull base, which should be respected during surgery.

The sphenoid sinuses are cage-like aerated spaces located at a central position along the midline skull base. Because of different types of aeration, they show large variations in the size and shape affecting the three-dimensional anatomical features of their surrounding walls. Behind the bony layer of the walls, which could also be occasionally dehiscent, the ICAs are situated at the mid-lateral walls and the optic nerves at the border of superior and lateral walls.

The projection of the optic nerves at the superolateral corner could sometimes be hidden by well pneumatized posterosphenoid cells challenging identification. The spatial orientation to the landmarks in sphenoid sinuses at any moment of endoscopic dissections during surgery is crucial, in order to avoid injuries which could result in devastating complications like arterial hemorrhages or visual loss. Emphasizing the significance of anatomical knowledge merged with endoscopic spatial orientation, this study aimed to highlight surgical landmarks of the sphenoid sinus and their anatomical relationships for pituitary surgery through an endoscopic view.

MATERIALS AND METHODS

Ten sides of five adult cadaveric heads were evaluated. All the cadavers were adult males aged between 42 and 68. The arteries of the heads were injected with red-colored latex through common carotid arteries. Endoscopic dissections were performed with endoscopic sinus and skull base surgery instruments and with the guidance of 18-cm long rigid endoscopes with 4-mm diameter and 0° and 30° angled lenses that are used for standard endoscopic sinus surgery (Karl Storz Co., Germany). A xenon light source and a single CCD digital video camera were connected to the endoscopes (Karl Storz Co., Germany). The images acquired were displayed on an LCD monitor to enable dissection and simultaneously recorded digitally on a DVD medium. For bony dissections, a high-speed drill system was used (Medtronic Co., USA). The measurements were done on a millimetric scale.

In each cadaver, dissection started with the evaluation of both endonasal cavities. Bilaterally, the sphenoid sinus ostiums were located at the sphenoid recess, medial to the superior turbinates. The sphenoid sinus ostiums were enlarged to facilitate the complete removal of the anterior wall of the sphenoid sinuses up to the level of planum sphenoidale, along with the lower portion of superior turbi-

Fig. 1. A, B: The sphenoid sinus, endoscopic view. Pituitary prominence, carotid prominences were seen. a, the distance between the medial margins of the optic nerves at the level of the opticocarotid recesses; *(ocr) b, the height of the sellar wall; c, the width of the anterior sellar wall, which is the distance between the medial margins of carotid prominences at the longest axis; d, the distance between the medial margins of the carotid

prominences at the lower margin of the anterior sellar wall; e, the distance between the lateral margins of the carotid prominences at the longest axis; f, the distance between the rostrum sphenoidale (the anterior wall of the sphenoid sinus) and the anterior sellar wall, on, optic nerve; p, pituitary; clv, clivus; ssw, sphenoid sinus wall; cap, carotid artery prominences; *ocr, opticocarotid recess. **C:** Schematic view of A and B.

Fig. 2. A, B: Endoscopical view of the sphenoid sinus after removal of the upper and lateral bony structures. g, the distance between the optic nerves at the level of opticocarotid recesses; h, the height of the pituitary; i, the width of the pituitary, which is the distance between the medial margins of the anterior curvature of the internal carotid artery at the longest axis; ts, dura of tuberculum sellae; d, diaphragma sella; p, pituitary; ca-ac, carotid artery anterior curvature; ca-pc, carotid artery posterior curvature; clv, clivus; cs, cavernous

sinus; *ocr, opticocarotid recess, j, the distance between the medial margins of the carotid artery at the inferior margin of the pituitary; k, the distance between the medial margins of the posterior curvature of the carotid artery at the shortest axis; l, the distance between the lateral margins of the anterior curvature of the carotid artery at the longest axis; m, the distance between the lateral margins of the posterior curvature of the carotid artery at the longest axis. **C:** Schematic view of A and B.

nates, as well as the posterior part of the septum and rostrum sphenoidale to expose the widest surgical field under anterior endoscopic view. Thus, bilateral 3 to 4 handed manipulations were facilitated. The pattern of the intersinus septa and other additional accessory septae were recorded according to the posterior termination structure. Then, the intersinus and accessory septae were completely removed, and the anterior wall of the sella was identified. Sphenoid sinus pneumatization and the type of sphenoid sinus (conchal, presellar, and sellar types) were determined. On both sides, along the lateral wall of the sphenoid sinus, optic nerves and ICA (anterior curvature at the superior portion and posterior curvature at inferior portion) were identified along with the opticocarotid recesses. Presence of Onodi cells was also recorded, as these most posterior ethmoid cells pneumatize superolaterally toward sphenoid sinus, pushing the superolateral aspect of the anterior wall of the sphenoid sinus backwards often leaving the path of optic nerves in those cells. As a result, Onodi cells cause postero-inferomedial oblique displacement of the sphenoid sinus anterior wall narrowing the view of lateral wall in the sphenoid sinus, which could interfere with landmark detection.

After defining the bony landmarks of the sphenoid sinus, the following were measured in the first step: a, the distance between medial margins of optic nerves at the level of the opticocarotid recess; b, the height of the sellar wall; c, the width of the anterior sellar wall, which is the distance between medial margins of carotid prominences at the longest axis; d, the distance between medial margins of the carotid prominences at the lower margin of the anterior sellar wall; e, the distance between the lateral margins of the carotid prominences at the longest axis; f, the distance between the rostrum sphenoidale (the anterior wall of the sphenoid sinus) and the anterior sellar wall (Figs. 1A and 1B). Then, bony walls of the sphenoid sinus were drilled and removed in all aspects except the inferior wall of the sphenoid sinus and clivus, leaving only the soft tissues on the lateral walls and the roof. In this second step, following measurements were done: g, the distance between the optic nerves at the level of the opticocarotid recess; h, the height of the pituitary gland; i, the width of the pituitary, which is the distance between the medial margins of the anterior curvature of the internal carotid artery at the longest axis; j, the distance between the medial margins of the carotid artery at the inferior margin of the pituitary; k, the distance between the medial margins of the posterior curvature of the carotid artery at the shortest axis; l, the distance between the lateral margins of the anterior curvature of the carotid artery at the longest axis; m, the distance between the lateral margins of the posterior curvature of the carotid artery at the longest axis (Figs. 2A and 2B).

In the third step, the dura mater of the anterior fossa along the tuberculum sellae and pituitary were removed, and the distance between the optic chiasm and the superior margin of the pituitary was measured (Fig. 3).

RESULTS

Endoscopic dissection enabled fast, uncomplicated, and direct access to the sphenoid sinus. The panoramic large view on the monitor facilitated straightforward recognition of the bony anatomical landmarks. On completely removing the anterior wall of the sphenoid sinuses up to the level of the planum sphenoidale, it was observed that the posterior termination of the intersinus septa and other additional accessory septae ended on the ICA prominence in four cadavers (two on the left and two on the right sides). One was terminating precisely on the midline. According to sphenoid sinus pneumatization, two cadavers had presellar type and three cadavers had sellar type sphenoid sinuses. In all the cadavers, the ON and ICA prominences along with the opticocarotid recess (OCR) and the pituitary bulge in the midline were identified on both sides. In two cadavers, bilateral Onodi cells were encountered.

After identifying the bony landmarks, the distance between medial margins of the ON at the level of the OCR was measured as 12.1 ± 2.4 mm (range: 9.3–16.3 mm). The width of the pituitary, which is the distance between the medial margins of the carotid prominences at its longest axis, was measured as 21 ± 2.5 mm (range: 17.7–24.4 mm) and the distance between the medial margin of the carotid prominences at the lower margin of the pituitary was 18 ± 3.1 mm (range: 11.2–24.9 mm). On sagittal plane, the distance between the rostrum sphenoidale (the anterior wall of the sphenoid sinus) to the anterior wall of the sellar wall was 20.6 ± 1.5 mm (range: 18.9–23 mm). After the bony structures were removed, further measurements were done. The width of the pituitary, which is the distance between the medial margins of the anterior curvature of the ICA at its longest axis was measured as 23.2 ± 3 mm (range: 18.2–25.7 mm), while the distance between the posterior curvature of the ICA at its shortest axis was 19.7 ± 4.9 mm (range: 13.2–26.2 mm). The results of all the measurements in the first and second steps have been presented in Tables 1 and 2. In the third step, the distance between the optic chiasm and the superior margin of the pituitary was measured as 5.3 ± 1.3 mm (range: 3.4–6.9 mm).

DISCUSSION

Earlier studies evaluated the surgical landmarks of the sphenoid sinuses and their relationships with

TABLE 1. The Results of the Bony Landmark Measurements (Fig. 1B)

	Mean \pm SD (mm)	Range (mm)
a	12.1 ± 2.4	9.3–16.3
b	8.7 ± 3.1	4.5–12.6
c	21 ± 2.5	17.7–24.4
d	18 ± 3.1	11.2–24.8
e	28 ± 6.2	20.8–37.4
f	20.6 ± 1.5	18.9–23

TABLE 2. The Results of the Measurements of the Carotid Artery, Optic Nerve, and Pituitary Relationships (Fig. 2B)

	Mean \pm SD (mm)	Range (mm)
g	12.7 \pm 1.1	11.5–14.5
h	7.3 \pm 2.5	4.5–10.3
i	23.1 \pm 3	18.2–25.7
j	19 \pm 4.4	13.5–24.9
k	19.7 \pm 4.9	13.2–26.2
l	36.6 \pm 6.6	29.2–46.4
m	34.2 \pm 6.8	25.8–44.1

neurovascular structures for pituitary surgery in detail. However, most of these anatomical studies were conducted either by sagittal sectioning of cadaver heads or by en-block removal of the sphenoid sinuses and sella turcica (Renn and Rhoton, 1975; Fujii, 1979; Lang, 1989). Afterwards, endoscopic surgeons started to investigate this same area from an endonasal point of view (Jankowski et al., 1992; Sethi et al., 1995; Carrau et al., 1996; Cappabianca et al., 2002, 2004; Kassam et al., 2005; Catapano et al., 2006; Sethi and Leong, 2006; Laufer et al., 2007). Their findings on the intrasphenoidal bony landmarks and the incidence of anatomical variations were similar to the results of earlier nonendoscopic studies. Nevertheless, it was confirmed that use of endoscopes with their panoramic, well illuminated and angled vision, facilitated an improvement for intraoperative recognition of these variations, which allowed altering the approach and technique or the selection of instruments according to the specific anatomic presentation during the surgery of this area as well as in pituitary surgery.

Both the increasing popularity of endoscopic pituitary surgery and recent introduction of expanded endonasal approaches around the sphenoid and sellar regions have emphasized once more the indispensable role of endoscopic anatomical knowledge of the neurovascular structures beyond the bony cage of the sphenoid sinuses (Kassam et al., 2005; Laufer et al., 2007). Because thorough knowledge on the surrounding structures and their relationships with each other as well as on the variations of these structures may eventually affect the success and safety of surgery, the measurements of neurovascular structures were done after the removal of the covering bone. Our measurements showed that the location of these structures (despite having a conventional pattern) could substantially vary, probably related to the extent of sphenoid pneumatization during its developmental period. The shape of the sinuses, optic nerve, and carotid protuberances may also vary. Sometimes there is no bony layer over either optic nerves or carotid arteries (Renn and Rhoton, 1975). In our study, no such bony variations were observed. However, the bone over these structures was sometimes very thin like a translucent membrane. Another finding was that the distance from the sinus ostium to the sellar wall and the width of the sinus might vary depending on different pneumatization grades (Das et al., 2001; de Divitiis et al., 2002). Similarly,

it was determined that the distance between both carotid arteries might also vary significantly below and over pituitary gland. Additionally, as shown earlier, the pituitary gland may overlap the intracavernous carotid artery with a tongue-like projection (Rhoton et al., 1979). Nevertheless, we did not observe such a tongue like extension of pituitary gland into the cavernous sinus. Our measurements also suggest that the distance between the optic chiasm and the superior margin of pituitary after removing the bony layers is normally not adequate for further dissection in between for suprasellar pathologies. Thus, caudal suspension of the pituitary gland is a necessity to gain space, if one desires to proceed through, as suggested by some authors (Kassam et al., 2005; Laufer et al., 2007).

Our dissections under endoscopic view proved once again the feasibility of fully endoscopic endonasal transsphenoidal approach for pituitary surgery in this very narrow area. In spite of the anatomic variations measured, all the important landmarks were identified with the bright illuminated panoramic vision of the sphenoid walls. Knowing the variations, one should also consider alterations in the normal anatomical structures due to pathologies in that region that actually indicates surgery. Thus, preoperative radiological workup certainly enhances the anatomical knowledge and consequently the safety of the endoscopic approach by delineating soft tissue and bony structures before surgery. This additional information guides the surgeons like a roadmap during dissections by giving hints about the surgical anatomy of that specific case. Accordingly, utilization of the same radiological information by computer-assisted navigation systems could also be a very helpful companion to endoscopic dissections, but they should never be a replacement to the anatomical knowledge due to their limitations and pitfalls. In our opinion, another key factor for optimal endoscopic surgery lies in the ongoing multidisciplinary management using 3–4 handed surgical technique, which merges and boosts the best skills of each discipline to achieve the ideal goals.

Endoscopic approaches are exponentially being used in our surgical fields, because of their distinct advantages and efficiency. Hereby, we emphasize once more the importance of anatomical dissections for endoscopic surgery of the sellar region, as the image of anatomical structures on the monitor may appear slightly altered in comparison to familiar microscopic view.

Anatomical studies are essential in increasing the anatomical knowledge and improving surgical performance in line with technological progress. Our endoscopic dissections showed us improved, wide panoramic view of the close relationship of ICA and optic nerves with the pituitary gland, presenting with some variations, which might be a concern during surgery. Thus, for clinical practice, our results point out the eminent role of preoperative radiological mapping of the bony structures and soft tissues in each case, even though the pure endoscopic endonasal transsphenoidal approach provides excellent view of the surgical landmarks.

REFERENCES

- Batay F, Vural E, Karasu A, Al-Mefty O. 2002. Comparison of the exposure obtained by endoscope and microscope in the extended trans-sphenoidal approach. *Skull Base* 12:119–124.
- Cappabianca P, Cavallo LM, Colao A, de Divitiis E. 2002. Surgical complications associated with the endoscopic endonasal trans-sphenoidal approach for pituitary adenomas. *J Neurosurg* 97:293–298.
- Cappabianca P, Cavallo LM, de Divitiis E. 2004. Endoscopic endonasal transsphenoidal surgery. *Neurosurgery* 55:933–941.
- Carrara RL, Jho HD, Ko Y. 1996. Transnasal-transsphenoidal endoscopic surgery of the pituitary gland. *Laryngoscope* 106:914–918.
- Catapano D, Sloffer CA, Frank G, Pasquini E, D'Angelo VA, Lanzino G. 2006. Comparison between the microscope and endoscope in the direct endonasal extended transsphenoidal approach: Anatomical study. *J Neurosurg* 104:419–425.
- Das K, Spencer W, Nwagwu CI, Schaeffer S, Wenk E, Weiss MH, Couldwell WT. 2001. Approaches to the sellar and parasellar region: Anatomic comparison of endonasal-transsphenoidal, sublabial-transsphenoidal, and transthemoidal approaches. *Neurol Res* 23:51–54.
- de Divitiis E, Cappabianca P, Cavallo LM. 2002. Endoscopic trans-sphenoidal approach: Adaptability of the procedure to different sellar lesions. *Neurosurgery* 51:699–707.
- Fujii K, Chambers SM, Rhoton AL Jr. 1979. Neurovascular relationship of the sphenoid sinus - a microsurgical study. *J Neurosurg* 50:31–39.
- Hardy J. 1969. Microneurosurgery of the hypophysis: A subnasal transsphenoidal approach with television magnification and televised radiofluoroscopic control. In: Rand RW, editor. *Microneurosurgery*. St. Louis, MO: CV Mosby. p 87–103.
- Jankowski R, Auque J, Simon C, Marchal JC, Hepner H, Wayoff M. 1992. Endoscopic pituitary tumor surgery. *Laryngoscope* 102:198–202.
- Kassam A, Snyderman CH, Mintz A, Gardner P, Carrau RL. 2005. Expanded endonasal approach: The rostrocaudal axis. I. Crista galli to the sella turcica. *Neurosurg Focus* 19:E3.
- Lang J. 1989. *Clinical anatomy of the nose, nasal cavity and paranasal sinuses*. New York: Thieme Medical Publishers, Inc. p 85–98.
- Lauffer I, Anand VK, Schwartz TH. 2007. Endoscopic, endonasal extended transsphenoidal, transplanum transtuberulum approach for resection of suprasellar lesions. *J Neurosurg* 106:400–406.
- Renn WH, Rhoton AL Jr. 1975. Microsurgical anatomy of the sellar region. *J Neurosurg* 43:288–298.
- Rhoton AL Jr, Hardy DG, Chambers SM. 1979. Microsurgical anatomy and dissection of the sphenoid bone, cavernous sinus and sellar region. *Surg Neurol* 12:63–104.
- Sethi DS, Leong JL. 2006. Endoscopic pituitary surgery. *Otolaryngol Clin North Am* 39:563–583.
- Sethi DS, Stanley RE, Pillay PK. 1995. Endoscopic anatomy of the sphenoid sinus and sella turcica. *J Laryngol Otol* 109:951–955.
- Stammberger H. 1986. Endoscopic endonasal surgery—Concepts in treatment of recurring rhinosinusitis. II. Surgical technique. *Otolaryngol Head Neck Surg* 94:147–156.