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Relation Between Paraclival Carotid Canal and Sphenoid Sinus Pneumatization Pattern: A New Classification

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ABSTRACT

Background: Many neurovascular structures are in critical proximity to the sphenoid sinus margins. The purpose of the study is to establish a simple classification for the relation of the paraclival carotid canal to sinus margins using computed tomography to minimize surgical risks.

Methods: This retrospective study included 168 patients who were referred to the Diagnostic Radiology Department for computed tomography scans on paranasal sinuses from June 2019 to June 2020. We evaluated the sphenoid sinus pneumatization pattern, the relation of the paraclival internal carotid artery canal to its margins, and the variations of the intersinus septum.

Results: Type 2 canal was the commonest in the midsellar pattern, type 3 canal was the commonest in the sellar pattern whereas type 4 canal was absent in conchal, presellar, and midsellar patterns. We found a highly significant association between type 4 canal and sellar and postsellar patterns of pneumatization on both sides ($p < .001$).

Conclusion: The establishment of a simple and applicable standard classification for the types of paraclival internal carotid artery by computed tomography can help to minimize vital surgical complications.

Keywords: Sphenoid sinus, pneumatization pattern, paraclival ICA, CT.

INTRODUCTION

The sphenoid sinus (SS) is radiologically evident by the age of six months and attains full pneumatization by adolescent age [1]. Pneumatization pattern (PP) was classified according to its posterior extent into conchal (pneumatization stops by about 10 mm before the sella), presellar (pneumatization stops at the anterior margin of the sella), and sellar types (pneumatization extends inferior to the sella) [2,3]. Others added a postsellar type [4].

A thin bony septum commonly divides the sinus cavity into right and left compartments which are commonly unequal in size. One side may overlap the other and rarely they may communicate [3,5,6]. The septum is the seat of many variations considering its position, orientation, number, and attachment. The incomplete and absent septum was also reported [7,8]. It may attach to the margins of the paraclival segment of the internal carotid artery (ICA) canal [4].

Many neurovascular structures are in critical proximity to the SS margins [9,10]. The ICA may induce bony prominence into the sinus cavity [3,11]. The bone covering the ICA may be thin or dehiscent [4,12].

Vital complications may occur when the neurovascular structures are involved by sinus inflammatory or neoplastic lesions [12]. Bleeding during endoscopic sinus surgery may hinder the precise identification of critical anatomical variations. A wide opening of the SS and removal of sinus septa are needed during extended endoscopic endonasal surgery to allow easy access and adequate visualization of the posterior sinus wall. Careful handling of the intersinus septum must be considered especially when it is attached to the margins of ICA [13].

A critical posterior pneumatization of SS is considered when the distance between the posterior sinus wall and the clivus is less than 2 mm on axial images [9].

Detailed preoperative radiological assessment of sinus PP, septum variations, the relation of the regional neurovascular structures and the variations in ICA course, degree of protrusion into the sinus cavity and septal attachment to it is of great concern for surgical planning by rhinologists and neurosurgeons [4,7,9,13].

This study aimed to establish a simple practical classification for the pattern of sphenoid sinus pneumatization and for the relation of the paraclival carotid canal to the sinus margins using multislice computed tomography (MSCT) to minimize surgical risks.

PATIENTS AND METHODS

This retrospective study included 168 patients with paranasal sinuses (PNS) related symptoms who were referred to the Diagnostic Radiology Department for a CT scan on PNS in the period from June 2019 to June 2020. Toshiba Alexion 16 slice CT scanner was used. Axial scans were conducted in a plane parallel to the hard palate with a 0.5mm slice thickness. Sagittal

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reconstructed images were obtained using dedicated workstations.

Inclusion criteria; Patients older than 18 years to guarantee full SS pneumatization.

Exclusion criteria; Patients with previous SS surgery, craniofacial malformations, and locally destructive sinus mass.

Image analysis

Axial images were used to assess the degree of protrusion of the paraclival segment of the ICA into each compartment and to assess the intersinus septum regarding no, branching pattern, and attachment to ICA. Sagittal reconstructed images were used to assess the PP of the Rt and Lt SS compartments. Axial, coronal, and sagittal images were used to assess the PNS for any underlying disease.

Classification of sphenoid sinus pneumatization pattern

We classified sphenoid PP into 5 types, conchal (pneumatization ends by about 1 cm before the anterior sellar margin), presellar (pneumatization ends at the anterior sellar margin), midsellar (infrasellar pneumatization extends to a point midway between its anterior and posterior margins), sellar (pneumatization extends opposite posterior sellar margin) and postsellar type (pneumatization extends beyond posterior sellar margin) **(Fig. 1).**

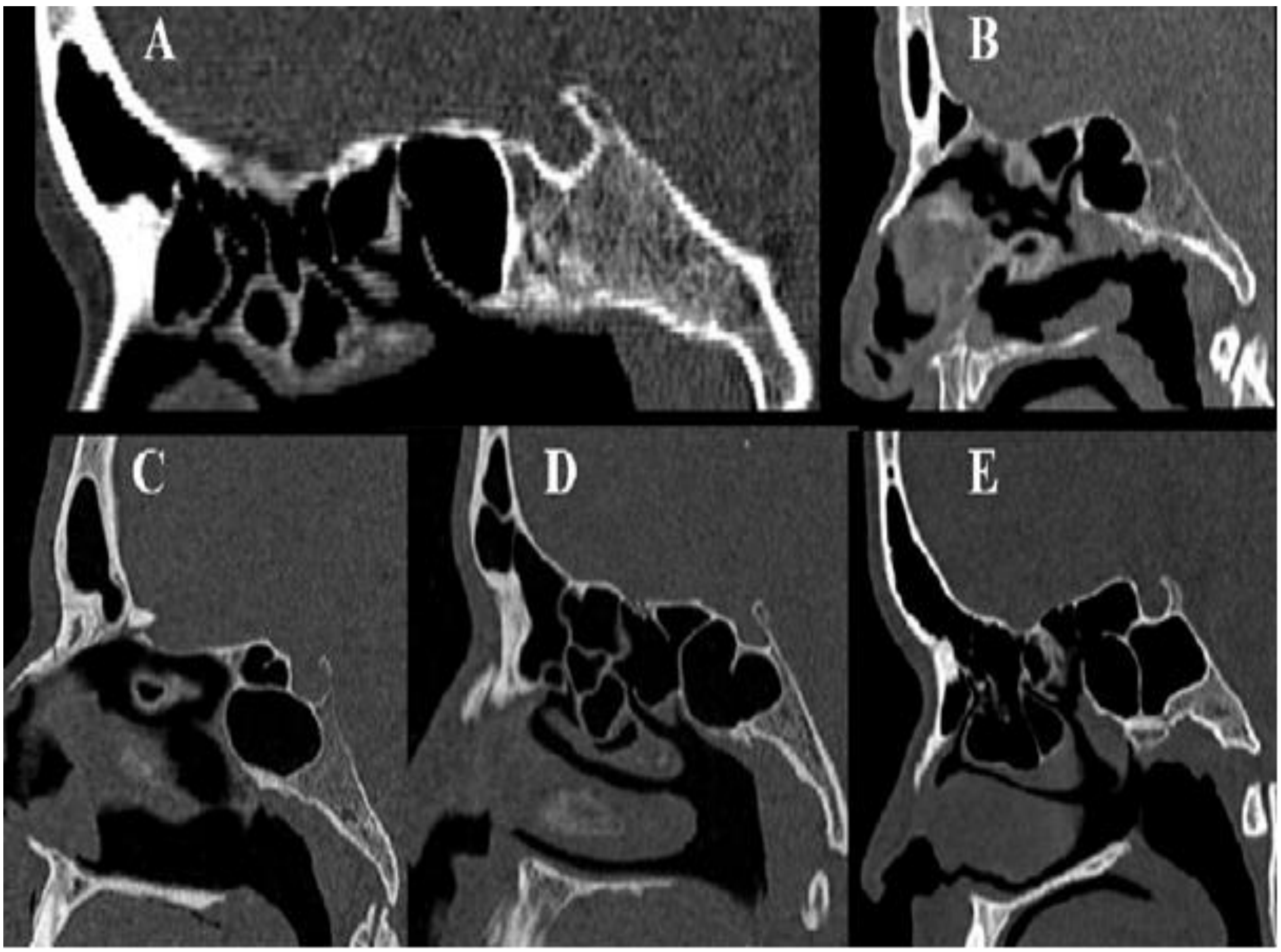

Fig.1. Sagittal reconstructed MSCT images showing different sphenoid sinus pneumatization patterns. (A) Conchal, (B) presellar, (C) midsellar, (D) sellar (E) postsellar.

Classification of types of paraclival ICA canal

Dal Secchi *et al.* defined ICA protrusion as if more than 50% of its circumference was protruding into the SS cavity [9]. We adopted a new classification according to the degree of ICA protrusion into the SS cavity as follows: type 1 (the canal is completely embedded within the bone), type 2 (the canal abuts the posterior margin of SS with or without minor protrusion into sinus cavity), type 3 (less than 50% of the circumference of the canal protrude into sinus cavity) and type 4 (50% or more of the circumference of the canal protrude into sinus cavity) **(Fig. 2)**.

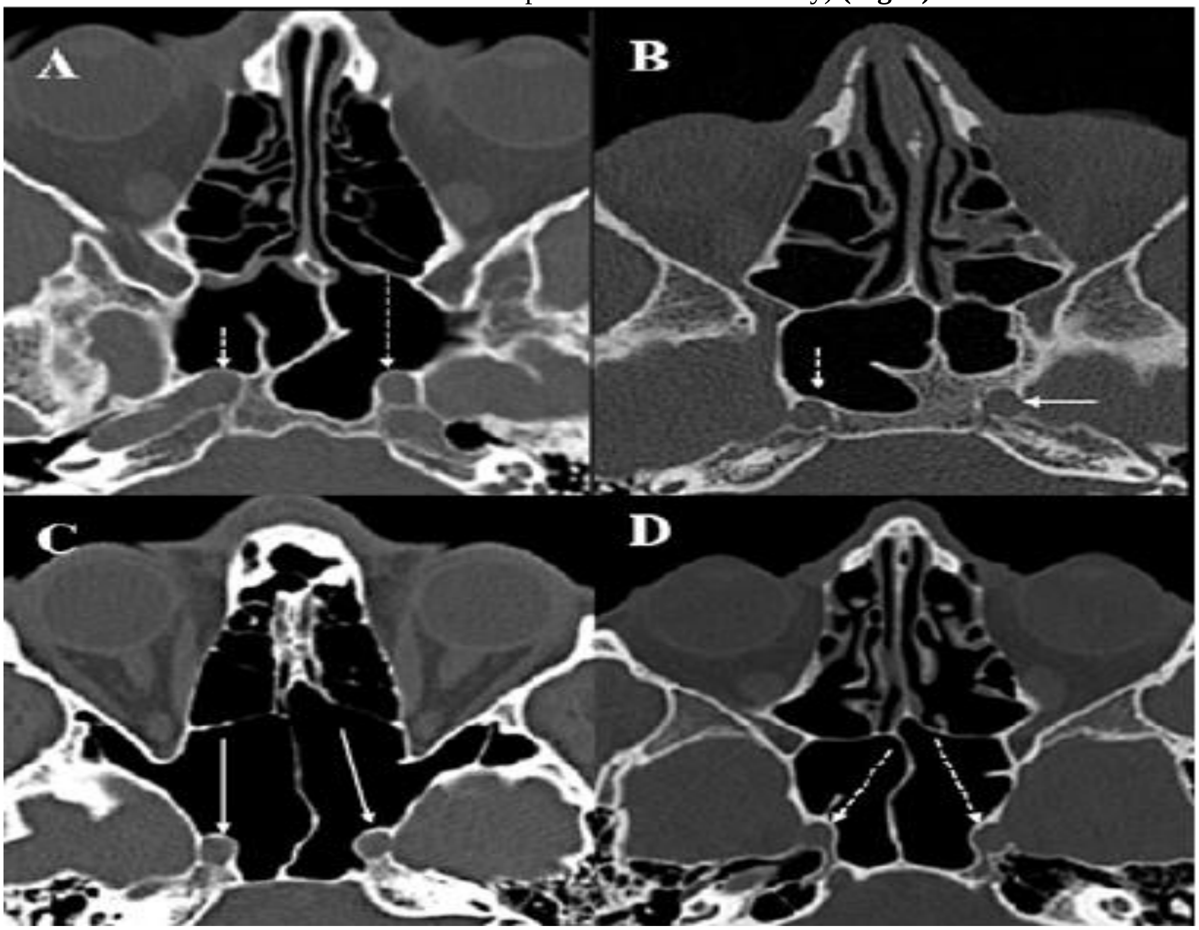

Fig.2. Axial MSCT images showing different types of paraclival ICA canal. (A) Rt type 2 (short dashed arrow) and Lt type 3 (long dashed arrow), (B) Rt type 2 (short dashed arrow) and Lt type 1 (short solid arrow), (C) bilateral type 4 (long solid arrows), (D) bilateral type 3 (long dashed arrow).

Ethical considerations

The study was approved by the Medical Research Ethics Committee of the Faculty of Medicine, Sohag University in Egypt in compliance with the Helsinki Declaration (DoH-oct20081) under IBR registration number: Soh-Med-21-03-16. Informed consent was not obtained as this was a retrospective study.

Statistical analysis

The data were analyzed using the statistical package for social sciences (SPSS 16 for windows). Statistical evaluations were performed for each measurement. The Chi-square test was used to measure the association between variable qualitative data on the right and left sides. P-value ≥ 0.05 was considered non-significant whereas P-value ≤ .001 was considered highly significant.

RESULTS

The study included 168 patients (96 were males and 72 were females). Their ages ranged from 20-72 years with the mean age being 40.6±13.3 years.

The Rt sphenoid compartment PP was conchal in 10 patients (6%), presellar in 26 (15.5%), midsellar in 57 (33.9%), sellar in 59 (35.1%) and postsellar in 16 (9.5%).

The Lt sphenoid compartment PP was conchal in 8 patients (4.8%), presellar in 34 (20.2%), midsellar in 72 (42.8%), sellar in 45 (26.8%) and postsellar in 9 (5.4%)**(Table 1)**.

Table 1. Pneumatization patterns of Rt and Lt compartments

	Pneumatization pattern					Total
	Conchal (A)	Presellar (B)	Midsellar (C)	Sellar (D)	Postsellar (E)	
Rt compartment	10 (6%)	26 (15.5%)	57 (33.9%)	59 (35.1%)	16 (9.5%)	168
Lt compartment	8 (4.8%)	34 (20.2%)	72 (42.8%)	45 (26.8%)	9 (5.4%)	168

The Rt ICA canal was type 1 in 23 patients (13.7%), type 2 in 96 (57.1%), type 3 in 28 (16.7%) and type 4 in 21 (12.5%). The Lt ICA canal was type 1 in 42 patients (25%), type 2 in 74 (44%), type 3 in 46 (27.4%) and type 4 in 6 (3.6%) **(Table 2).**

Table 2. Types of Rt and Lt ICA canal.

	Total				
	Type 1	Type 2	Type 3	Type 4	
Rt canal	23 (13.7%)	96 (57.1%)	28 (16.7%)	21 (12.5%)	168
Lt canal	42 (25%)	74 (44%)	46 (27.4%)	6 (3.6%)	168

On the Rt side, type 1 canal was commonest in conchal PP (43.5%) and absent in sellar and postsellar patterns. Type 2 canal was absent in conchal pattern and commonest in midsellar pattern (41.7%). Type 3 canal was absent in conchal and presellar patterns and commonest in sellar patterns (53.6%). Type 4 canal was absent in conchal, presellar, and midsellar patterns. There was a highly significant association between type 4 canal and sellar and postsellar patterns of pneumatization (p <.001) **(Table 3)**.

Table 3. The association between Rt pneumatization pattern and Rt ICA canal type.

			Rt carotid canal				Total
			Type 1	Type 2	Type 3	Type 4	
Pattern Rt canal	A	Count	10	0	0	0	10 (6.0%)
		%	43.5%	.0%	.0%	.0%	
	B	Count	6	20	0	0	26 (15.5%)
		%	26.1%	20.8%	.0%	.0%	
	C	Count	7	40	10	0	57 (33.9%)
		%	30.4%	41.7%	35.7%	.0%	
	D	Count	0	33	15	11	59 (35.1%)
		%	.0%	34.4%	53.6%	52.4%	
	E	Count	0	3	3	10	16 (9.5%)
		%	.0%	3.1%	10.7%	47.6%	
Total		Count	23	96	28	21	168 (100.0%)
		%	100.0%	100.0%	100.0%	100.0%	

On the Lt side, type 1 canal was commonest in presellar PP (66.7%) and absent in sellar and postsellar patterns. Type 2 canal was absent in conchal and postsellar patterns and commonest in midsellar patterns (68.9%). Type 3 canal was absent in conchal and presellar patterns and commonest in sellar patterns (54.3%). Type 4 canal was absent in conchal, presellar, and midsellar patterns. There was a highly significant association between type 4 canal and sellar and postsellar patterns of pneumatization (p <.001) **(Table 4) (Fig. 3,4,5).**

Table 4. The association between Lt pneumatization pattern and Lt ICA canal type.

			Lt carotid canal				
			Type 1	Type 2	Type 3	Type 4	Total
Pattern. Lt canal	A	Count	8	0	0	0	8 (4.8%)
		%	19.0%	.0%	.0%	.0%	
	B	Count	28	6	0	0	34 (20.2%)
		%	66.7%	8.1%	.0%	.0%	
	C	Count	6	51	15	0	72 (42.8%)
		%	14.3%	68.9%	32.6%	.0%	
	D	Count	0	17	25	3	45 (26.8%)
		%	.0%	23.0%	54.3%	50.0%	
	E	Count	0	0	6	3	9 (5.4%)
		%	.0%	.0%	13.1%	50.0%	
Total		Count	42	74	46	6	168 (100.0%)
		%	100.0%	100.0%	100.0%	100.0%	

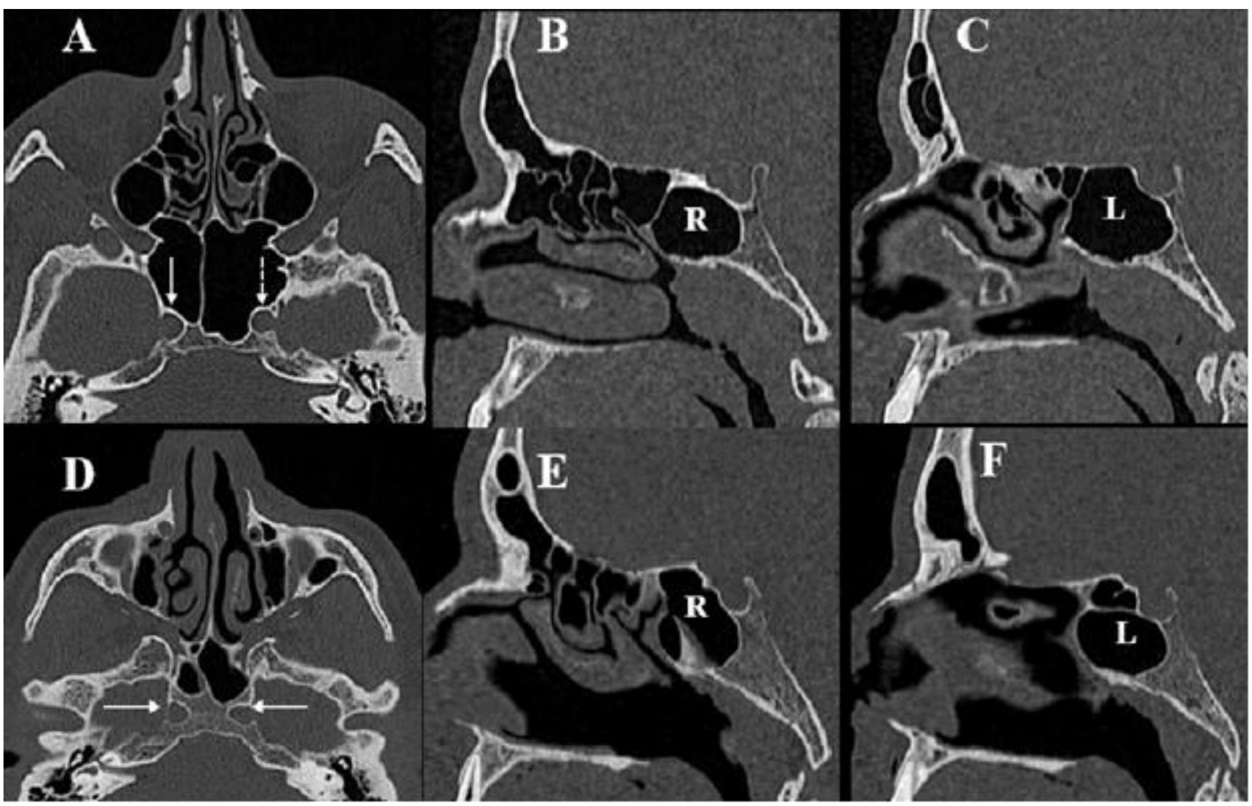

Fig.3. (A-C) Male patient 38 ys old with Rt type 2 (solid arrow in A) and Lt type 3 (dashed arrow in A) ICA with bilateral midsellar patterns of pneumatization (B, C). (D-F) Male patient 45 ys old with bilateral type 1 (solid arrows in D) ICA with Rt presellar (E) and Lt midsellar (F) patterns of pneumatization.

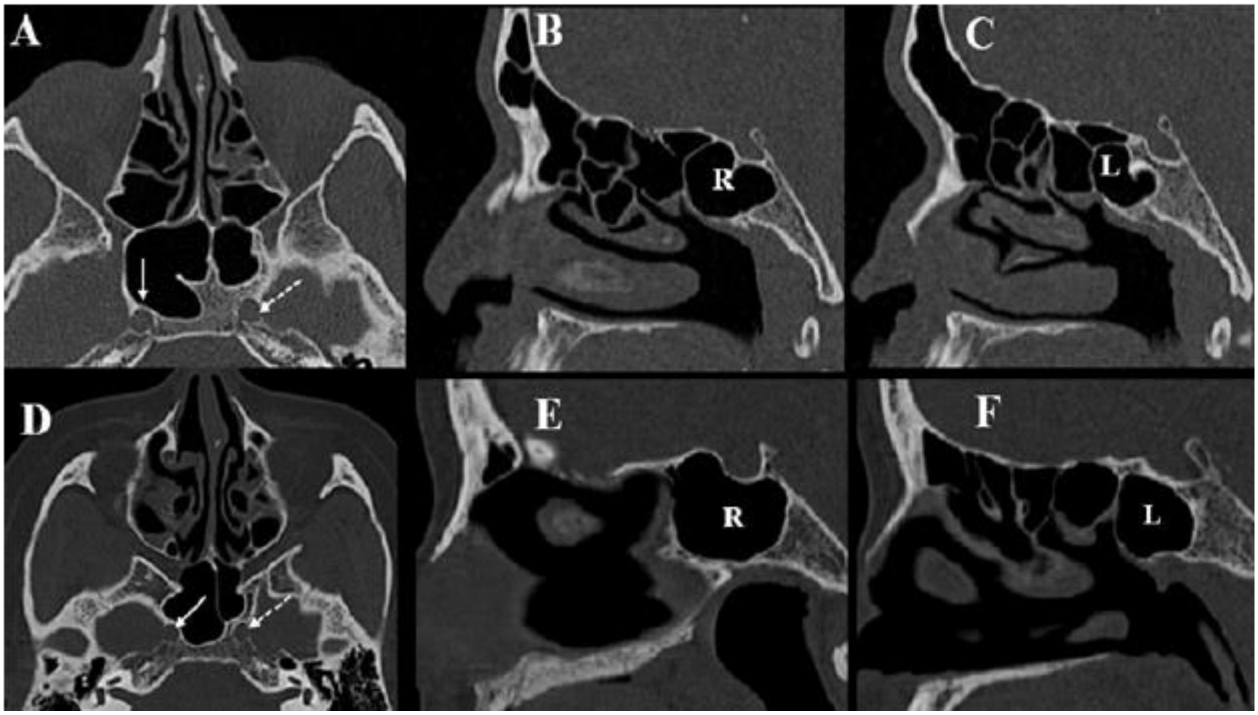

Fig.4. (A-C) Male patient 25 ys old with Rt type 2 (solid arrow in A) and Lt type 1 (dashed arrow in A) ICA with Rt sellar (B) and Lt presellar (C) patterns of pneumatization. (D-F) Female patient 37 ys old with Rt type 2 (solid arrow in D) and Lt type 1 (dashed arrow in D) ICA with Rt postsellar (E) and Lt presellar (F) patterns of pneumatization.

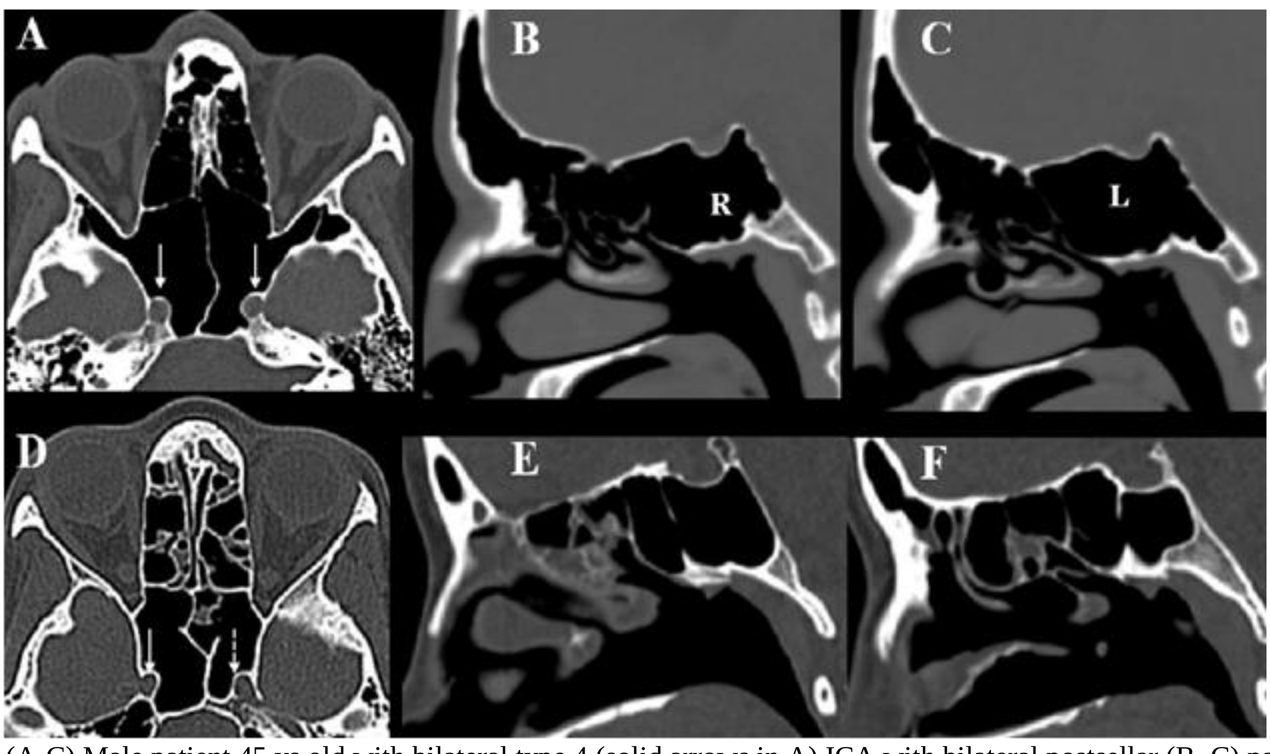

Fig.5. (A-C) Male patient 45 ys old with bilateral type 4 (solid arrows in A) ICA with bilateral postsellar (B, C) patterns of pneumatization. (D-F) Female patient 23 ys old with Rt type 4 (solid arrow in D) and Lt type 3 (dashed arrow in D) ICA with Rt postsellar (E) and Lt sellar (F) patterns of pneumatization.

Bilateral conchal PP was found in 6 patients, bilateral presellar pattern in 17, bilateral midsellar pattern in 26, bilateral sellar pattern in 20, and bilateral postsellar pattern in 7. There was a highly significant association between PP on Rt and Lt side ($p < .001$) **(Table 5)**.

Table 5. The association between Rt and Lt patterns of pneumatization.

		Pattern. Lt						Total
			A	B	C	D	E	
pattern. Rt		168	0	0	0	0	0	168
	A	0	6	4	0	0	0	10
	B	0	2	17	6	1	0	26
	C	0	0	11	26	18	2	57
	D	0	0	2	37	20	0	59
	E	0	0	0	3	6	7	16
Total		168	8	34	72	45	9	336

The intersinus septum was single in 122 patients (73%) and multiple in 46 (27%). It was branching in 36 patients (21%); 22 were males and 14 were females; whereas it was non-branching in 132 (79%) 74 were males and 58 were females. Using the Chi-square test, no significant association was found between gender and septal branching (p=0.705). The septum was attached to the Rt ICA canal in 29 patients (17%), to the Lt ICA canal in 17 (10%), and was attached to the posterior sphenoid wall in 122 (73%) **(Fig. 6)**.

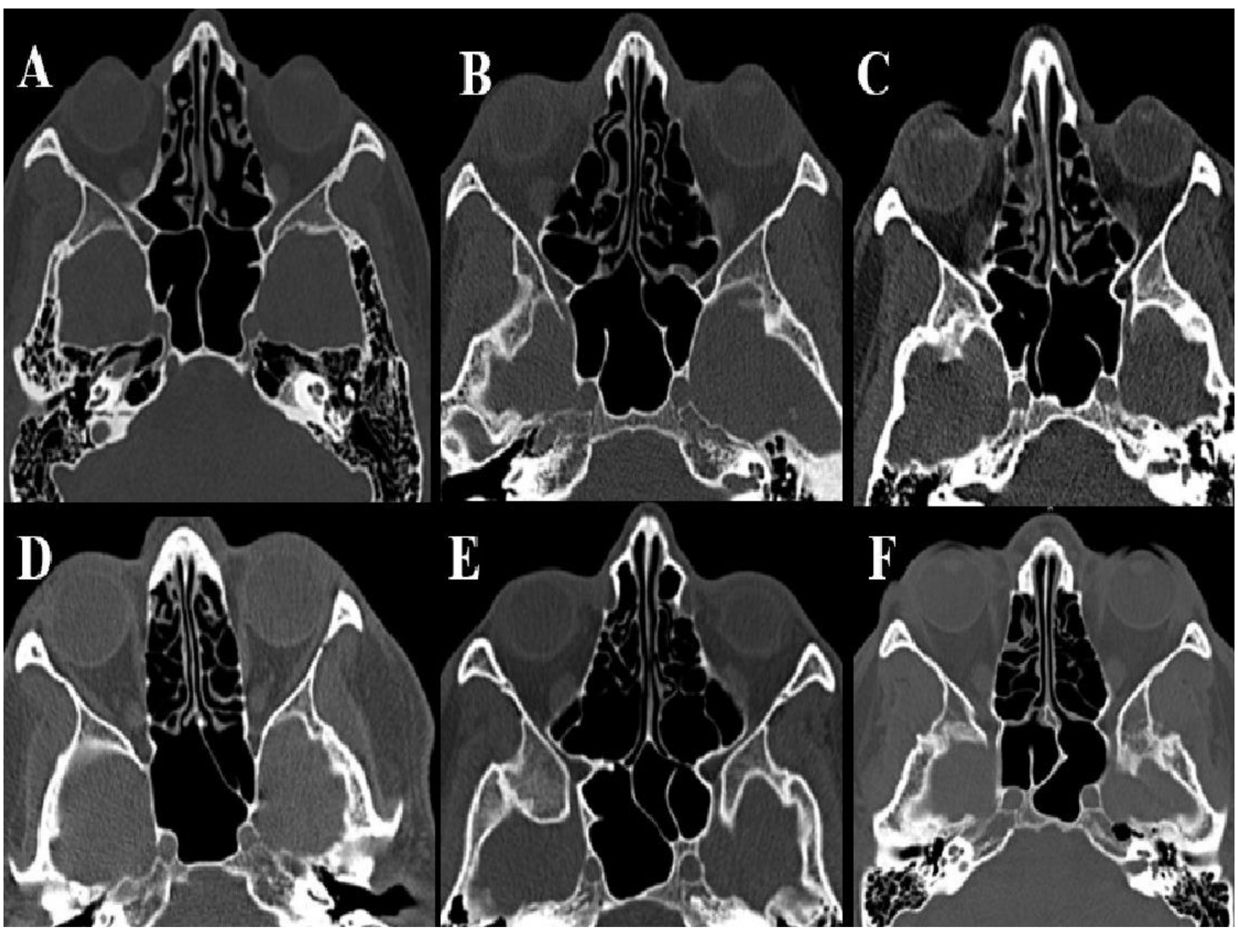

Fig.6. Intersinus septum. (A) complete septum attached to posterior sinus wall and incomplete septum attached to Rt type 3 ICA, (B) Rt incomplete and Lt complete septum attached to Rt and Lt type 2 ICA, (C), multiple septae with the Lt incomplete septum attached to Lt type 2 ICA, (D) single complete septum attached to Lt lateral sinus wall with the Rt and Lt ICA canals belong to Rt sinus cavity, (E) two complete septae not attached to either ICA canal, (F) branching septum nearby Rt ICA canal.

DISCUSSION

The great evolution in endonasal endoscopic surgery in the last few years makes the radiological assessment of sinus anatomy and variations crucial before surgery. The sphenoid sinus is one of the most variables of all sinuses. Its position at the skull base and the close relation of important neurovascular structures to its thin bony walls make it vulnerable to surgical vital complications [2,13,14,15].

Most studies classified SS pneumatization into conchal, presellar, and sellar types considering its relation to the sella turcica [1]. We classified pneumatization into conchal, presellar, midsellar, sellar, and postsellar types.

The sellar type was the commonest in the studies conducted by **Cho *et al.*** (90%) [16], **ELKammash *et al.*** (85.7%) [8], **Dal Secchi *et al.*** (98%) [9], **Vaeizi *et al.*** (73.8%) [10] and **Sevinc *et al.*** (83%) [2]. **Rennie *et al.*** found that the sellar type was the commonest on both sides (45.2% on Rt and 49% on Lt) [17]. **Sareen *et al.*** found that the postsellar type was the commonest (75%), they classified PP into postsellar and presellar [18].

In our study, the Rt sided pneumatization was conchal in 6%, presellar in 15.5%, midsellar in 33.9%, sellar in 35.1%, and postsellar in 9.5% whereas the Lt-sided pneumatization was conchal in 4.8%, presellar in 20.2%, midsellar in 42.8%, sellar in 26.8% and postsellar in 5.4%. The sellar type was the commonest on Rt (35.1%) whereas the midsellar type was the commonest on Lt (42.8%).

Vaezi *et al.* found that pneumatization was similar on the left and right sides [10]. **Dziedzic *et al.*** reported similar pneumatization in 21%. We have similar pneumatization on both sides in 45.2% [7].

We classified the paraclival ICA canal into four types according to its degree of protrusion into the sinus cavity and we evaluated both sides independently. The Rt ICA canal was type 1 in 13.7%, type 2 in 57.1%, type 3 in 16.7%, and type 4 in 12.5%. The Lt ICA canal was type 1 in 25%, type 2 in 44%, type 3 in 27.4%, and type 4 in 3.6%. The Rt ICA canal was bulging into the sinus cavity in 29.2% (type 3 and 4) and the Lt was bulging into the sinus cavity in 31% (type 3 and 4). The reported protrusion of the paraclival ICA canal was 34% by **Cho *et al.*** [16], 35% by **Dal Secchi *et al.*** [9], and 30.3% by **Unal *et al*.** [13].

We found that type 1 canal was commonest on the Rt side in the conchal pattern (43.5%) but it was commonest on Lt in the presellar pattern (66.7%). It was absent in sellar and postsellar patterns on both sides. Type 2 was the most common midsellar pattern on both sides (Rt was 41.7% and Lt was 68.9%). It was absent in the conchal pattern on Rt and in conchal and postsellar patterns on Lt. Type 3 was commonest in the sellar pattern on both sides (Rt was 53.6% and Lt was 54.3%). It was absent in conchal and presellar patterns on both sides. Type 4 was present only in sellar and postsellar patterns on both sides. There was a highly significant association between type 4 canal and sellar and postsellar patterns on both sides (p = 0.001). **Cho *et al.*** found that bulge was more frequent with more sinus pneumatization. They reported bulge in 72.1% of complete sellar type [16].

ICA wall dehiscence was reported in 5.3% by **Unal *et al*.** [13] and in 3.6%. by **Dal Secchi *et al.*** [9] while it was 0% by **Cho *et al*.** [16]. We have no cases of canal wall dehiscence.

We found that the intersinus septum was single in 73% and multiple in 27%. It was branching in 21% and non-branching in 79%. There was no significant association between gender and septal branching in our study (p=0.705). Single septum reported in 63% by **Dziedzic *et al*.** [7], in 70% by **ELKammash *et al*.** [8], in 20% by **sareen *et al.*** [18], and in 90.2 % by **Rennie *et al.*** [17]. Branched septa reported in 15.4% by **Dziedzic *et al.*** [7]. Septum was absent in 13.2% by **ELKammash *et al.*** [8] and in 61% by **Dal Secchi *et al.*** [9]. We have no cases with absent intersinus septum.

The intersinus septum may attach to the ICA bony wall which carries a high potential for ICA injury [4,13,19,20,21,22]. We found septal attachment to the ICA canal in 27% (17% on Rt and 10% on Lt) and to the posterior sphenoid wall in 73%. Septum attachment to ICA canal found in 49% by **Dziedzic *et al*.** [7], in 26.7% by **Unal *et al.*** [13] and in 19.8% by **ELKammash *et al.*** [8].

CONCLUSION

The great variation in the pattern of sphenoid sinus pneumatization carries the risk of vital injury to adjacent neurovascular structures including the paraclival carotid canal during surgery. The establishment of a simple and applicable standard classification for the types of paraclival ICA by MSCT can help to minimize vital surgical complications.

Abbreviations

Sphenoid sinus (SS), pneumatization pattern (PP), internal carotid artery (ICA), multislice computed tomography (MSCT), paranasal sinuses (PNS).

Availability of data and materials

Data will be available upon request via contacting the corresponding author.

Competing interests

The authors declare that they have no competing interests.

Conflict of Interest

There are no conflicts of interest to disclose.

Funding

None to declare.

Authors' contributions

MA conceived the study and designed it. MA and MH contributed equally to data collection and data analysis. The manuscript was written by MA and AA. Statistical analysis was done by AA. The manuscript revision was done by KF and MM.

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