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Sinonasal Anatomy Variations on CT Scans of a Sample of Filipino Adults With Chronic Rhinosinusitis

ABSTRACT

Objective: To determine the prevalence of sinonasal anatomic variations seen on paranasal sinus (PNS) CT scans of a sample of Filipino adults with chronic rhinosinusitis.

Methods:

Design: Cross-sectional study
Setting: Tertiary Government Training Hospital
Participants: The PNS CT scans of 51 Filipino patients with chronic rhinosinusitis with and without nasal polyposis diagnosed at our outpatient Department of Otorhinolaryngology-Head and Neck Surgery between October 2015 to December 2020 were reviewed for the presence of sinonasal anatomic variants. The prevalence of the identified variants was calculated.

Results: The CT scans of 51 patients, 41 (80.4%) men and 10 (19.6%) women, were included. The median age was 48 years (Q25: 35, Q75: 56, IQR:21). The median Lund Mackay Score (LMS) was 15 (Q25: 12, Q75: 20, IQR:8). Majority (94%) had an LMS of ≥5. The most common anatomic variant in the study population was agger nasi (n=46/51, 90.2% present bilaterally) followed by uncinate process attachment to the lamina papyracea (n=90/102, 88.24%). The third to sixth most common findings were Keros type II classification (n=76/102, 74.51%), nasal septal deviation (n=35/51, 68.62%), optic nerve canal type 1 (n=67/102, 65.69%) and anterior ethmoid artery grade 1 (n=46/102, 45.1%), respectively. Less common variants were Onodi cell (n=13/51, 25.49% unilateral and n=10/51, 19.61% bilateral), Haller cell (n=8/51, 15.69% unilateral and n=1/51, 1.96% bilateral), supraorbital cell (n=4/51, 7.84% unilateral and n=4/51, 7.84% bilateral), middle turbinate concha bullosa (n=3/51, 5.88% unilateral and n=6/51, 11.76% bilateral), superior turbinate concha bullosa (n=2/51, 3.92% unilateral and n=1/51, 1.96% bilateral), pneumatized crista galli (n=2/51, 3.92%) and optic nerve dehiscence (n=1/51, 1.96% bilateral).

Conclusion: In the adult Filipino population with CRS sampled in this study, the six most common sinonasal anatomic variants were agger nasi, superior attachment of the uncinate process to the lamina papyracea, Keros type II classification, septal deviation, optic nerve canal type 1 and anterior ethmoid artery grade 1. Pre-operatively, the PNS CT scan of every patient must be meticulously evaluated for the sinonasal anatomic variants to avoid surgical complications.

Keywords: *chronic rhinosinusitis; paranasal sinus CT; anatomic variants*

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The management for chronic rhinosinusitis (CRS) includes medical treatment. However, those who have failed medical therapy will subsequently undergo surgery.[1] According to the European Position Paper (EPOS) on Rhinosinusitis and Nasal Polyps 2020, a paranasal sinus (PNS) computed tomography (CT) scan is required prior to undergoing Endoscopic Sinus Surgery (ESS) to determine both the extent of the disease and the sinonasal anatomic variants that may increase the risk of surgical complications.[2] Thus, knowledge of these radiologic anatomic variants is important especially because they differ individually and between ethnic groups. A local study that included PNS CT scans of 45 patients with presumably sinonasal symptoms found out that the most common anatomic variation was the agger nasi cell.[3] In 2018, the group of Espinosa determined the prevalence of six anatomic variations, namely agger nasi (AN), Haller cell, septal deviation, concha bullosa, everted uncinate process and paradoxical middle turbinate, of the nasal cavity and paranasal sinuses in patients with chronic rhinosinusitis.[4] Acosta and Vicente, on the other hand, described other sinonasal variants such as asymmetric ethmoid roof, deep olfactory fossa, Onodi cells and dehiscent lamina papyracea in patients with nasal polyposis only.[5]

A search in PubMed Central, Medline, Google Scholar, and HERDIN revealed a lack of published local data that investigates all the other possible sinonasal anatomic variants in CRS patients with or without nasal polyposis such as uncinate process attachment, anterior ethmoid artery grading types, presence or absence of frontal cells, turbinate pneumatization, carotid artery and optic nerve dehiscence, which can have an impact in the surgical management.

Hence, this study aimed to identify the prevalence of radiologic sinonasal anatomic variants in the PNS CT scans of a sample of adult Filipino patients with CRS with and without nasal polyposis. It is important for the surgeon to determine all the anatomic variants because failure to do such may lead to complications (i.e. injury to critical structures such as the orbit, skull base, internal carotid artery and optic nerve). As part of describing the PNS CT scans, this study also determined the severity of CRS radiologically using the Lund-Mackay staging system.

METHODS

With Rizal Medical Center Institutional Review Board Approval (2021-ORL-#020-RP-1.IV), this cross-sectional study considered for inclusion all CT scans of adult Filipino patients with CRS with and without nasal polyposis, as defined by the criteria in the Clinical Practice Guidelines of the Philippine Society of Otolaryngology – Head and Neck Surgery.[1] Patients were those diagnosed at the outpatient department of Otorhinolaryngology - Head and Neck Surgery (ORL-HNS) from October 2015 to December 2020 whose CT scans were available at the Department of Radiology, Section of Computed Tomography. Scans of those with prior sinus surgery or craniofacial anomalies were excluded.

The PNS CT scan images were taken using the CT scan machines GE Healthcare Revolution ACT with slice thickness of 1.25mm and Philips MX 16-slice with slice thickness of 2mm, and were hosted in the PACS system of the Department of Radiology. The slice thickness of images was set at ≤2 mm intervals. A single number code was assigned to each CT scan DICOM file to anonymize the patient's identity.

All CT scans were independently evaluated and interpreted by each author. The multiplanar views (axial, coronal and sagittal planes) of the imaging studies were evaluated in bone window (width 2000, level 350)[6] using Horos or Radiant DICOM medical image viewer. The authors used their laptops to evaluate the CT scans. The laptops satisfied the display requirements for clinical review work, which means that the viewing and interpretation of images were carried out to influence clinical management and not to generate a formal radiology report.[7]

The Lund-Mackay CT Score (LMS) was first obtained by scoring the 1); opacification of 5 bilateral sinuses (frontal, maxillary, anterior ethmoid, posterior ethmoid, sphenoid); and 2) obstruction of the ostiomeatal complex. Possible range of total Lund-Mackay score was between 0 and 24.

The presence or absence of the anatomic variants were identified in each imaging study: Keros classification (I, II, III) – height of the lamella or depth of the olfactory fossa;[8] frontal sinus cells (K1, K2, K3, K4);[9] frontal sinus outflow tract obstruction; hypoplastic frontal sinus; interfrontal sinus septal cell; agger nasi cell; supraorbital ethmoidal cell; suprabullar cell; infraorbital ethmoidal cell or Haller cell; sphenoethmoidal cell or Onodi cell; dehiscence of lamina papyracea (LP); pneumatized crista galli, pneumatization of superior/middle/inferior turbinate, nasal septum; paradoxic middle turbinate; nasal septal deviation (measured by drawing a line from the superior insertion of the nasal septum at the crista galli to the inferior insertion at the level of the anterior nasal spine) classified as absent (nasoseptal angle 4 degrees and below) or present (nasoseptal angle 5 degrees and above);[10] septal spur; uncinate process attachment; sinus lateralis; grading of anterior ethmoid artery (AEA): (Grade 1 – AEA courses within skull base, Grade 2 – AEA adjacent but inferior to, described as prominent from, inferior surface of the skull base, Grade 3 – AEA courses freely inferior to skull base);[11] types of sphenoid sinus pneumatization: conchal (region below sella completely ossified and consists of a solid block of bone with no air cavity), presellar (air cavity does not penetrate beyond a vertical plane parallel to anterior sellar wall), incomplete sella (sinus is well developed, and pneumatization extends beyond tuberculum sella below the sella and sometimes with bulging of sellar floor into sinus cavity), complete sella (air cavity extends into body of sphenoid, continues beyond posterior margin of dorsum sella into clivus bone);[12] sphenoid sinus wall dehiscence in relation to optic nerve and internal carotid artery; and types of optic nerve canals (ONC): Type 1 (canal superolateral to sphenoid sinus without indentation on sinus wall on coronal CT sections), Type 2 (indentation on sphenoid sinus contour with less than 50% protrusion of nerve circumference on coronal view), Type 3 (optic nerve traversing through sphenoid sinus with coronal view showing more than 50% protrusion of nerve circumference into sinus), Type 4 (canal adjacent to sphenoid and posterior ethmoid sinuses/presence of Onodi cell).[13]

The sample size was calculated using the formula n = N*X / (X + N – 1), where, $X = Z_{\alpha/2}^{2} * p * (1-p) / MOE^{2}$, and $Z_{\alpha/2}$ is the critical value of the normal distribution at α/2, MOE is the margin of error, p is the sample proportion, and N is the population size. Using a margin of error of 5%, confidence level at 99.1%, population set at 1000 and sample proportion of 98% based on a study by Shpilberg,[14] the minimum sample size calculated was 51 CT scan images.

The results were recorded using a data collection form. In case of disagreements in interpretation, the authors convened, and the decision was made by consensus (i.e. at least 3 out of the 4 authors agreed). If consensus was not reached, the interpretation of the most senior (and most experienced) rhinologist (RAR) was deemed final. All collected data were tabulated in Microsoft Excel version 16.71 (Microsoft Corp., Redmond, WA, USA).

The frequencies or proportions were summarized in appropriately labeled tables. The median, 1st quartile, 3rd quartile and interquartile range (IQR) were reported for age and LMS because of non-normal distribution of age and the ordinal nature of LMS data. For statistical analysis, Python version 3.11.0 (Python Software Foundation, Beaverton, OR, USA) was used.

RESULTS

Out of 53 PNS CT scans initially retrieved, 2 were excluded (1 with craniofacial anomaly, 1 with previous sinus surgery), and the CT scans of 51 patients, 41 (80.4%) men and 10 (19.6%) women, were finally included in this study. The median age was 48 years (Q25: 35, Q75: 56, IQR:21). The Lund Mackay scores (LMS) ranged from 0 to 24 with a median score of 15 (Q25: 12, Q75: 20, IQR:8). Among the participants, 94% had an LMS of ≥5.

Table 1 shows the distribution of sinonasal anatomic variants from the right and left side of each patient's nasal cavity (n=102), while *Table 2* shows the anatomic variations that were either present unilaterally or bilaterally (n=51). The most common anatomic variant in this study was AN (n=46/51, 90.2% present bilaterally and n=1/51, 1.96% present unilaterally). The second most common variant was uncinate process attachment to the lamina papyracea (n=90/102, 88.24%). Keros type II classification (n=76/102, 74.51%) was the third most common variant noted, followed by nasal septal deviation (n=35/51, 68.62%), optic nerve canal type 1 (n=67/102, 65.69%) and anterior ethmoid artery grade 1 (n=46/102, 45.1%).

Less common variants were Onodi cell (n=13/51, 25.49% unilateral and n=10/51, 19.61% bilateral), Haller cell (n=8/51, 15.69% unilateral and n=1/51, 1.96% bilateral), supraorbital cell (n=4/51, 7.84% unilateral and n=4/51, 7.84% bilateral) and middle turbinate concha bullosa (n=3/51, 5.88% unilateral and n=6/51, 11.76% bilateral).

Some anatomic variants were rarely seen in this study. Only three patients had superior turbinate concha bullosa (n=2/51, 3.92% unilateral and n=1/51, 1.96% bilateral). Two patients had pneumatized crista galli (n=2/51, 3.92%), and only one had optic nerve dehiscence (n=1/51, 1.96% present bilaterally).

None had lamina papyracea dehiscence, carotid artery dehiscence, paradoxic middle turbinate, inferior turbinate concha bullosa and pneumatized nasal septum.

DISCUSSION

Our study found that the majority (94%) of patients had a Lund-Mackay Score (LMS) of ≥5. This score has an excellent positive predictive value, which strongly indicates true disease in patients according to EPOS 2020.[2] It is interesting to note that 6% had an LMS of less than 5. This finding of having a low LMS in CRS patients is supported by the study of Dietz de Loos *et al*.[2] In their investigation, 26% (n=107) of patients who were diagnosed with CRS based on nasal symptoms only had an LMS of 1 to 3 in their CT scans.[2] They also found out that LMS can be 0 in 50% (n=107) of CRS patients.[2]

Overall, AN was the most common anatomic variation, which was present bilaterally in 90.2% (n=46) patients and unilaterally in 1.96% (n=1) patient. Similarly, in the other three studies on Filipino patients, AN was also the most common variant detected with a prevalence of 86% (n=88), 62% (n=28) and 78% (n=47), respectively.[3,4,15] The presence of this variant helps the surgeon to access the frontal recess faster. However, its pneumatization must be carefully evaluated. A well-pneumatized AN may be mistaken for the frontal recess.[13] Removal of an extensively pneumatized AN in a patient with a thin lacrimal bone may increase the risk of orbital injury.[13] In the case of an overly pneumatized AN displacing the middle turbinate more medially, resection must be executed with caution to prevent destabilization of the middle turbinate.[13] More important than determining the presence of the AN is the thorough assessment of its relationship to the surrounding critical structures to prevent complications.

Table 1. Distribution of right and left sinonasal anatomic variants

Anatomic variant	Classification	Right *n=51* *n (%)*	Left *n=51* *n (%)*	Total *n=102 for 2 sides* *n (%)*
Keros classification	Type I	12 (23.5)	12 (23.53)	24 (23.53)
	Type II	39 (76.4)	37 (72.55)	76 (74.51)
	Type III	0	2 (3.92)	2 (1.96)
Frontal (Kuhn) cell	None	37 (72.55)	34 (66.67)	71 (69.61)
	K1	4 (7.84)	7 (13.73)	11 (10.78)
	K2	0	0	0
	K3	5 (9.8)	7 (13.73)	14 (13.73)
	K4	5 (9.8)	3 (5.88)	8 (7.84)
Uncinate process attachment	Lamina papyracea	44 (86.27)	46 (90.2)	90 (88.24)
	Middle turbinate	7 (13.73)	5 (9.8)	12 (11.76)
	Skull base	0	0	0
Anterior ethmoid artery	Grade 1	23 (45.1)	23 (45.1)	46 (45.1)
	Grade 2	8 (15.69)	4 (7.84)	12 (11.76)
	Grade 3	20 (39.22)	24 (47.06)	44 (43.14)
Sphenoid sinus pneumatization	Conchal	3 (5.88)	4 (7.84)	7 (6.86)
	Presellar	14 (27.45)	10 (19.61)	24 (23.53)
	Incomplete	23 (45.1)	21 (41.18)	44 (43.14)
	Complete	11 (21.57)	16 (31.37)	27 (26.47)
Optic nerve canal	Type 1	34 (66.67)	33 (64.71)	67 (65.69)
	Type 2	1 (1.96)	3 (5.88)	4 (3.92)
	Type 3	1 (1.96)	3 (5.88)	4 (3.92)
	Type 4	15 (29.41)	12 (23.53)	27 (26.47)
				n=51 *n (%)*
Septal deviation	Present	30 (58.82)	5 (9.8)	35 (68.62)
Septal spur	Present	7 (13.73)	0	7 (13.73)

Table 2. Distribution of unilateral or bilateral sinonasal anatomic variants

Anatomic variant	Unilateral n (%)	Bilateral n (%)
Frontal sinus		
Frontal sinus outflow tract obstruction	13 (25.49)	28 (54.9)
Interfrontal sinus septal cell	6 (11.76)	0
Hypoplastic frontal sinus	7 (13.73)	1 (1.96)
Ethmoid sinus and related anatomy		
Haller cell	8 (15.69)	1 (1.96)
Supraorbital cell	4 (7.84)	4 (7.84)
Agger nasi	1 (1.96)	46 (90.2)
Suprabullar cell	13 (25.49)	16 (31.37)
Sinus lateralis	8 (15.69)	19 (37.25)
Onodi cell	13 (25.49)	10 (19.61)
Lamina papyracea dehiscence	0	0
Sphenoid sinus and related anatomy		
Intersphenoid septa	13 (25.49)	1 (1.96)
Carotid dehiscence	0	0
Optic nerve dehiscence	0	1 (1.96)
Turbinates		
Paradoxic middle turbinate	0	0
Superior turbinate pneumatization	2 (3.92)	1 (1.96)
Middle turbinate pneumatization	3 (5.88)	6 (11.76)
Inferior turbinate pneumatization	0	0
Crista galli		**Present**
Pneumatized crista galli		2 (3.92)
Nasal septum		**Present**
Pneumatized septum		0

Next to *agger nasi* in terms of prevalence was the uncinate process (UP) superior attachment to the lamina papyracea (n=90/102, 88.24%). This finding was consistent with the study by Tuli *et al.* wherein 79.8% (n=67) of the study participants had the UP attached to the lamina papyracea.[16] In this study, none of the UP was attached to the skull base, while the rest was noted to have superior attachment to the middle turbinate (n=12/102, 11.76%). This was in contrast to the study of Tuli et al. where the least common attachment was to the middle turbinate (n=3, 3.57%).[16] These findings suggest that careful uncinectomy must be done to avoid inadvertent injury to the lamina papyracea where it most commonly attaches to. However infrequent, the attachment of the uncinate to the skull base and middle turbinate must still be identified pre-operatively to prevent iatrogenic damage that can cause complications like cerebrospinal fluid (CSF) leak.

The third most prevalent variant was the presence of a type II Keros classification (n=76/102, 74.51%). This was in contrast with the local study done by Paber *et al.* where the most common identified classification was type I Keros (n=165, 81.6%), and only 17.9% (n=52) had type II Keros.[17] This varying distribution among Filipinos means that surgeons must be attentive to each patient's depth of olfactory fossa in each side to avoid skull base and intracranial injuries. It was also notable that Keros type III was the least prevalent in this study which was found in only 1.96% (n=2) patients. This very low prevalence was consistent with the local study of Paber[17] and other studies conducted among the Saudi, Indian and Egyptian populations[18,19] suggesting that although it was the most dangerous classification, it was uncommon.

Next, the fourth most frequently seen variant in this study was septal deviation, which was present in 68.62% (n=35, more commonly found in the right side n=30). This was in contrast to the findings of other anatomic studies.[14,20] Kaygusuz *et al.* reported that in the Turkish population, the most common anatomic variant was nasal septal deviation (72.7%, n=72).[20] In addition, Shpilberg *et al.* reported that among the population in New York in their investigation, nasal septal deviation was also the most common variant with a prevalence of 98.4% (n=189).[14] The slightly lower prevalence among Filipinos may mean that challenging surgical exposure in endoscopic sinus surgeries secondary to an obstructing deviated septum may be a less likely problem. Septal spur may also cause obstruction, but it was not that common in our study population (n=7, 13.73%).

Type 1 optic nerve canal was the fifth most common anatomic variant. Among the other types of optic nerve canal, the second most common was type 4 (n=27, 26.47%). Only one patient had optic nerve dehiscence. Onodi cells were present in 23 patients (n=13, 25.49% unilateral and n=10, 19.61% bilateral). This study reported a higher prevalence of Onodi cells compared to other studies involving Filipino participants where the prevalence ranged from 8.2%-8.8%.[3,5] The presence of these variants warrants vigilance when approaching the posterior ethmoid and sphenoid sinuses to prevent damage to the optic nerve, which can ultimately cause blindness.

The sixth most common variant was grade 1 anterior ethmoid artery (AEA). In this study, grade 1 and grade 3 AEA had close prevalence, 45.1% (n=46) and 43.14% (n=44), respectively. The symmetry of the grading on each patient's side did not largely deviate from each other. These results were similar to the study of Taha *et al.* wherein 45% of the patients had grade 1 AEA, and another 45% of the patients had grade 3 AEA, with the prevalence of the right and left side not far from each other.[21] From these findings, the AEA can commonly hang below the skull base, hence, extra caution when performing ethmoidectomy is recommended. Inability to recognize the AEA particularly when it travels freely from the skull base can cause unintentional transection of the artery. Its subsequent retraction to the orbit can lead to retro-orbital hemorrhage, which may progress to optic nerve compression and blindness.

Other anatomic variants had lower prevalence in this study. Only 9 patients (17%) had Haller cells. In the local studies available, the prevalence of Haller cells was higher ranging from 28% to 41.6%.[3,4,15] From the analysis of Badia, which tabulated results of 10 studies including Asian and Caucasian populations, the prevalence of Haller cells ranged from 3% to 46%.[22] Another infrequent variant in our study was the supraorbital cell (n=8, 15.6%). None of the local publications described its prevalence among Filipinos. From Shpilberg *et al.*[14] and Gouripur *et al.*,[23] supraorbital cells were present in 28.1% and 26% of patients, respectively. Regardless of the lower prevalence observed in this study, the presence of Haller cells and supraorbital cells should be noted prior to the surgery as they can increase the risk of injury to the orbit. A retained Haller cell may also have an impact on the drainage of the maxillary sinus.

Dehiscence in the lamina papyracea (LP) and bone through which the carotid artery runs in relation to the sphenoid sinus are other important variants to evaluate. Further violation of a dehisced LP can lead to prolapse of or damage to the orbital contents. Aggressive clearance of secretions from the sphenoid sinus may result in massive hemorrhage for patients with carotid canal dehiscence. Likewise, sphenoid sinus septations that are connected to the bone overlying the carotid may increase the risk for bleeding during removal. In this present study, none of the subjects had a dehiscence in the LP or bony canal of the carotid artery. Meanwhile, in the study of Santos and Jarin, 37% (n=18) of the Filipino participants had LP dehiscence.[15]

Lastly, pneumatization of the nasal turbinates is also important to assess. The presence of such can either be a contributing factor to the pathophysiology of chronic rhinosinusitis or may affect the field exposure in sinus surgeries. In this analysis, middle turbinate concha bullosa was present in nine patients (17.6%). This prevalence was similar to the study of Santos *et al*. (n=9, 20%).[3] Interestingly, Badia *et al.* cited a study where the prevalence of concha bullosa among Caucasians was as high as 53%.[22] Superior turbinate pneumatization was rare in this present study, only presenting in three patients (n=2, 3.92% unilateral and n=1, 1.96% bilateral). None of the patients had a pneumatized inferior turbinate.

To date, this study has the most number of sinonasal anatomic variants evaluated from the PNS CT scans of Filipinos with CRS. However, it also has several limitations. First, the windowing used in this review was fixed to one setting only. Second, the readers only used laptops instead of primary diagnostic workstations. These factors could have affected the visibility of some anatomic variants and interrater variability. The use of different bone window levels and diagnostic display monitors is suggested in the future. Further multicenter studies with a larger sample size is another recommendation to increase the generalizability of the results. The different ethnicities of Filipinos (e.g., Chinese, Malay, Caucasoid and combinations) can also be captured and analyzed.

In the Filipino sample included in this study, the six most common sinonasal anatomic variants were agger nasi, superior attachment of the uncinate process to the lamina papyracea, Keros type II classification, septal deviation, optic nerve canal type 1 and anterior ethmoid artery grade 1. The prevalence of some anatomic variants differ among different ethnicities and even among studies including the same ethnicity. Therefore, the PNS CT scan of each patient who will undergo sinus surgery must be meticulously analyzed. Every possible anatomic variant mentioned in this study should be noted to avoid inadvertent injuries to the critical structures during ESS.

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