

# Anatomical variants of surgically important landmarks in the sphenoid sinus: a radiologic study in Southeast Asian patients

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## Abstract

**Purpose** Failure of a surgeon to understand the local variations of the anatomical landmarks of the sphenoid sinus is a potential risk factor to cause damage to the optic nerve (ON) or internal carotid artery (ICA) that lies on the walls of the sphenoid sinus. The aim of this study was to identify the anatomical variants of the sphenoid sinus and its related surrounding structures among the Southeast Asian (SEA) population, based on computed tomography (CT) scans.

**Materials and methodology** This cross-sectional study analyzed 300 CT scans of the brain, paranasal sinuses (PNS), and head and neck (H&N) at a tertiary referral centre in Malaysia utilizing the Osirix software. The images were reconstructed into 1 mm cuts on bone window. Demographic details and scan findings were documented in a standardized data collection sheet.

**Results** The rates of ON dehiscence, ICA dehiscence and ICA protrusion in the SEA population were 7.0, 3.0 and 10.0 %, respectively. The rate of ON protrusion was 2.3 %. There was no statistically significant relationship ( $p > 0.05$ ) noted on Chi-square test, between anterior clinoid process (ACP) pneumatization and ON protrusion. The rate of

Onodi cells in our population was 14.3 %. The average vertical distance of the ostia from the roof of the posterior choanae was 1.42 cm ( $\pm 0.32$ ). The horizontal distance of the ostia from the anterior end of the superior turbinate was 1.58 cm ( $\pm 0.41$ ) and the oblique distance of the ostia from the anterior nasal spine was 5.35 cm ( $\pm 0.48$ ). Independent  $t$  tests showed that there is a statistically significant difference between the means of each of these parameters ( $p < 0.001$ ) and their international averages.

**Conclusion** The rate of ON protrusion is lower in the SEA population, whereas the rates of ON dehiscence, ICA dehiscence and ICA protrusion fall within the range of international averages. In our population, ACP pneumatization is not related to ON protrusion. The distance of the ostia from given landmarks was significantly shorter than in other studies.

**Keywords** Sinus · Sphenoid · Anatomical variations · Asian · Carotid artery · Optic nerve

## Introduction

The sphenoid sinus and its adjacent structures are a subject of great interest not only to otolaryngology surgeons, skull base and neurosurgeons operating in this area, but also to radiologists who view and report these images on a day-to-day basis. The findings with regard to the sphenoid sinus in many of the CT and anatomical studies of the past describe a multitude of variations and highlight their findings in their respective populations [2, 3, 5]. Most of these results, however, are based on the Caucasian population and there are growing but limited data on the Asian population to fall back on.

The authors of this study aim to provide comprehensive data with regard to the variations of the sphenoid sinus, ON

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and ICA in the SEA population. We also determine the various distances of the ostia from given landmarks within the nasal cavity in the local population.

## Materials and methods

This cross-sectional descriptive study of 300 brain, PNS and H&N CT scans done as per their respective protocols, was conducted at a tertiary referral centre in Malaysia, over a period of 1 year. The study population was Malaysians 18 years and older. All malignancies including H&N cancers, patients with chronic rhinosinusitis and patients with intracranial pathology [without skull base (SB) involvement] were included in the study. Patients with previous history of SB surgery, irradiation to the SB, traumatic facial bones and PNS fractures, nasal polyposis and those with diseases involving the SB and PNS were excluded.

All CT scans were done using the Aquilion TSX-101A (2B201-370EN\*R) multislice scanner by Toshiba Medical Systems Corporation. The raw data of the identified CT scans were reconstructed to bone algorithm, 1 mm slice thickness using OSIRIX, 64-bit DICOM Viewer, analyzed and recorded together with the relevant demographic information onto a data collection sheet.

Every scan was read by three investigators, a radiologist, a rhinologist, and a general otorhinolaryngologist, to reach a consensus. This method was performed to eliminate inter-observer bias. Where discrepancies arose, further evaluations of the scans were done by the researchers and another investigator's opinion sought, and a mutual consensus was reached.

The distance of the midpoint of the sphenoid sinus ostia from various landmarks in the nose was measured. Three sets of measurements were taken for each of the vertical, horizontal and oblique distances, respectively, by three researchers, and an average value was calculated. As for the horizontal length, if the superior turbinate was visible straightforward on the sagittal cuts, then the measurements were taken on that plane. However, if it was noted to be tilted or obscured, then the superior turbinate had to be first identified on the coronal plane, and the corrected measurement had to be subsequently taken from the anterior end on axial cuts. All the information obtained was analyzed using Statistical Package for Social Sciences (SPSS) software version 17.

## Results

A total of 194 male patients' and 106 female patients' CT scans were analyzed. The bulk of the scans was made up of 140 brain scans, followed by an equal number of PNS and H&N scans with 80 each.

## Pneumatization of the sphenoid sinus

The sellar type was the commonest form of pneumatization of the sphenoid sinus noted in this study with 279 patients (93.0 %), followed by 20 patients (6.7 %) with the pre-sellar type. Only one patient (0.3 %) in this study was noted to have the conchal form of pneumatization of the sphenoid sinus (Fig. 1).

## Intersphenoid septum

A total of 161 patients (53.7 %) were noted to have a single intersphenoid septum, whereas 139 patients (46.3 %) were noted to have multiple intersphenoid septums with various sites of attachment (Fig. 2).

## Optic nerve dehiscence

Optic nerve dehiscence (Fig. 3) was observed in 23 patients (7.0 %); 14 (60.9 %) males and 9 (39.1 %) females. Out of this figure, 13 (56.5 %) were noted on the right side, 7 (30.4 %) on the left side and 3 (13.0 %) were noted bilaterally.

## Optic nerve protrusion

Optic nerve protrusion was observed in 7 patients (2.3 %); 4 (57.1 %) males and 3 (42.9 %) females. Out of this figure, 2 (28.5 %) were noted on the right side, 4 (57.1 %) on the left side and 1 (14.2 %) bilaterally.

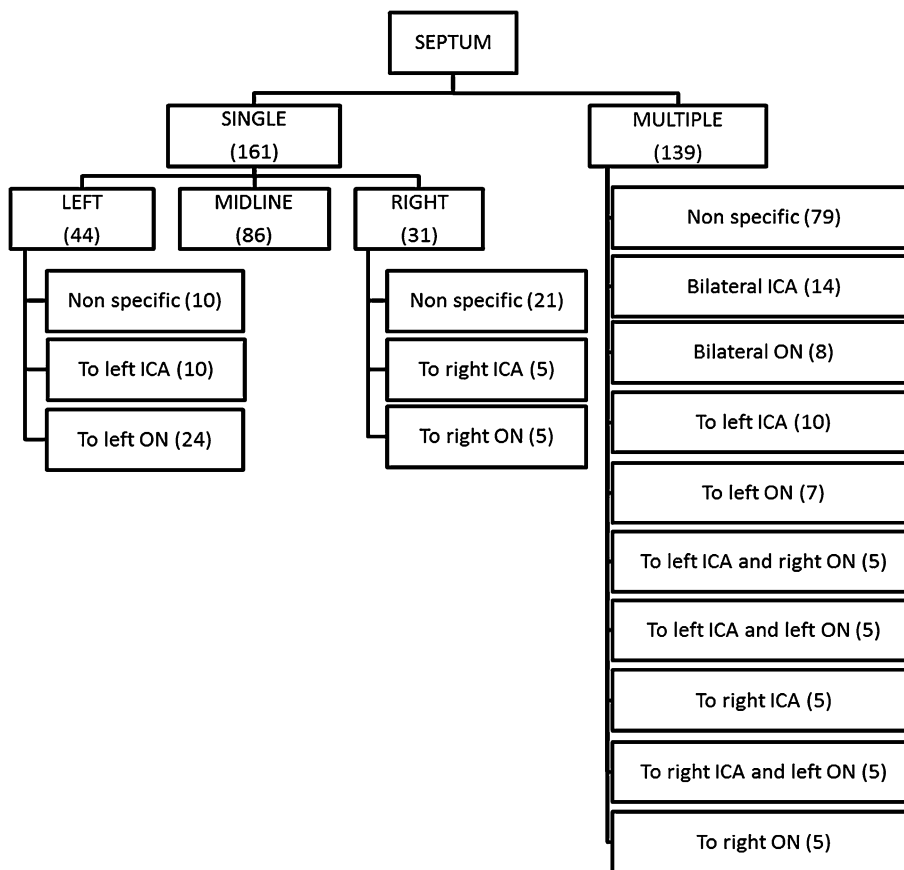
## Internal carotid artery dehiscence

Internal carotid artery dehiscence (Fig. 4) was observed in 9 patients (3.0 %); 6 (66.7 %) males and 3 (33.3 %) females. Out of this figure, 5 (55.5 %) were noted on the right side, 4 (44.4 %) on the left side and none bilateral.

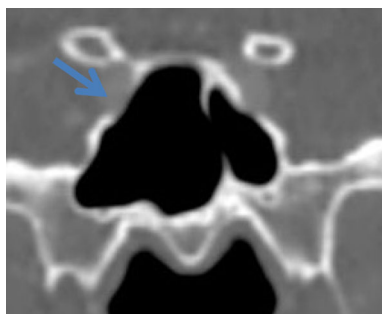


**Fig. 1** An axial CT with solid bone demonstrating conchal pneumatization of the sphenoid sinus

**Fig. 2** Frequency of intersphenoid septums and their attachment sites



**Fig. 3** Multiple intersphenoid septum, one of which is attached to the left ON which is also dehiscent (arrow)



**Fig. 4** Coronal CT demonstrating right ICA dehiscence (arrow)

**Internal carotid artery protrusion**

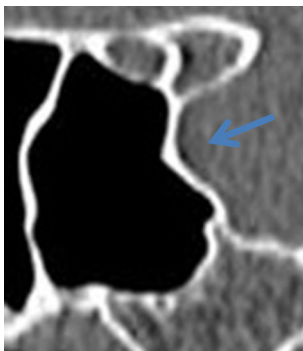
Internal carotid artery protrusion (Fig. 5) was observed in 30 patients (10.0 %); 19 (63.3 %) males and 11 (36.7 %) females. 11 (36.7 %) were noted on the right side, 16 (53.3 %) on the left side and 3 (10.0 %) were noted bilaterally.

**ACP pneumatization and ON protrusion**

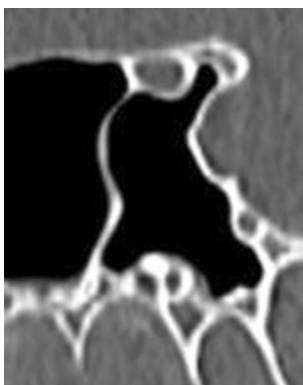
Two scans with a pneumatized ACP had protruding optic nerves (Fig. 6). Chi square test showed no significant association between ACP pneumatization and ON protrusion with a *p* value of 0.17 (*p* > 0.05).

**Measurements**

The average vertical distance of the ostia from the roof of the posterior choanae (Fig. 7a) was 1.42 cm (±0.32). The average horizontal distance of the ostia from the anterior end of the superior turbinate (Fig. 7b) was 1.58 cm (±0.41). The average oblique distance of the ostia from the anterior nasal spine (Fig. 7c) was 5.35 cm (±0.48). Independent *t* tests on each of these results revealed that there was a statistically significant difference between each of



**Fig. 5** Coronal CT demonstrating left ICA protrusion (*arrow*)



**Fig. 6** This patient had left ACP pneumatization associated with left ON protrusion

these parameters ( $p < 0.001$ ) and their international measurements. The details of the mean measurements, standard deviations, maximum and minimum values for the vertical, horizontal and oblique distances, respectively, are depicted in Tables 1, 2 and 3.

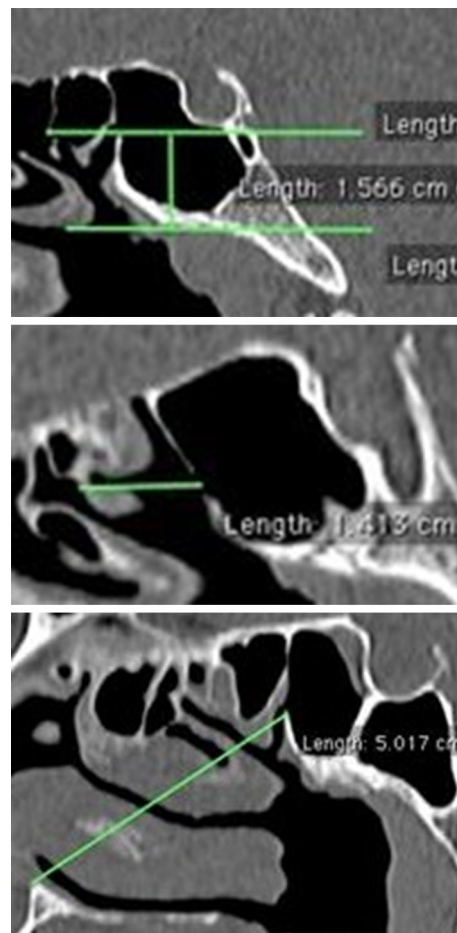
### Onodi cells

The rate of Onodi cells in this study was 14.3 %; 14 of them (32.6 %) being on the right side, 17 on the left (39.5 %) and 12 (27.9 %) bilateral.

## Discussion

### Demography

The 300 patients in our study consisted of adult Southeast Asians made up of Malay, Chinese and Indian patients above the age of 18 years. The reason for taking the minimum cut-off age of 18 was because the sphenoid sinus usually attains its mature size by the age of 14 years [11]. However, full pneumatization is considered complete at



**Fig. 7** **a** Measurement of vertical distance of ostia. **b** Measurement of horizontal distance of ostia. **c** Measurement of oblique distance of ostia

adulthood. Therefore, to maintain the precision of this study, the cut-off age of 18 years was used, similar to that used by Hamid et al. [13] and Sirikci et al. [25] in their respective studies, but contrary to the 16 years that was used by Davoodi et al. [8] and Heiwaidi et al. [15].

### Pneumatization of the sphenoid sinus

The conventional Hammer and Radberg (1961) classification [14] was used to classify sphenoid sinus pneumatization. In our study, we found the sellar type to be the predominant type of pneumatization pattern with 93.0 %, followed by the pre-sellar pattern at 6.7 %. Although the conchal type of pneumatization is rare and if ever seen, is usually present in young adults as the pneumatization process might be incomplete, we did note a 46-year-old Chinese male with conchal pneumatization of the sphenoid sinus (Fig. 1).

Our findings seem to concur with studies done on the Asian population by Tan et al. [27] and Cho et al. [6], in which the sellar type of pneumatization was the

**Table 1** Details of vertical distance measurements

	Ostia distance from roof of posterior choanae (cm)			
	Vertical 1	Vertical 2	Vertical 3	Vertical average
Mean	1.42	1.42	1.42	1.42
Standard deviation	0.32	0.32	0.32	0.32
Minimum	0.66	0.67	0.66	0.67
Maximum	2.26	2.23	2.25	2.24

**Table 2** Details of horizontal distance measurements

	Ostia distance from anterior end of superior turbinate (cm)			
	Horizontal 1	Horizontal 2	Horizontal 3	Horizontal average
Mean	1.58	1.59	1.59	1.58
Standard deviation	0.41	0.41	0.41	0.41
Minimum	0.74	0.74	0.75	0.74
Maximum	2.75	2.74	2.74	2.74

**Table 3** Details of oblique distance measurements

	Ostia distance from anterior nasal spine (cm)			
	Oblique 1	Oblique 2	Oblique 3	Oblique average
Mean	5.35	5.35	5.35	5.35
Standard deviation	0.48	0.48	0.48	0.48
Minimum	4.01	4.02	4.02	4.02
Maximum	6.90	6.86	6.90	6.88

commonest, followed by the presellar type. However, this was contrary to that reported by Madiha et al. [21], in which an endoscopic examination of 25 sphenoid sinuses of Egyptian patients and cadavers revealed a higher number of presellar type of pneumatization at 76 %, the remainder followed by the sellar type. This difference could probably be true due to the difference in ethnicity, or perhaps the sample size of the study done by Madiha et al. [21] was much smaller resulting in their findings.

Importance is given to the pattern of pneumatization as it would not only determine the extent of surgery but also the type of approach to the sphenoid sinus, be it the transseptal, transantral, transethmoidal, transpalatal, or the endonasal endoscopic approach. The sphenoid sinus in turn can be used as a route to access the parasellar and sellar region, anterior skull base, clivus, cavernous sinus and petroclival region [2]. A highly pneumatized sinus with large cavity may be so extensive to envelope the surrounding structures, extend to the greater wing of the sphenoid or pterygoid process, that during opening of the sella, the neurovascular structures may risk being injured. Conversely, endoscopic transphenoidal approach will not be an option as a surgical route to the skull base and pituitary in conchal type of pneumatization in view of the fact that the cavity would be filled by cancellous bone and there would be no association with the sella turcica [2].

### Intersphenoid septum

Previous studies by Elwany et al. [10] and Sareen et al. [24] found that the majority of the intersphenoid septum was of the multiple type. But these were small studies, for example, Sareen et al. [24] reported on 20 cadavers. It is interesting to note that 53.7 % of our patients were documented to have a single intersphenoid septum, and the remainder 46.3 % were multiple in nature. Although they are almost equal, it is worthy to note that the majority of the septum in our population appears to be of the single type based on our data. Not only can the septum be multiple but it may also be skewed to either side resulting in asymmetrical sinus cavities as well as asymmetrical appearance of the floor of the sella [7]. It is for these reasons that the septum is an unreliable guide to approaching the midline in sphenoid sinus surgery. A more reliable guide to the midline would be to follow the nasal septal floor.

It is wise for an operating surgeon to review the attachment site of an intersphenoid septum prior to surgery as it may be attached to the ON or ICA on the lateral walls of the sphenoid sinus. It may not be necessary to remove all the septums in endoscopic sinus surgery, and occasionally, removing them can prove challenging and risky especially in an attempt to access the sella. Batra et al. [4] not only elegantly demonstrated the various degrees of carotid

protrusion in their study but also quoted a high rate of 37.5 % of septal insertion onto the ICA.

### Optic nerve: dehiscence and protrusion

The rate of ON dehiscence found in our study is 7.0 %. This not only falls into the range of the international averages, that is between 0.7 and 30.6 % [2], but also close to Tomovic et al.'s figure of 7.7 % specifically in the Asian population, although this study quoted only in six patients [28]. But this study compared patients of various ethnicity. The rate of ON protrusion observed in our study is 2.3 %, which is much lower than the international rates that range between 4.1 and 35.6 % [2].

The wide range of international averages could be attributed to the difference in sample size between studies as well as the types of scans analyzed and their respective methodology or due to ethnicity, although Tomovic et al. [28] demonstrated that there is no statistically significant difference with regard to optic nerve dehiscence and ethnicity. Another possible reason is because the definition of dehiscence varies among studies, some defining it as absence of bony margins, others defining it as thinning of bony covering up to less than 0.5 mm [11]. We described bony dehiscence as total absence of bony wall covering the neurovascular structures.

Protrusion of the ON for the purpose of this study was defined as a bulging of the optic canal into the sphenoid sinus cavity, so as to cause exposure of more than half of the circumference of the nerve, with or without defects in the bony margins, as per that followed by Dessi et al. [9], Unal et al. [30] and Sirikci et al. [25]. This definition was applied because the risk of ON injury during surgery was noted to be raised when 50 % or more of the nerve circumference was exposed [9]. The question here is whether the low rate in our patients is indeed a true reflection of the incidence in our population, or whether a magnetic resonance imaging (MRI) study is required for a more precise rate. Besides the difference in sample size, the difference in the definition of ON protrusion could play a part in causing the variations in the incidence rates.

The ON may lie adjacent to, indent into or traverse through the sphenoid sinus. The risk of injury and causing potential defect in the visual field, visual acuity and blindness is obviously greater if the nerve was protruding or dehiscent in its bony wall covering [23], more so if a septum is attached to it and the septum requires removal. It is even more challenging when the sinus is filled with disease or the surgical indication was for an extensive tumour, in which case the anatomy would have been greatly distorted. It cannot be emphasized enough on the paramount importance for a surgeon to read the scans carefully and pre-operatively plan the procedure accordingly, and not merely rely on experience.

Irreversible blindness intraoperatively could be due to either direct insult and hence injury to the ON or, retrobulbar haematoma causing compression, and in turn not only resulting in ischaemia of the nerve but also impeding its venous outflow. It is for this reason that one must be prepared and competent to perform a lateral canthotomy or a medial orbital wall decompression when required.

### Internal carotid artery: dehiscence and protrusion

The ICA lying on the lateral wall of the sphenoid sinus is essentially a reflection of its intracavernous portion. It may present as a mere bulge or be visible in a serpentine course along its entire length. It is mandatory to identify its position and variation on the preoperative CT.

The international averages for ICA dehiscence are between 1.5 and 30.0 % [2]. The rate of ICA dehiscence in our study fell within this range and was noted to be low at 3.0 %, and lower than Tomovic's figure of 8.3 % [28] and Batra's 19.5 % [4]. Generally the rate of ICA dehiscence has been low at about 5 % as reported by Meloni et al. [22] and Unal et al. [30], with the exception of Heiwaidi's [15] study that reported a high rate of 30.0 %. The rate of ICA protrusion has a wide range and can be as high as 67.0 % as reported by Meloni et al. [22] or as low as 5.2 % as reported by Kazkayasi et al. [18]. The rate of ICA protrusion in our study was 10.0 %, which is within the range of international rates. However, this rate is low when compared with Tan's [27] 67.7 % and Tomovic's 50.0 % [28] on the Asian population.

The degree of pneumatization can affect the position of the ICA [4], whereby protrusion and dehiscence are higher when the sinus is well or over pneumatized [25] as the sinus walls are thinned out, even up to 0.5 mm. In this study, ICA protrusion was defined as presence of more than half of the diameter of the vessel into the sphenoid sinus as followed by Unal et al. [30]. The problem with a protruding ICA is that it could be accidentally yanked out easily, especially so if the surgeon does not constantly check his orientation and position of the endoscope. In the event of an ICA injury either due to inadvertent puncture or during avulsion of a septum, tight packing, balloon occlusion, gelatin or cellulose-based sponge application and compression of the common carotid artery against the cervical vertebra may be employed. If these attempts fail, neurosurgical exploration may deem necessary.

### Relationship of ACP pneumatization to ON protrusion

The apex of the posterior most ethmoidal cell is directed towards the anterior clinoid process. The ON is in proximity to the wall adjacent to this apex. One point worth bearing in

mind is that the ON may be present in the posterior ethmoids in Asians, as demonstrated by Yeoh and Tan in 65 % of their 51 cadavers [32]. More importantly, in 15 % this relationship was not visible endoscopically and hence the potential greater risk of injury to the ON. An extensive sphenoid sinus pneumatization may involve the vidian canal, pterygoid process, foramen rotundum, ON and the ACP [25]. A pneumatized ACP may surround the ON and may also result in a deeper carotico-optic recess [20, 22].

The rate of ACP pneumatization in our study was observed to be at 12.0 %. Again, this falls into the international range of 6.0–29.3 % [3, 15, 18, 23, 25, 30]. There is statistical evidence to suggest a significant relationship between ACP pneumatization and ON protrusion as those suggested in studies by Dessi et al. [9] and Sirikci et al. [25]. These studies however, utilized a smaller number of CT scans at 150 and 92 scans, respectively. Chi square test, however, showed statistically no significant association between ACP pneumatization and ON protrusion with a  $p$  value of 0.17 ( $p > 0.05$ ) in our study population of 300 SEA patients.

The point to ponder here is whether this is indeed a true reflection of our population given the large sample size of our study, or whether a larger study is required to compare and contrast our data. If there is no significant association between these two factors indeed, then surgeons operating on our patients with a pneumatized ACP need not worry excessively of the risk of ON protrusion, as the pneumatization might be an isolated event in these patients, although it would be wise nevertheless to bear in mind the possibility of a nerve protrusion.

### Onodi cells

Onodi cells which are also known as sphe-no-ethmoidal cells, in essence are the posterior most ethmoidal cell invading into the sphenoid sinus. They could migrate into, or encapsulate the medial portion of the ON. Opening up this cell under the impression that a posterior ethmoidectomy is being done, could result in undesirable injury to the ON. Occasionally, the anterior wall of the sphenoid sinus would have to be opened by way of anterior and posterior ethmoidectomy. It has been suggested by Lanza et al. [20], Meloni et al. [22] and Stammberger [26], that once the ground lamella has been perforated, a surgeon should never make the grave mistake of dissecting posterolaterally along the lamina papyracea to access the sphenoid sinus behind the Onodi cells. It is exactly at this point that the ON tends to get injured.

The rate of Onodi cells in our study population was noted to be 14.3 %, which is remarkably close to Tan's 15 % [27], but higher than Isyk et al. [17] and Van Alyea's [31] average of 12.0 %, and Meloni's [22] 13.0 %. Therefore, it may be safe to say that the rate of Onodi cells

in our SEA population is generally higher than that quoted in literature on the Caucasian or Turkish population. There is room however for comparison of our rates and the various international rates in future. The slightly higher rate of Onodi cells would warrant surgeons to be wary of the ON when operating on the sphenoid sinus in our population.

### Measurements

The sphenoid ostia can be located intraoperatively by the following methods; by way of anterior and posterior ethmoidectomy, directly medial and either from the anterior end or postero-inferior end of the superior turbinate, 7 cm from the collumela at an angle of 30° from the floor of the nostril, 1.5 cm directly above the roof of the posterior choanae or at the level of the posterior orbital floor adjacent to the nasal septum once a middle meatal antrostomy has been performed [1, 12, 16, 19, 29]. Instead of probing blindly, knowledge of previous literature in a specific population can be used to estimate the location of the ostia from fixed landmarks, especially so when the anatomy is distorted or the operative field is filled with mucosal disease, tumour or polyposis.

Many studies in various populations quote varying landmarks to locate the sphenoid sinus, hence the diversity of results. We used bony landmarks, the anterior nasal spine, anterior end of the superior turbinate and the accepted roof of posterior choana as our reference points for their consistency and for their nature of being easily identifiable intraoperatively. The wide range of results could be attributed to the difference in build, skull size in males and females, different populations, where exactly the ostia is measured, i.e. at its midpoint or inferior edge and the location of the ostia on the anterior face of the sinus; for instance, Gupta et al. [12] report 77 % of the ostia in their study to be located in the upper 1/3rd portion, whereas Kim et al. [19] report the majority to be in the middle of the sinus.

Independent  $t$  test comparing our rates and the international averages [1, 12, 16, 19, 29] proved to be statistically significant and shorter compared to other studies. These results clearly demonstrate that if the surgeon has gone beyond 1.42 cm above the roof of the posterior choanae, 1.58 cm from the anterior end of the superior turbinate or 5.35 cm obliquely from the anterior nasal spine endoscopically in our population, then he most probably is in the sphenoid sinus cavity.

### Conclusion

Sound knowledge of surgical anatomy and its variations is essential to perform safe surgery with minimal morbid outcome. Although the rate of optic nerve protrusion is

lower in the Southeast Asian population, the rates of optic nerve dehiscence, internal carotid artery dehiscence and internal carotid artery protrusion are within the range of international values. In this study, pneumatization of the anterior clinoid process does not seem to affect the protrusion of optic nerve, in contrast to that reported in literature. The distance of the ostia from given landmarks was significantly shorter than in other studies. We hope these data would benefit those with interest in this area and serve as a reference for future studies.

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**Conflict of interest** All authors have made significant contributions to this work. All co-authors have approved the final version of the paper and have agreed to its submission for publication. This paper has not been published in another journal, nor is it currently being considered for publication in another journal. All authors have no conflict of interest in the production of this paper.

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