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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.
GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.
ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНИТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman (Кириллица)**, ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ,რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

Содержание:

ANATOMICAL VARIABILITY OF THE ETHMOID AND SPHENOID SINUSES

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Abstract.

Background: The ethmoid and sphenoid sinuses exhibit marked anatomical variability that can impact surgical approaches and predispose individuals to complications during sinus and skull base procedures.

Objective: To characterize the morphometric patterns and anatomical variants of the ethmoid and sphenoid sinuses based on high-resolution CT data and to analyze their surgical and clinical significance.

Methods: A total of 400 CT scans were analyzed. Sinuses were classified by pneumatization type, dimensions, and presence of anatomical variants. 3D reconstructions were performed to assess spatial orientation and proximity to neurovascular structures.

Results: Ethmoid sinus complexity was classified into three distinct types, with higher complexity correlating with narrower surgical corridors and increased risk of incomplete ethmoidectomy. Sphenoid pneumatization showed significant variability, including presellar, sellar, and postsellar types. Onodi cells were identified in 13% of cases, closely related to the optic canal. Septated sphenoids were present in 21%, often traversing the internal carotid artery canal.

Conclusion: Detailed anatomical understanding of posterior sinus morphology and variation is essential for safe and effective sinus and skull base surgery. This study provides a morphometric atlas to support individualized surgical planning.

Key words. Computer tomography, paranasal sinusis, anatomy, sphenoid sinus, ethmoid sinus.

Introduction.

The human paranasal sinuses exhibit remarkable anatomical variability, both in their external morphology and internal architecture [1,2]. Among them, the ethmoid and sphenoid sinuses are particularly notable for their complex, variable pneumatization patterns and their proximity to critical neurovascular structures such as the optic nerve, internal carotid artery (ICA), anterior skull base, and orbit [3,4]. For otolaryngologists, neurosurgeons, and radiologists alike, detailed anatomical understanding of these posterior sinuses is essential, not only for safe and effective surgical access but also for the accurate diagnosis of sinus disease and planning of endoscopic procedures [5,6].

The ethmoid sinus comprises a labyrinth of air cells between the nasal cavity and the orbit. Its architecture ranges from a few large, simple cells to dozens of small, interwoven compartments. This complexity impacts surgical visibility and the risk of residual disease after endoscopic ethmoidectomy. Additionally, the presence of anatomical variants, such as Onodi cells (posterior ethmoid cells that encroach on the optic canal), can dramatically increase the risk of intraoperative complications if not preoperatively identified [7-9].

The sphenoid sinus, which lies deeper and more posteriorly in the skull base, also shows wide variability in size, septal configuration, and pneumatization extent. It may be presellar, sellar, or postsellar, depending on how far posteriorly it extends relative to the sella turcica [10-11]. The sphenoid septum is often asymmetric and may deviate toward the ICA or optic nerve, increasing the risk of catastrophic injury during sphenoidotomy or transsphenoidal pituitary surgery. Moreover, bony dehiscence of the optic canal or carotid canal may leave these structures exposed directly to the sinus lumen.

Although the surgical and diagnostic importance of ethmoid and sphenoid anatomy is well established, large-scale quantitative studies describing their variability and prevalence of critical variants remain limited [12,13]. Many anatomical atlases and surgical guides rely on single-case illustrations or small cadaveric series that may not capture the full spectrum of variation encountered in clinical practice [14,15].

The present study aims to address this gap by providing a comprehensive morphometric analysis of the ethmoid and sphenoid sinuses using high-resolution CT data from 400 adult individuals. We assess the prevalence of key anatomical patterns including ethmoid morphotypes, sphenoid pneumatization types, and high-risk variants such as Onodi cells and sphenoid septations - and discuss their clinical significance. By establishing normative data and identifying high-risk configurations, we hope to support improved surgical safety, anatomical education, and radiologic reporting in sinonasal and skull base procedures.

Materials and Methods.

This descriptive anatomical study was based on retrospective analysis of 400 anonymized high-resolution craniofacial CT scans obtained for diagnostic purposes (non-surgical) from adult patients aged 18 to 75 years. All scans were evaluated for inclusion based on the following criteria:

1. **Inclusion:** Full visualization of paranasal sinuses; absence of acute sinusitis, tumors, fractures, or surgical alterations.
2. **Exclusion:** Prior sinus surgery, craniofacial trauma, congenital cranial deformities, or radiologic artifacts.

The sample included a balanced distribution of cranial types (brachy-, meso-, and dolichocranic skulls) and both sexes, ensuring representative anatomical diversity.

CT scans were acquired using a 64-slice multidetector CT scanner with a slice thickness of 0.6–1.0 mm. Images were reconstructed in both axial and coronal planes and saved in DICOM format.

Image processing and segmentation were performed using 3D Slicer (v5.2). Manual segmentation of the ethmoid and sphenoid sinuses, including key anatomical structures, was carried out by two independent reviewers (a radiologist and an anatomist). Discrepancies were resolved by consensus, and inter-observer agreement exceeded 0.9 (ICC).

Anatomical structures were assessed and classified as follows:

Ethmoid Sinus based on number and arrangement of air cells was classified into 3 morphotypes.

1. Simple: 1–3 large cells.
2. Intermediate: 4–6 moderate-sized cells.
3. Complex: >6 small, closely spaced cells.

Also, some structural variants were noted: concha bullosa, paradoxical middle turbinate, and ethmoid bullae.

Sphenoid Sinus was classified into 3 groups according to the pneumatization type

1. Presellar: pneumatization anterior to the sella.
2. Sellar: pneumatization extending under the sella.
3. Postsellar: pneumatization extending posterior to the sella.

And into 2 groups according to the septa location:

1. Single central, deviated, or multiple septa.
2. Septa attachment to or near the ICA or optic canal recorded.

Specific anatomical variants were y identified.

1. Onodi Cells: posterior ethmoid air cells superior/posterolateral to the sphenoid sinus, in contact with the optic canal.
2. Bony Dehiscence of optic canal and internal carotid artery canal.
3. Measurements included distance from sinus wall to optic nerve and ICA (in mm) and number and orientation of sphenoid septa.

All morphometric data were recorded in a standardized form. The following parameters were calculated:

1. Prevalence of each morphotype and variant.
2. Mean distances and standard deviations.
3. Cross-tabulation by sex and craniotype.

Descriptive statistics were calculated using SPSS (v26.0). Proportional differences were tested using chi-square analysis, with significance set at $p < 0.05$.

Results.

Among the 400 CT scans analyzed, the ethmoid sinus architecture varied widely. Subjects were classified into three morphotypes based on the number and configuration of ethmoidal air cells:

1. **Simple morphotype (1-3 large cells):** Observed in 25% of cases (n = 100). These individuals showed broad air chambers with minimal internal septation, most commonly seen in dolichocranic skulls.
2. **Intermediate morphotype (4-6 mixed cells):** Present in 48% (n = 192). This was the most common pattern, typically associated with mesocranic skulls and moderate infundibular complexity.
3. **Complex morphotype (>6 small, crowded cells):** Found in 27% (n = 108), more frequently in brachycranic skulls. This group exhibited a dense lattice of lamellae, complicating visualization of the ethmoidal roof and posterior boundary.

The complexity of ethmoid cells was positively associated with surgical difficulty and reduced visibility of adjacent structures ($p < 0.01$).

Cross-tabulated analysis showed that complex ethmoid morphotypes were significantly more prevalent in brachycranic skulls ($\chi^2 = 16.42$, $p = 0.002$) and associated with reduced visibility of the lamina papyracea in 71% of cases. Table 3 presents cross-tabulated distributions of ethmoid morphotypes by cranial type.

Sphenoid sinus pneumatization type was categorized as:

1. Presellar: 14% (n = 56) – pneumatization remained anterior to the sella turcica.
2. Sellar: 63% (n = 252) – pneumatization extended beneath the sella, exposing the pituitary floor.
3. Postsellar: 23% (n = 92) – pneumatization extended posteriorly into the clivus, often with thinner posterior walls.

The mean sphenoid sinus volume varied significantly:

- Presellar: 2.8 ± 0.7 cm³
- Sellar: 4.6 ± 1.1 cm³
- Postsellar: 6.3 ± 1.5 cm³

Postsellar sinuses showed significantly reduced bone thickness overlying the internal carotid artery (mean = 1.2 mm, $p < 0.01$) (see Table 1).

Postsellar sinuses show thinner bone overlying the ICA, increasing surgical risk.

The prevalence of key anatomical variants was as follows:

1. **Onodi cells:** Identified in 13% (n = 52) of cases. In 92% of these, the Onodi cell was in direct contact with the optic canal, and in 21% the cell roof extended above it.
2. **Sphenoid sinus septations:**
   a. Single septum: 66%
   b. Multiple septa: 21%
   c. Septa deviating toward the ICA: 11%
3. **Bony dehiscence:**
   a. Optic canal dehiscence: 7% (n = 28)
   b. Carotid canal dehiscence: 6% (n = 24)

The ethmoid sinus was classified into three morphotypes based on the number and arrangement of air cells. The simple morphotype consists of 1–3 large, well-defined cells with minimal internal septation, offering relatively clear anatomical landmarks. The intermediate morphotype includes 4–6 moderately sized cells with moderate complexity and partial compartmentalization. The complex morphotype is characterized by more than six small, densely packed cells with intricate septal patterns, often obscuring key anatomical structures and increasing surgical difficulty.

In particular, patients with complex ethmoid morphotypes often demonstrated lower Keros classification types (I–II), with reduced vertical height of the olfactory fossa. This limited visualization of the fovea ethmoidalis and cribriform plate during surgery and potentially elevated the risk of iatrogenic skull base injury. Future studies should more precisely correlate ethmoid complexity with Keros class and surgical outcomes.

Table 1. *Sphenoid Pneumatization Patterns.*

Pneumatization Type	Count (n)	Prevalence (%)	Mean Volume (cm³)	Posterior Wall Thickness to ICA (mm)
Presellar	56	14%	2.8	2.4
Sellar	252	63%	4.6	1.6
Postsellar	92	23%	6.3	1.2

Table 2. *Measurements and Morphometric Data.*

Measurement	Mean (mm) ± SD	Range (mm)
Distance: sphenoid wall to ICA	3.1 ± 1.2	0.8 – 6.5
Distance: sphenoid wall to optic canal	2.4 ± 1.1	0.6 – 5.9
Ethmoid roof height (cribriform to lamella)	5.6 ± 1.4	3.2 – 9.3

Table 3. *Distribution of Ethmoid Morphotypes by Cranial Type.*

Cranial Type	Simple	Intermediate	Complex
Brachycranic	18%	40%	42%
Mesocranic	26%	52%	22%
Dolichocranic	31%	51%	18%

Discussion.

The last decade has witnessed widespread adoption of digital medicine, particularly driven by challenges posed by the COVID-19 pandemic and healthcare [16-18] disruptions during regional conflicts [19,20]. These factors have accelerated the need for digitally enhanced neurosurgical planning, including 3D navigation [21,22] and AI-assisted imaging, especially in the context of complex skull base anatomy [23,24]. This study presents a comprehensive analysis of the anatomical variability of the ethmoid and sphenoid sinuses using high-resolution CT imaging in a large adult cohort. Through morphometric classification, prevalence mapping of critical anatomical variants, and structural measurement, we contribute valuable insights into how these variations impact surgical planning, radiological interpretation, and risk stratification in sinonasal and skull base procedures [25,26]. That area relates to common inflammatory processes [27,28] which started in oral cavity often [29,30].

The ethmoid sinuses, located at the intersection of the nasal cavity, orbit, and anterior cranial base, are highly variable in shape and complexity. We categorized them into three morphotypes: simple, intermediate, and complex based on the number and arrangement of ethmoidal air cells [31,32]. The complex morphotype, present in approximately 27% of cases, is of particular surgical concern. It features numerous, tightly packed cells with irregular septations that can obscure anatomical landmarks and increase the risk of incomplete ethmoidectomy, orbital injury, or cerebrospinal fluid (CSF) leak, especially during dissection near the fovea ethmoidalis or lamina papyracea [33].

Our findings reinforce previous literature that highlights the surgical difficulty of densely septated ethmoids, especially when visualization is compromised by inflammation or anatomical distortion [32,34]. Surgeons should use ethmoid morphotype classification as a preoperative guide to anticipate the degree of difficulty, particularly in revision cases or procedures requiring extensive clearance of ethmoid cells [35,36].

From a radiologic perspective, structured reporting of ethmoid complexity may help flag high-risk cases before surgery [37]. This classification could be integrated into routine CT evaluation protocols to improve communication between radiologists and surgeons.

The sphenoid sinus shows not only variable volume but also critical differences in pneumatization patterns - presellar, sellar, and postsellar. Each type carries implications for surgical exposure and proximity to neurovascular structures [38]. Postsellar pneumatization, found in 23% of subjects, results in deeper sinus cavities and thinner posterior walls. Our data show that this pattern brings the internal carotid artery (ICA) and optic nerve closer to the sinus lumen, with bony thickness in some cases falling below 1.5 mm.

This has major implications for transsphenoidal surgery, where sellar and postsellar sinuses are routinely traversed to access the pituitary gland. Postsellar cases, though offering greater working space, increase the risk of injuring the ICA or optic nerve - especially if dehiscence is present. Our identification of ICA dehiscence in 6% and optic nerve dehiscence in 7% aligns with previous cadaveric and imaging studies [39-41].

These findings support the routine measurement of sphenoid wall thickness and documentation of pneumatization type during preoperative planning for endoscopic and neurosurgical approaches [42].

Onodi cells, posteriorly located ethmoid air cells that closely abut or encase the optic canal, were observed in 13% of cases. In most of these, the Onodi cell roof was directly adjacent to the optic nerve, confirming the high risk of optic nerve injury during posterior ethmoidectomy or sphenoidotomy if the variant is unrecognized [4,43] (see Figure 2).

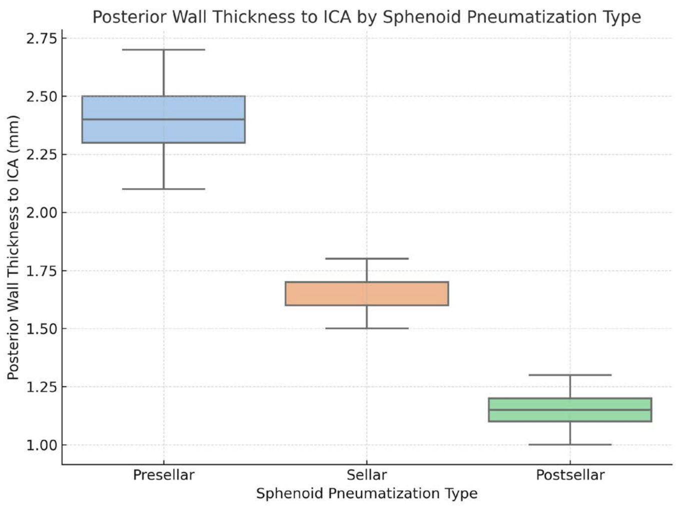

Figure 1. *Boxplot showing posterior wall thickness overlying the ICA by sphenoid pneumatization type (Presellar vs. Sellar vs. Postsellar).*

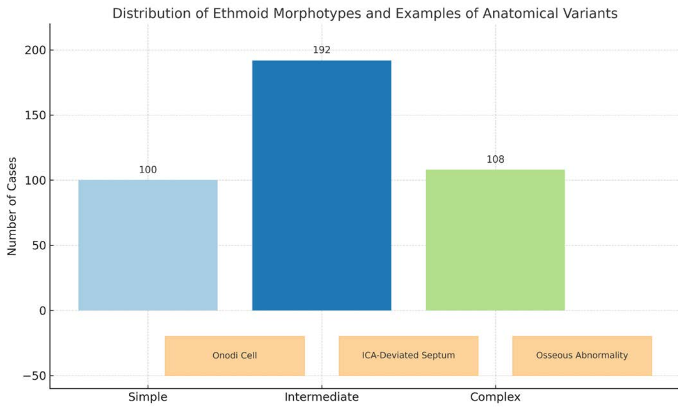

Figure 2. *Visual breakdown of ethmoid morphotype distribution.*

Similarly, sphenoid septa, typically assumed to insert centrally, were found to deviate toward the ICA in 11% of cases. These septa may provide misleading visual cues during surgery and, if followed by instrumentation, could direct force into the carotid artery - a potentially fatal complication [44,45].

Both anatomical variants underline the necessity of high-resolution imaging and careful review before surgery. Image-guided navigation systems, while helpful, do not replace the need for structural awareness and individualized anatomical mapping [46].

This study's morphometric framework offers value beyond surgery. It supports:

1. Medical education by illustrating the spectrum of normal and variant anatomy.
2. Radiologic standardization through terminology and quantitative reference values.
3. Forensic anthropology via cranial-type correlation and sinus configuration.
4. Personalized medicine, where imaging guides not only diagnosis but tailored intervention strategies.

Our study has several limitations. It is retrospective and based on radiologic rather than cadaveric verification, so histological correlation (e.g., mucosal coverage of dehiscent nerves or vessels) is not available. Clinical outcomes (e.g., postoperative complications) were not assessed, and ethnic variations were not stratified, which could influence morphotype prevalence.

Additionally, the study is limited by its single-center design, which may restrict the generalizability of findings to other populations or ethnic groups. Multicentric studies are needed to validate these anatomical patterns across broader demographics and different geographic regions.

Future research should aim to correlate anatomical risk profiles with real-world surgical outcomes, expand to pediatric populations, and include multiethnic cohorts for broader generalizability.

Conclusion.

This study highlights the significant anatomical variability of the ethmoid and sphenoid sinuses, emphasizing the importance of preoperative imaging and morphometric evaluation for safe and effective surgical planning. Our findings confirm that complex ethmoid sinus morphology increases surgical risk, particularly near the skull base and orbit. Sphenoid pneumatization patterns influence sinus volume, access to the sella, and proximity to critical neurovascular structures. Anatomical variants, including Onodi cells, deviated sphenoid septa, and bony dehiscence of the optic canal and carotid artery, are not uncommon and should be explicitly reported in imaging assessments.

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Conflict of interest statement.

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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