

Sphenopalatine foramen: endoscopic approach with bony landmarks

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Abstract

Objective: To establish whether nasal bony landmarks on computed tomography could be utilised reliably in endoscopic approaches to the sphenopalatine foramen.

Methods: A prospective analysis of 102 consecutive helical computed tomography scans of the paranasal sinuses was carried out by 2 senior ENT surgeons. Distances from the sphenopalatine foramen to endoscopically palpable bony landmarks were measured.

Results: There were a total of 102 patients (45 females and 57 males), with a mean age of 62 years. The mean distance from the posterior fontanelle to the sphenopalatine foramen was 14.1 mm (standard deviation = 2.13). The average vertical distance of the sphenopalatine foramen opening from the bony attachment of the inferior turbinate was 14.13 mm. There were no statistically significant differences between any of these measurements (foramen width p -value = 0.714, distance from fontanelle p -value = 0.43 and distance from inferior turbinate p -value = 0.48).

Conclusion: Determination of reliable bony landmarks is clinically useful in endoscopic surgery and can aid identification of the sphenopalatine foramen. The inferior turbinate concha and posterior fontanelle may be used as reliable computed tomography landmarks for endoscopic approaches to the sphenopalatine foramen.

Key words: Pterygopalatine Fossa; Sphenopalatine Foramen; Sphenopalatine Artery; Epistaxis

Introduction

The sphenopalatine foramen is a clinically important landmark in endoscopic sinus surgery; it transmits the sphenopalatine artery and is a site at which nasal pathology may arise. Anatomical variations of the sphenopalatine foramen and its surroundings can lead to difficulty in intra-operative visualisation, which may contribute to surgical failures. The identification of reliable bony landmarks for endoscopic approaches to the sphenopalatine foramen is clinically significant for diagnostic purposes and the planning of endoscopic procedures.¹ Endoscopic sinus surgery often routinely entails pre-operative imaging. The use of validated surgical landmarks identified on computed tomography (CT) imaging would allow surgeons to reliably identify the sphenopalatine foramen and anatomical variability pre-operatively in patients.

Currently, sphenopalatine foramen identification through bony landmarks is poorly documented in the literature, with most available data relying on anatomical dissection.² The cadavers used in dissection studies can be subject to artifactual damage. Furthermore, the location of the sphenopalatine foramen can be harder

to determine in cadavers with artifactual preservation of tissue.

This study aimed to establish, independently of age and gender, whether nasal bony landmarks on CT imaging could be reliably utilised to identify the sphenopalatine foramen. A study by Hadoura *et al.*³ previously determined that osteological data correlated with radiological data, thus supporting the use of radiological imaging as an alternative for anatomical measurements.

Relevant anatomy

The sphenopalatine foramen is the main route of communication between the pterygopalatine fossa and the nasal cavity through which the neurovascular bundle enters. The sphenopalatine foramen lies on the lateral nasal wall and consists of a single or double orifice. It is related to the ethmoid crista of the palatine bone where it fixes to the tail of the middle turbinate.⁴ The anterior border of the sphenopalatine foramen is characterised by a sharp bony crest, called the crista ethmoidalis, located at the narrow middle part of the hourglass-shaped foramen. However, the shape of the

sphenopalatine foramen varies; it can be oval, square, triangular or piriform (pear-shaped). It has an average horizontal diameter of 5.1 mm (range, 4–7 mm) and an average vertical height of 6.2 mm (range, 4.5–7.5 mm).^{3,4} The opening of the sphenopalatine foramen is a vertically oriented oval shape, located at the end of the 4–7 mm canal which extends superiorly and inferiorly.⁵ Anatomical variations on the lateral nasal wall include accessory foramina, arterial ramifications, variations within sphenopalatine foramen morphology and dimension, and relations to the middle turbinate.^{6,7}

Traditionally, the sphenopalatine foramen was described as an opening in the superior meatus located at the posterior end of the attachment of the middle turbinate on the lateral nasal wall. Some authors have reported the sphenopalatine foramen lying under the cover of the posterior part of the middle turbinate attachment, extending superiorly beyond the posterior horizontal portion of the superior turbinate lamella.^{8,9} In other studies, the sphenopalatine foramen has been reported to lie below the posterior end of the line of the middle turbinate attachment (middle meatus) and crista ethmoidalis, or at the transition of the middle and superior meatus.^{2,3}

The ethmoidal crest is a protrusion of bone formed as the perpendicular plate of palatine bone blends with the middle turbinate. It is an important anatomical landmark for the sphenopalatine foramen.¹⁰ As the perpendicular plate of palatine bone runs obliquely and in a forwards direction, the plane of the sphenopalatine foramen opens forwards at an angle with the sagittal plane ranging from 0 to 30 degrees.¹¹

The sphenopalatine artery arises in the pterygopalatine fossa and courses medially in a large 'S' shape, eventually piercing the sphenopalatine foramen into the nasal cavity.^{12,13} The sphenopalatine artery is the terminal branch of the maxillary artery, which continues as a single stem artery and then divides into two branches: the posterior nasal artery and the nasopalatine artery.³ The artery supplies 90 per cent of nasal mucosa, with the posterior septal artery supplying the septum and the posterolateral nasal artery supplying the middle and inferior turbinates and fontanelle.² Additional collateral branches to the superior and/or middle turbinates can arise from the stem of the main branches or directly from the sphenopalatine foramen.^{2,14} Often, the sphenopalatine and posterior nasal artery may not emerge in close proximity in the sphenopalatine foramen.¹⁴ Thus, it follows that the success rate of sphenopalatine artery ligation is based on accurate identification and ligation of these responsible branches at the sphenopalatine foramen.^{15,16}

Anatomical variability

Wareing *et al.*,¹⁷ in 1998, were the first to propose a classification system of the osteology of the sphenopalatine foramen (Table I). The authors analysed 238 cadaveric lateral nasal walls and proposed 3 classes

TABLE I
OSTEOLOGICAL CLASSIFICATION OF
SPHENOPALATINE FORAMEN¹⁷

Class	Cases (%) [*]	Description
I	35	Opening of SPF is purely into superior meatus, above middle turbinate & ethmoidal crest of palatine bone
II	56	SPF spans ethmoidal crest, opening at middle & superior meatus transition region
III	9	2 separate openings on both sides of ethmoidal crest; ethmoidal crest is anterior to SPF in 98% of cases

^{*}As reported in Wareing *et al.*¹⁷ SPF = sphenopalatine foramen

of sphenopalatine foramen opening. In class I cases (accounting for 35 per cent in that study), the opening of the sphenopalatine foramen is purely in the superior meatus, above the middle turbinate and the ethmoidal crest of the palatine bone. In class II cases (56 per cent), the sphenopalatine foramen spans the ethmoidal crest to open at the transition of the middle and superior meatus. In class III cases (9 per cent), there are two separate openings on either side of the ethmoidal crest, which in 98 per cent of cases lies anterior to the sphenopalatine foramen.

Traditionally, identifying the bony ethmoidal crest of the palatine bone, onto which the middle nasal turbinate is attached, forms the basis for locating the sphenopalatine foramen for endonasal access. Since Wareing *et al.*, only a limited number of studies have focused on identifying the anatomy of the sphenopalatine foramen and its relations. Most of the study findings were based on cadaveric dissection and have limited application in a surgical setting.

Materials and methods

A prospective analysis of 102 consecutive helical CT scans of the paranasal sinuses was carried out by 2 senior ENT surgeons. Distances from the sphenopalatine foramen to endoscopically palpable bony landmarks were measured. The following mean measurements were recorded on axial CT images: sphenopalatine foramen width and length; distances from the sphenopalatine foramen to the posterior fontanelle and to the inferior turbinates; and pterygomaxillary raphe width. On the coronal views, the vertical distance between the floor of the sphenopalatine foramen and the bony attachment of the inferior turbinate was measured (Figure 1). The sphenopalatine foramen was categorised as having the foramen opening either at, above or below the middle turbinate. Each of these measurements (Table II) were determined for the left and right sides, and verified by a second senior consultant.

Results

There were a total of 102 patients, comprising 45 females and 57 males with mean ages of 73 years

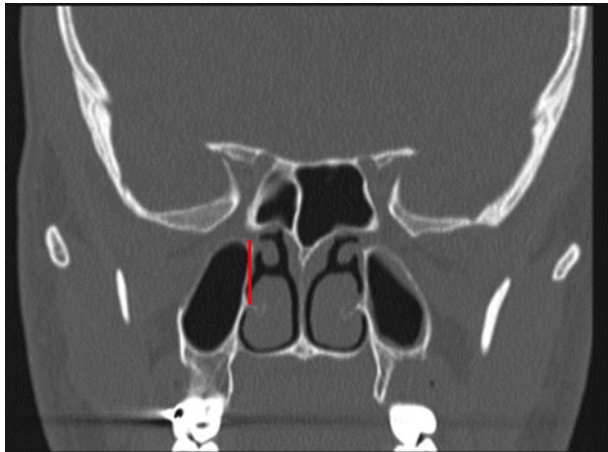


FIG. 1

Sphenopalatine foramen appears to open symmetrically at the level of the middle turbinate (red line), as shown on coronal computed tomography.

and 51 years respectively (Table III). The mean distance from the posterior fontanelle to the sphenopalatine foramen was 14.1 mm (standard deviation (SD) = 2.13). The average vertical distance of the sphenopalatine foramen opening from the bony attachment of inferior turbinate was 14.13 mm. The average width of the sphenopalatine foramen was 4.62 mm (SD = 1.55). Data showing the relation of the sphenopalatine foramen to the middle turbinate are presented in Table IV.

The data were analysed for statistical differences between left and right sides and in terms of gender based on individual measurements. The data were first analysed in terms of symmetry. This revealed no significant difference between the left and right sides for any individual measurement. Differences in the average distances to the sphenopalatine foramen between genders were then compared. Analyses demonstrated no statistically significant difference between any of our measurements according to gender. Analyses revealed no statistically significant differences between any of the measurements (foramen width p -value = 0.714, distance from fontanelle p -value 0.43 and distance from inferior turbinate p -value = 0.48).

The measurement of most clinical relevance to endoscopic procedures was the distance of the sphenopalatine

TABLE II
BONY LANDMARKS OF SPHENOPALATINE FORAMEN

Axial CT views
– Sphenopalatine foramen AP width
– Pterygomaxillary raphe length
– Sphenopalatine foramen to posterior fontanelle distance
– Pterygomaxillary raphe width
Coronal CT views
– Vertical distance between floor of sphenopalatine foramen
– Bony attachment of inferior turbinate

CT = computed tomography; AP = anteroposterior

TABLE III
PATIENT DEMOGRAPHICS

Gender	n^*	Average age (years)	Age range (years)
Female	45	73	20–97
Male	57	51	12–93

*Total $n = 102$

TABLE IV
RELATION OF SPHENOPALATINE FORAMEN DISTANCE TO MIDDLE TURBINATE

Sphenopalatine foramen location	n	Distance measurements		
		Min (mm)	Max (mm)	SD
Above middle turbinate	35	11.6	18.2	2.73
At or across middle turbinate	130	6.7	18.8	2
Below middle turbinate	22	3.2	17.1	4.3

Min = minimum; max = maximum; SD = standard deviation

foramen to the posterior fontanelle; this average length was 14.1 mm (Table V). Notably, only 3 of 102 patients had measurements that lay outside of a 10–20 mm range (Figure 2). The SD was 2.13, indicating that 95 per cent of the sphenopalatine foramens in our sample population opened between 12 and 16 mm from the posterior wall of the fontanelle.

Discussion

This study aimed to identify surgically reliable and reproducible landmarks for endoscopic approaches to the sphenopalatine foramen. The findings revealed a mean distance from the posterior fontanelle to the bony attachment of the inferior turbinate of 14.1 mm (SD = 2.13), with a mean sphenopalatine foramen width of 4.62 mm (SD = 1.55). Importantly, these measurements did not vary significantly with age or gender. The results of this work also reflect variability in the position of the sphenopalatine foramen, consistent with Wareing and colleagues¹⁷ findings of three distinct patterns of sphenopalatine foramen position (Table I). Several cadaveric studies have confirmed this variability in the sphenopalatine foramen position (Table VI).^{2,12}

Prades *et al.*² performed a cadaveric analysis of 12 adult dry skulls under microscopy. The study aimed to locate the sphenopalatine foramen with emphasis on the sphenopalatine artery. The inferior border of the sphenopalatine foramen was situated 18.27 mm (range, 15.09–20.87 mm) above the horizontal plate of the palatine bone. It lay 13.04 mm (range, 9.01–14.85 mm) above the horizontal lamina of the inferior turbinate. Endoscopically, the posterior wall of the maxillary sinus was located at the level of or anteriorly within 10 mm of the anterior edge of the

TABLE V
CT CORRELATED LANDMARKS FOR IDENTIFYING SPHENOPALATINE FORAMEN

Gender	Sphenopalatine foramen measurements (mm)				
	Width	Length	PMR width	Distance from fontanelle	Distance from inferior turbinate
Male	4.76	9.06	3.64	13.86	14.11
Female	4.47	9.73	3.72	14.38	14.17
Total	4.62	9.35	3.67	14.1	14.13

CT = computed tomography; PMR = pterygomaxillary raphe

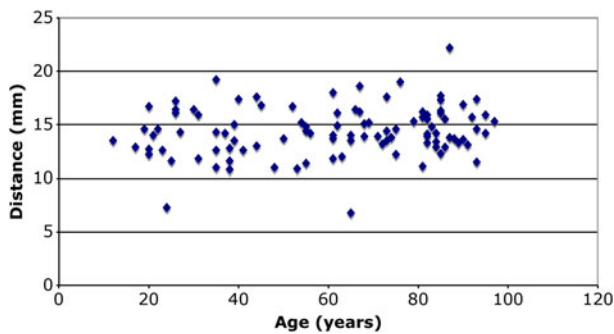


FIG. 2

Distance of the sphenopalatine foramen to the posterior fontanelle for all patients.

sphenopalatine foramen.² In another study, by Simmen *et al.*,¹⁸ 97 per cent of specimens had 2 or more branches, and 64 per cent of specimens had between 3 and 10 branches. The findings of the Prades *et al.*² study were in agreement with the frequencies of the sphenopalatine foramen locations described by Wareing *et al.*,¹⁷ with the middle and superior meatus transitional region being the most frequent location.

Padua and Voegels¹ reported that the ethmoidal crest lay anterior to the sphenopalatine foramen in 98 per cent of cases. In that study, the sphenopalatine foramen most frequently lay at the transitional region of the middle and superior meatus (86.9 per cent), and less frequently at the superior meatus (13.1 per cent). The mean distance from the sphenopalatine

foramen to the anterior nasal spine was 6.6 cm and to the accessory foramen was 6.7 cm, the latter of which is often found inferior and anterior to the sphenopalatine foramen. In endoscopic surgery, the ethmoidal crest may not be well demarcated. As the posterior ethmoidal cells lie just above the ethmoidal crest, this can be a particularly hazardous route.

Hadoura *et al.*³ performed a radiological study of the sphenopalatine foramen that confirmed the validity of CT scans as an alternative to osteological studies. The anterior nasal spine on the plane of the piriform aperture was used as a fixed bony landmark. The mean distance from the sphenopalatine foramen to the nasal spine was 59.027 mm and to the piriform aperture was 48.481 mm, and the mean angle of elevation from the nasal floor was 22.5608 degrees.³ Limitations of that study include the small sample size of 28 patients, inter/intra-observer variation and the use of surgically inappropriate landmarks.

To address the anatomical variations of the sphenopalatine foramen, Midilli *et al.*¹² examined the bony landmarks of 20 cadaveric specimens. The sphenopalatine foramen appeared as a single foramen in 90 per cent of the specimens ($n = 18$); bony bridges created multiple foramens in the remaining two specimens. The sphenopalatine foramen was located superiorly to the horizontal lamina of the middle turbinate in 20 per cent of specimens ($n = 4$), and was located at the transition of the middle and superior meatus in 80 per cent of specimens ($n = 16$). The vertical distance

TABLE VI
SURGICAL LANDMARKS FOR IDENTIFYING SPHENOPALATINE FORAMEN

Study (year)	Surgical landmark	Co-ordinates	Measurements
Prades <i>et al.</i> ² (2008)	Horizontal lamina of inferior turbinate	Inferior border of SPF	13.04 mm (range, 9.01–14.85)
	Horizontal plate of palatine bone	Inferior border of SPF	18.27 mm (range, 15.09–20.87)
	Superior-inferior length of SPF	Inferior border of SPF	6.13 mm (range, 5.24–6.84)
Hadoura <i>et al.</i> ³ (2009)	Anterior nasal spine	Angle of elevation	22.560°
		Distance	59.027 mm
Midilli <i>et al.</i> ¹² (2009)	Base of nose	Vertical distance to inferior tip of SPF	22.1 ± 3 mm
Lee <i>et al.</i> ⁸ (2002)	Limen nasi	SPF	49.1 ± 3.7 mm
	Nasal sill	SPF	59.4 ± 4.2 mm
Current (2015)	Posterior fontanelle	Floor of SPF	14.11 mm
	Inferior turbinate	Floor of SPF	14.13 mm

SPF = sphenopalatine foramen

between the inferior tip of the sphenopalatine foramen and the base of the nose was 22.1 ± 3.0 mm (range, 16.6–29.6 mm).¹²

Lee *et al.*⁸ examined 50 mid-sagittal cadaver sections; in 45 specimens (90 per cent), the sphenopalatine foramen was located in the superior meatus, between the middle turbinate and the posterior horizontal end of the superior turbinate lamella, attaching to the lateral nasal wall. The distance from the anterior part of the nose to the sphenopalatine foramen was 49.1 ± 3.7 mm from the limen nasi, and was 59.4 ± 4.2 mm from the nasal sill.⁸ During surgery, the ethmoidal crest that is exposed following removal of mucosa is often used as a landmark for the sphenopalatine foramen.

Scanavine *et al.*⁴ examined 54 hemiskulls and 12 hemifaces from cadavers in order to determine the anatomical variation of the sphenopalatine foramen. The authors measured the opening of the sphenopalatine foramen and the anterior nasal spine, and determined that the mean distance from the anterior nasal spine to the sphenopalatine foramen was 55.24 ± 3.85 mm, whilst the mean angle between the nasal floor and sphenopalatine foramen was 25.8 degrees. The ethmoid crista was observed in 44 bone specimens (81.5 per cent) and was directed towards the inferior margin of the sphenopalatine foramen, in the superior meatus. Additionally, the superior nasal turbinate was noted to point towards the superior border of the sphenopalatine foramen in 55.6 per cent of cases. However, the role of these structures as landmarks remains unclear.

- **Anatomical variations of the sphenopalatine foramen and its surroundings can hinder intra-operative visualisation, contributing to surgical failures**
- **The average vertical distance of the sphenopalatine foramen opening from the inferior turbinate bony attachment was 14.13 mm**
- **The average width of the sphenopalatine foramen was 4.62 mm (standard deviation = 1.55)**
- **The sphenopalatine foramen is a superior meatus opening at the posterior end of the middle turbinate attachment on the lateral nasal wall**
- **Inferior turbinate attachment and posterior fontanelle are reliable surgical landmarks for endoscopic approaches to the sphenopalatine foramen**

None of the aforementioned studies identified a clinically relevant landmark in the endoscopic identification of the sphenopalatine foramen. The data from this work suggest that the posterior fontanelle and inferior turbinate are relevant and consistent landmarks for locating

the sphenopalatine foramen during endoscopic sinus surgery. Furthermore, the identification of an accessory foramen on pre-operative CT imaging can be helpful in order to minimise therapeutic failure.

Surgery for sphenopalatine artery ligation may fail if dissection is not continued up to the posterior portion of the sphenopalatine foramen. This is because of the presence of arterial branches through the accessory foramen that are considered the primary source of bleeding.

Conclusion

This work suggests that the inferior turbinate attachment and posterior fontanelle may be used reliably as surgical landmarks for endoscopic approaches to the sphenopalatine foramen. The dimensions of the pterygomaxillary fissure and sphenopalatine foramen do not vary significantly with age or gender. Identification of the accessory foramina is important to correctly identify all branches of the sphenopalatine artery. Finally, the sphenopalatine foramen has a variable relationship to the posterior end of the middle turbinate and has a variable number of vessels passing through it.

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