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Risky anatomic variations of sphenoid sinus for surgery

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Abstract We searched for the surgically risky anatomic variations of sphenoid sinus and aimed to compare axial and coronal tomography in detection of these variations. Fifty-six paranasal tomography images (112 sides) were evaluated for coronal, axial and both coronal and axial images. Tomographic findings including bony septum extending to optic canal or internal carotid artery; protrusions and dehiscences of the walls of internal carotid artery, optic nerve, maxillary nerve and vidian nerve; extreme medial course of internal carotid artery; patterns of aeration of the anterior clinoid process; and Onodi cells were evaluated. The results were classified as “present, absent, suspicious-thin (only for dehiscence) or no-consensus”. The results of each plane were compared with that of the result of the both planes together. Kappa coefficient and Chi-square tests were used to compare both planes. Twelve cadaveric dissections were performed to reveal the proximity of sphenoid sinus to surgically risky anatomic structures. Endoscopy was applied to five cadavers. 18 evaluations were classified as ‘no-consensus’. We detected 34, 35, 34 and 40 protrusions of internal carotid artery, optic nerve, maxillary

nerve, vidian nerve, respectively. Dehiscences were present in 6, 9, 4 and 8, and suspicious-thin in 8, 10, 16 and 25 in canals of internal carotid artery, optic nerve, maxillary nerve and vidian nerve, respectively. Bony septum to internal carotid artery and optic nerve was observed in 30 and 22 cases. We observed 9 extreme medial courses of internal carotid artery, 27 aerated clinoid process and 9 Onodi cells. Axial images were superior in detection of bony septum to internal carotid artery and Onodi cells; while the coronal images were more successful in detection of protrusion of optic nerve and vidian nerve, and dehiscence of maxillary nerve and vidian nerve ($P < 0.05$). In cadaveric dissections, the septa were inserted into the bony covering of the carotid arteries in two sinuses (8.3%). Detailed preoperative analysis of the anatomy of the sphenoid sinus and its boundaries is crucial in facilitating entry to the pituitary fossa and reducing intraoperative complications. Coronal tomography more successfully detects the sphenoid sinus anatomic variations.

Keywords Sphenoid sinus · Variation · Tomography · Endoscopic sinus surgery · Transsphenoidal surgery

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Introduction

The endoscopic endonasal transsphenoidal approach was proposed in the past decade as a minimally invasive surgical technique for the removal of pituitary tumors [16]. It appeared to be less traumatic than the traditional microsurgical approach, was very effective, and was characterized by a reduced number of complications. But serious complications still occur and must be reduced as much as possible [6–8, 15, 18, 25, 29]. Furthermore, the use of endoscopic endonasal technique has been expanded to include other skull base lesions at the anterior skull base fossa, cavernous sinus, clivus and petroclival posterior fossa, meaning increased risk of possible complications [17] and additional radiological

assessment is required. Tomography is the best tool to demonstrate paranasal sinuses [1, 10, 32].

The study is performed to demonstrate surgically dangerous variations of sphenoid sinus for the safe removal of the intrasphenoid and pituitary lesions in the light of the radio-anatomic concepts with the goal of preventing complications and achieving the best possible outcome. The importance of a thorough preoperative radiological work-up and preoperative CT intensifying control is outlined. We also compared the efficacy and accuracy of coronal and axial planes detecting the risky anatomic variations of sphenoid sinus.

Materials and methods

This prospective study comprised 56 paranasal CTs (112 sides) of the nasal sinus region. The patients were explored in the University of Kirikkale, Faculty of Medicine, Department of Radiology. Of the patients, 33 were males and 23 were females, age ranged between 25 and 62. For the tomographic study, a SeleCT (Marconi, Israel) was used. In all cases systematic studies of the nasal sinus region were performed in coronal and axial scans. Taking the hard palate as reference axis, in the coronal study the plane of section was perpendicular to this structure. Direct scans 3 mm in thickness were made, from the anterior wall of the frontal sinus to the posterior wall of the sphenoid sinus. Axial sections were performed in a plane parallel to the hard palate from the upper dental arch to the roof of the frontal sinuses. In all cases; the existence of the following variants was investigated: (1) protrusion of internal carotid artery (ICA), optic nerve (ON), maxillary nerve (MN), vidian nerve (VN); (2) dehiscence of the walls of ICA, ON, MN, VN; (3) site of attachment of the sphenoid sinus septum (4) extreme medial course of ICA; (5) patterns of aeration of the anterior clinoid process; (6) Onodi cells (the posterior ethmoidal cell in contact with the optic nerve). Every scan was assessed for coronal, axial and coronal-axial investigations by two radiologists. The results were classified as "present, absent, suspicious-thin (only for dehiscence) or no-consensus". In cases of marked suspicion of both observers' decision, results were accepted as "no-consensus". In cases of not to obtain a clear decision between "very-thin bony wall" and "total dehiscence", the results were accepted as suspicious-thin. In coronal sections, protrusion is determined as a finding for placement of a neural or vascular structure with more than 50% of its diameter in sphenoid sinus. As far as we know, there is no reported criteria about protrusion of vidian and optic nerve. Presence of air density around these structures is accepted as a clue of the protrusion for VN and ON, at least in a section of coronal or axial investigation. A pilot study comprising 26 patients was performed to determine the protrusion of maxillary nerve. According to the results of this preliminary trial, presence of a thin structural imaging

along the inferior wall of sphenoid sinus through the pterygopalatine fossa and absence of double contour image in the inferolateral wall of the sinus were accepted in favor of MN protrusion (Figs. 1a, b). Axial-coronal investigation which coronal and axial sections assessed together was accepted as the golden standard of the study. The efficacy and accuracy of the axial and coronal scans to obtain the investigated criteria compared with the axial-coronal investigation were assessed. Data obtained from these two groups were statistically determined using Kappa coefficient determinant and Chi-square analysis. All calculations were performed using the SPSS package program 11.5. The values less than 0.05 were accepted statistically significant. The sphenoid sinus was studied on formalin-fixed 12 adult cadaver heads (24 sinuses) to reveal the anatomical relationship of sphenoid sinus with surgically risky structures. There were five male cadavers and seven female cadavers. The specimens were obtained after routine autopsy procedures had been performed and had been embalmed in 10% formaldehyde solution.

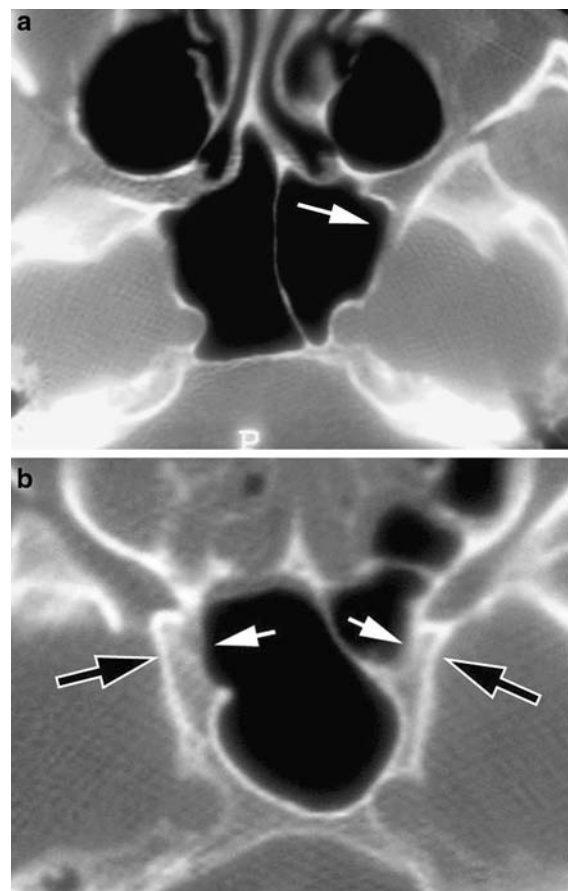


Fig. 1 **a** Axial view of a maxillary nerve (arrow) protruded into sphenoid sinus extending along the inferolateral wall of sphenoid sinus through the pterygopalatine fossa. **b** Axial views of bilateral maxillary nerves embedded in the sphenoid bone creating double contour image (black and white arrows; black arrows indicating medial contour of bony contour of maxillary nerve)

The internal carotid arteries, the vertebral arteries and the internal jugular veins were dissected, cannulated and irrigated with saline solution to remove any residual blood clots in the lumens. The vascular structures were perfused with colored silicon in order to facilitate their definition. Cadaveric heads were examined under 3–40× magnification using the Opmi-Zeiss surgical microscope. Endoscopic investigations were performed on five cadaveric heads with the use of 0°, 30°, 70° endoscopes (STORZ, Germany). All areas of the sphenoid sinus were explored with special attention to relationship of sphenoid sinus with ICA and ON. Pertinent findings were recorded and photographed (Fig. 2).

Results

From initial CT scans of 112 nasal regions, 12 had inflammatory findings that do not obscure the reliability of the investigation. Eighteen evaluations were assessed as “no-consensus”.

Anatomic variations of 112 sphenoid sinuses were first determined in axial–coronal scanning (Table 1). Protrusions were detected for ICA in 34 (30.3%) of 112 sides; for ON in 35 (31.3%) (Fig. 3); for MN in 34 (30.3%) and for VN in 40 (35.7%) of the sides. Bony septum of the sphenoid sinus was attached in 30 (26.7%) of the sides to the wall of the ICA (Fig. 4) and in 22 (19.6%) to the wall of the optic nerve. Bony septa were seen in 19 cadaveric sinuses (79.1%). In cadaveric dissections, the septa were inserted into the bony covering of the carotid arteries in two sinuses (8.3%) (Fig. 5); and none into the bony covering of optic nerve. Close proximity of sphenoid sinus to ICA, pituitary gland and clivus were shown by standard peritoneal approach in two of the cadaveric heads (Fig. 6).

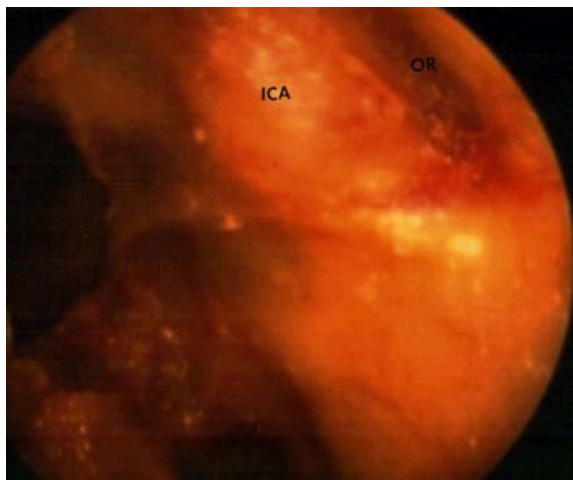


Fig. 2 Transsphenoidal endoscopic view of the sphenoid sinus showing the close relationship of sinus with ICA and optico-carotid recess (OR)

Dehiscences were assessed: for the wall of the ICA (Fig. 4), present in 6 (5.3%), suspicious-thin in 8 (7.1%); for ON present in 9 (8%), suspicious-thin in 10 (8.9%); for MN present in 4 (3.5%) (Fig. 4), suspicious-thin in 16 (14.2%); for VN present in 8 (7.1%), suspicious-thin in 25 (22.3%). Extreme medial course of the ICA was detected in 9 (8%) of the sides. The anterior clinoid process was pneumatized in 27 (24.1%) of the sides (Figs. 3, 4). Onodi cells were present in 9 (8%) of the sides.

Axial scans were more preferable to detect the site of attachment of the sphenoid bony septum and Onodi cell; while protrusions and dehiscences of maxillary and vidian nerve were detected on coronal sections more successfully ($P < 0.05$) (Table 1). In detecting dehiscences of vidian, maxillary and optic nerves and protrusions of maxillary and optic nerves, the axial scans; and in detecting the sphenoid septum attached to the ICA and Onodi's cell, the coronal scans were failed with less accordance with the axial–coronal investigation's findings from whom obtained. Results related with other criterias searching in this study were statistically insignificant for both CT planes.

Discussion

Transsphenoidal surgery, either microscopic or endoscopic is a safe procedure. Combination of the transsphenoidal route with the endoscope or neuronavigation may improve the effectiveness of the operation. Sphenoid sinuses are the most inaccessible paranasal sinuses and are surrounded by significant anatomical structures like the orbit and its content, cavernous sinus and ICA and the anterior cranial fossa [14, 30]. Only thin bones separate these structures from the sphenoid sinus. With the expanding role of endoscopic sinus surgery (ESS), proper understanding of the anatomy of the sphenoid sinuses has become increasingly important [13, 21]. Furthermore, anatomical landmarks vary in a wide range from patient to patient. The surgical significance of these variations including indentations, dehiscences or more medial placement of vascular structures lies in the vulnerability of the underlying structures.

The use of endoscopic endonasal technique has been expanded to include other skull base lesions at the anterior fossa skull base, cavernous sinus, clivus (Fig. 7) and petroclival posterior fossa, meaning increasing the possible complications. Complications of transsphenoidal surgery may lead to mortality with an incidence rate of less than 1% and serious morbidity a relatively higher rate [9, 23]. Pertinent radiologic landmarks are extremely helpful in providing sufficient detail for the neurosurgeon to successfully extend a standard transsphenoidal approach for treatment of lesions involving the region of the tuberculum sellae, planum sphenoidale and medial cavernous sinus.

During ESS, because of excessive bleeding, the location of the surgical instrumentation may be difficult to

Table 1 The incidence of anatomic variations in coronal–axial investigation and the efficacy of coronal and axial scanning in detection of these variations

	C–A		Coronal		Kappa	Axial		Kappa	Chi ²
	Pr.	S-T	Pr.	S-T		Pr.	S-T		P
Protrusion									
ICA	34		25 (73.5%)		0.753	32 (94.1%)		0.895	0.093
ON	35		31 (88.5%)		0.914	22 (62.8%)		0.659	0.442
MN	34		31 (91.1%)		0.935	17 (50.0%)		0.580	0.001
VN	40		38 (95%)		0.960	33 (82.5%)		0.817	0.028
Septum									
ICA	30		18 (60.0%)		0.528	29 (96.6%)		0.839	0.007
ON	22		19 (86.3%)		0.713	14 (63.6%)		0.527	0.156
Dehiscence									
ICA	6	8	4 (66.6%)	5 (62.5%)	0.747	4 (66.6%)	6 (75.0%)	0.782	0.500
ON	9	10	8 (88.8%)	7 (70.0%)	0.874	5 (55.5%)	5 (55.5%)	0.537	0.442
MN	4	16	4 (100%)	15 (93.7%)	0.941	2 (50.0%)	5 (31.2%)	0.386	< 0.001
VN	8	25	7 (87.5%)	25 (100%)	0.960	4 (50.0%)	10 (40.0%)	0.547	< 0.001
ICA-medial	9		8 (88.8%)		0.936	9 (100%)		1.000	0.500
Onodi cell	9		2 (22.2%)		0.215	8 (88.8%)		0.936	0.003
Clinoid aeration	27		27 (100%)		1.000	26 (96.2%)		0.950	0.249

ICA internal carotid artery, ON optic nerve, MN maxillary nerve, VN vidian nerve, C–A coronal–axial investigation, Pr. present, S-T suspicious thin, kappa kappa coefficient, P comparison of the results obtained from coronal and axial scanning. ($P < 0.05$, statistically significant)

ascertain and complications of the procedure do occur. Certain operative difficulties and complications may be the result of the marked variability in the anatomy of the sphenoid bone and its sinus. If lack of knowledge about variable anatomy of the patient is present, as usually without further radiographic evaluation; the complications may be more severe or undesirable. During the transseptal sphenoidectomy surgery, while the septum detaching is being performed, care must be taken not to crack the variant septum violently inserted to the wall of the ICA or ON due to damage of these structures. Uncontrollable bleeding, retrobulbar hematoma with acute proptosis, diplopia caused by extraocular muscle injury and stretching of the optic nerve resulting in blindness may occur if the intracavernous and intraorbital compartments are invaded [15, 25, 29], especially if

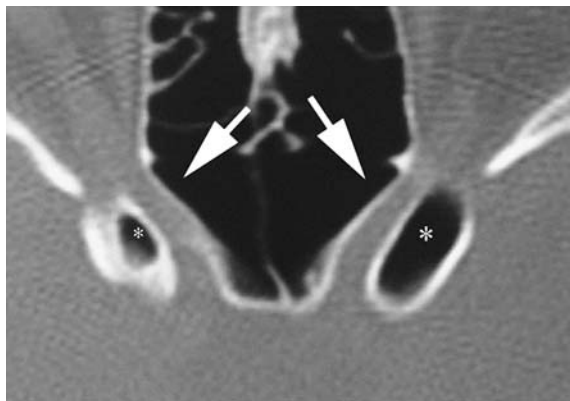


Fig. 3 Axial CT images showing the protrusion of the optic nerve (short arrows). Asterisks show aerated clinoid processes

punch-biting forceps are used, when care is not taken about dehiscences as the absence of bony margins or protrusions as well as bulging of the structures into the air space or extreme medial course of ICA. The close relationship between the wall of the sphenoid sinus, Onodi cells and the optic nerve is a risk factor for complications during surgery; this risk is greatly increased when there is a protrusion of more than 50% of the circumference of the nerve [11]. The air cells in the sphenoid sinus may extend into the anterior clinoid process called clinoid process pneumatization which may lead to pneumocephalus or rhinorrhea. The

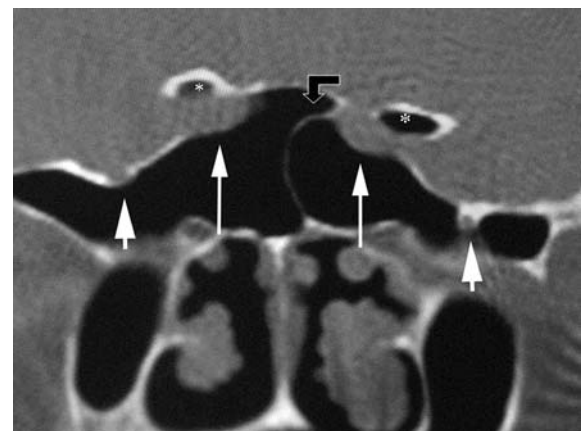


Fig. 4 Coronal CT image showing the protrusion of ICA, bony septum (black arrow) extending to ICA and dehiscence of bony canal of ICA (long white arrows). Suspicious-thin bony dehiscence of maxillary canal bilaterally (short arrows), and protrusion of the left maxillary nerve (left short arrow) were also observed. Clinoid processes are aerated bilaterally (asterisks)

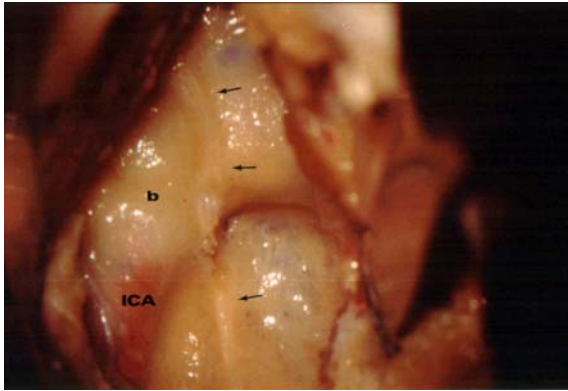


Fig. 5 Transsphenoidal cadaveric dissection shows bony septum extending to the bony covering of ICA (*arrows*). ICA internal carotid artery; *b* bony covering of ICA

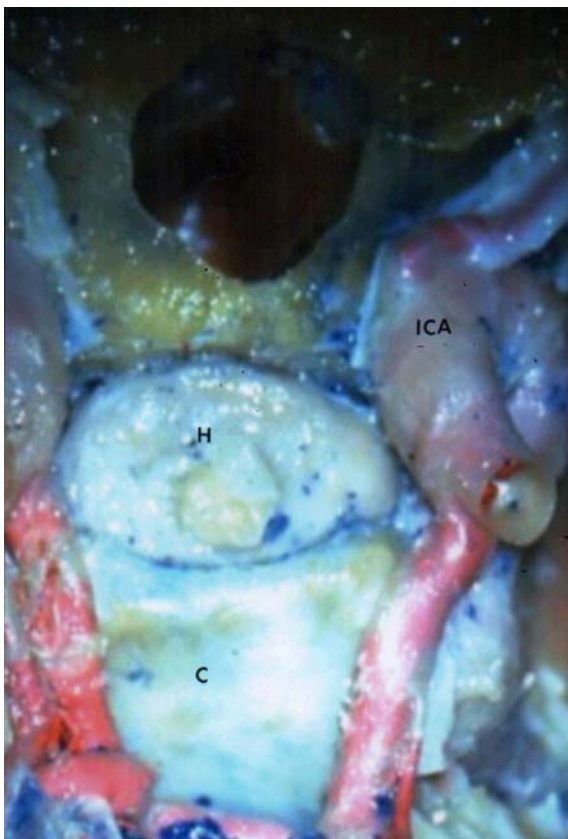


Fig. 6 Right side standard peritomeal approach on cadaveric head (the brain lobes are removed) reveals close relationship of sphenoid sinus (the roof of sphenoid sinus was circularly opened) with ICA and pituitary gland. ICA internal carotid artery; *H* pituitary gland; *C* clivus

sphenoid sinus may pneumatize structures outside the sphenoid body leading to the development of various recesses. Such recesses are named according to the area of pneumatized bone. These recesses may place the sinus in close proximity to important structures. The optico-carotid recess (Fig. 2), between the optic nerve and

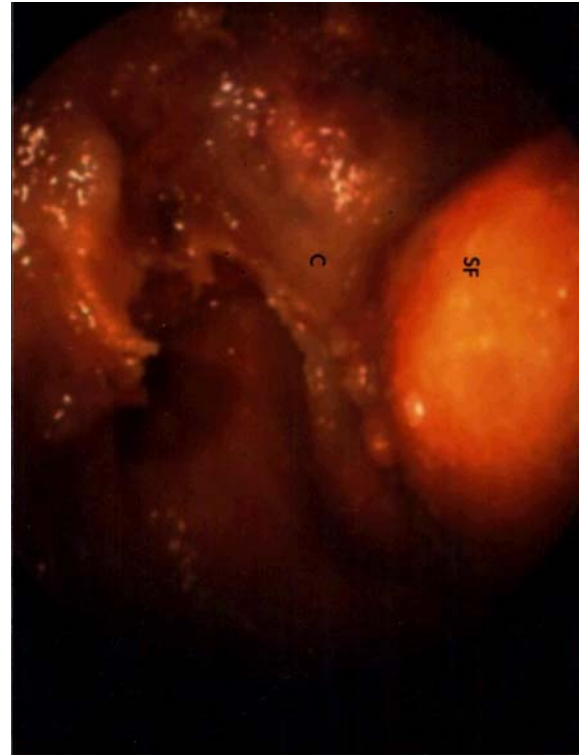


Fig. 7 Endoscopic view shows that it can be reached to the clival pathologies by transsphenoidal route. *SF* sella floor; *C* clivus

carotid artery was the most frequently encountered in our series and is apparently the most important.

The preoperative radiologic evaluation plays a major role of patients considered for ESS. The existence of the anatomical variations and their role in the ESS have been well documented by previous studies [5, 13, 22, 24, 26–28, 31]. Our results were compared with the previous anatomical and radiological studies (Table 2). Significant differences were basically seen on the detection of sphenoid septum because our study concluded all major and minor septums. However, there are only a few studies concerning the dangerous areas, guiding points and the anatomical variations that may lead to complications, done by CT [1–4, 11, 19, 20]. CT is a more valuable tool in the imaging of sphenoid sinus. Preoperative CT examination of the sphenoid sinus is extremely helpful in planning the safest and most direct route to the sella. CT scans also detect the anatomic variations that may place the patient at an increased risk for intraoperative complications. Detailed preoperative analysis of the anatomy of the sphenoid sinus and its boundaries is crucial in facilitating entry to the pituitary fossa and reducing intraoperative complications. In general all patients undergo CT scanning, in both the coronal and axial planes, prior to surgery that means excessive radiation exposure. Choosing one of the axial and coronal planes also provides patients to expose less radiation and more time and money to spare. Our study suggests that coronal scans are superior to detect some

Table 2 The incidence of anatomic variations in present study comparing with previous anatomical and radiological studies

Variation	Structure	This study (%)	Anatomical studies (%)	Radiological (CT) studies (%)
Protrusion	ICA	30.3	18–78 [13, 20, 29]	8 [1]
	ON	31.3	29 [13]	13 [3]
	MN	30.3	40 [29]	28.6 [25]
	VN	37.5	18 [21]	
Sphenoid Septum	ICA	26.7	12.9 [13]	8 [3]
	ON	19.6	5.9 [13]	8 [3]
Dehiscence	ICA	5.3	4.8–12 [13, 14]	5–14.4 [18, 25]
	ON	8.0	0–12 [13, 19]	9–24 [10, 25]
	MN	3.5	2–4 [14, 25]	4 [14]
	VN	7.1	10 [21]	10 [25]
ICA-Medial course		8.0		12 [3]
Onodi air cell		8.0	12–42 [10, 12, 20, 29]	7–12 [10, 21]
Clinoid aeration		24.1		6–14 [1, 3]

ICA internal carotid artery, ON optic nerve, MN maxillary nerve, VN vidian nerve (numbers in square brackets indicate reference number of the studies)

variations in sphenoid sinus. Coronal screening sinus CT focused especially on detection of protrusion of ON and VN, and dehiscence of MN and VN, while axial images were superior on assessing septal details and Onodi air cells [12]. Coronal screening should be accepted as the standard in the presurgical evaluation of patients under consideration for possible ESS. Axial scanning must be added to the investigation when the coronal scans fail to reveal some variations. Pertinent radiologic landmarks described in sufficient detail provide neurosurgeon to successfully extend a standard transsphenoidal approach for treatment of lesions involving the region of the tuberculum sellae, planum sphenoidale and medial cavernous sinus.

Our results classified by “suspicious-thin” for dehiscence are also important in the preoperative evaluation of patients considered for ESS to avoid even minor complications and should be reported to the surgeon.

A great prudence during surgical procedure is emphasized as well as the necessity of a perfect knowledge in radiologic anatomy of sphenoid sinus to avoid the inflation of related complications. Better preplanning and improved familiarity with the regional anatomy should further lower the incidence of death and morbidity resulting from this procedure in the hands of all neurosurgeons.

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