MAGIERA, Michał, SIKORA, Miłosz, and CZWAŁGA, Piotr. The Evolution of Anatomical Classification Systems for Sinonasal Malignancies. Quality in Sport. 2026;49:67438. eISSN 2450-3118.
https://doi.org/10.12775/QS.2026.49.67438
https://apcz.umk.pl/QS/article/view/67438

The journal has been awarded 20 points in the parametric evaluation by the Ministry of Higher Education and Science of Poland. This is according to the Annex to the announcement of the Minister of Higher Education and Science dated 05.01.2024, No. 32553. The journal has a Unique Identifier: 201398. Scientific disciplines assigned: Economics and Finance (Field of Social Sciences); Management and Quality Sciences (Field of Social Sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).

The authors declare that there is no conflict of interest regarding the publication of this paper.
Received: 13.12.2025. Revised: 16.12.2025. Accepted: 04.01.2026. Published: 05.01.2026.

The Evolution of Anatomical Classification Systems for Sinonasal Malignancies

Michał Magiera[1]:

ORCID: https://orcid.org/0009-0006-5999-745X

lek.magiera@gmail.com

Miłosz Sikora[1]

ORCID: https://orcid.org/0009-0000-0351-5358

Piotr Czwałga[1]:

ORCID: https://orcid.org/0009-0001-6717-4609

[1]Department of Geriatrics, Ludwik Rydygier Medical College in Bydgoszcz of Nicolaus Copernicus University in Toruń

Corresponding author

Piotr Czwałga

E-mail: pczwalga@gmail.com

ABSTRACT
Background. Malignant tumors of the nasal cavity and paranasal sinuses present unique diagnostic challenges. Due to their concealed location and nonspecific symptoms, over 70% of cases are diagnosed at an advanced stage, leading to high mortality. While modern oncology utilizes precise imaging (CT, MRI), earlier approaches relied on physical examination and topographical classifications. Understanding this evolution remains crucial for contemporary rhinosurgery.
Aim. This study analyzes historical concepts to understand how pioneers perceived anatomical barriers and tumor spread. It further links these perspectives to tumor biology and the evolution of modern strategies, including skull base surgery.
Materials and methods. This study synthesizes historical and contemporary data to trace the evolution of anatomical classifications. A search of PubMed, Google Scholar, and Web of Science databases was performed, focusing primarily on English-language articles relevant to sinonasal tumor surgery and imaging.
Results. Early classifications (Sebileau, 1906; Öhngren, 1933) relied on geometric planes for prognosis. The advent of CT/MRI and the TNM system (1977) shifted the paradigm from theoretical geometry to anatomical barriers, while Harrison (1976) proved the feasibility of skull base resection. Consequently, surgery evolved from rigid "en bloc" resections to "compartment theory" and endoscopic techniques based on wall infiltration. Future trends point towards multidimensional models integrating radiomics and molecular profiling, extending beyond anatomy to biological signatures.
Conclusions. The evolution of classification systems, from historical topographic lines to modern radiomic algorithms, reflects the progression from macroscopic assessment to digital precision. Despite the paradigm shift toward a functional approach, the precise delineation of tumor boundaries remains a critical challenge for optimizing surgical efficacy and minimizing complications
Keywords: paranasal sinuses, CT/MRI imaging, carcinoma, prognostic factors, maxillectomy

Introduction

Malignant neoplasms of the maxillo-ethmoidal complex (nasal cavity and paranasal sinuses) constitute one of the most complex challenges in head and neck surgery. An analysis of epidemiological data reveals a specific demographic and clinical profile for this patient group. Although the annual incidence remains low, at approximately 0.83 cases per 100,000 population, these statistics do not fully reflect the unique diagnostic and clinical significance of these malignancies. The peak incidence occurs between the 5th and 7th decades of life, with a median age of 62.6 years. A notable predilection for the male sex is observed (58.6% of cases) [1,2].

The concealed location within the pneumatic spaces of the facial skeleton results in symptoms often being trivialized due to their highly nonspecific nature, exhibiting a deceptive resemblance to more common benign inflammatory pathologies or conditions of allergic etiology [3]. Furthermore, the neoplastic process develops in close proximity to critical structures, such as the orbit, the skull base, and the brain [4]. Additionally, the paucisymptomatic onset of the disease is reflected in dramatic diagnostic indicators: at the time of diagnosis, over 72% of patients are diagnosed with an advanced stage of the cancer process, and the mortality rate is 558% relative to the general population. The observed 5-year survival rate reaches only 53%, while the median survival time oscillates around 6 years [2].

Contemporary oncology utilizes advanced imaging methods (CT, MRI) that allow for three-dimensional tumor mapping with millimeter precision. Computed tomography (CT) remains the method of choice for assessing the integrity of bone structures, precisely imaging foci of osteolysis and calcification, which constitutes the foundation of preoperative surgical planning. Conversely, magnetic resonance imaging (MRI) is characterized by higher soft-tissue contrast resolution, which is crucial for differentiating the actual tumor mass from accompanying inflammatory reactions and secretion retention [5,6].

However, in the era prior to the widespread adoption of computed tomography, surgeons had to rely on physical examination, conventional radiography, and clinical intuition. It was during this period that the need arose to create systematic topographical classifications that would allow not only for the description of tumor location but, above all, for the assessment of its operability and prognosis.

Material and methods

This study traces the evolution of anatomical classification systems by synthesizing selected historical references dating back to the early 20th century alongside the most recent literature. A comprehensive search was conducted in PubMed, Google Scholar, and Web of Science databases using the following keywords: paranasal sinuses, CT/MRI imaging, carcinoma, prognostic factors, and maxillectomy. The analysis primarily focused on articles published in English.

Results

The history of diagnosing sinonasal malignancies dates back to antiquity; however, for centuries, their clinical presentation remained obscure. Craniofacial tumors were described as early as the Egyptian Ebers Papyrus and Edwin Smith Papyrus (c. 1600 BCE), yet until modern times, malignant lesions were notoriously confused with chronic inflammatory states or nasal polyps (polypos), as described by Hippocrates [7,8].

A breakthrough in understanding the pathology of this region occurred only in the 17th century, with the detailed description of the maxillary sinus anatomy by Nathaniel Highmore (1651). The discovery of a pneumatic space within the bone allowed physicians to understand that a proliferative process could develop in hidden manner, within the antrum, manifesting symptoms only after the destruction of bony walls [8]. In 1676, Richard Wiseman was one of the first clinicians to clearly distinguish "malignant tumors of the jaw" from benign lesions, highlighting their destructive nature [9].

Nevertheless, for the next two centuries, tools for the precise assessment of tumor location were lacking. It was not until the development of surgical anatomy at the turn of the 19th and 20th centuries that the need arose to create classification systems to organize this complex group of neoplasms.

The Era of "Lines and Planes": A Geometric Approach to Predicting Operability

In the epoch preceding the CT era, the diagnosis and treatment planning of sinonasal tumors were based on geometric simplifications. Surgeons, equipped only with conventional radiography and physical examination, sought schematics that would allow them to predict the three-dimensional behavior of a tumor based on two-dimensional images. The designation of arbitrary lines on the skull aimed not only to localize the lesion but primarily to assess the patient's chances of surviving the surgical procedure.

The foundation for all subsequent classification systems was the concept by Pierre Sebileau in 1906. The French surgeon developed a horizontal division, delineating three anatomical zones within the complex: the infrastructure (L'infrastructure), comprising the alveolar process and the floor of the maxillary sinus; the mesostructure (La mésostructure), containing the maxillary sinus proper and the lateral nasal wall; and the suprastructure (La suprastructure), which included the ethmoid, frontal, and sphenoid sinuses, as well as the roof of the maxillary sinus (i.e., the orbital floor). Sebileau was the first to identify the suprastructure as a region associated with the worst prognosis due to its direct proximity to the skull base and brain, which at that time constituted a nearly insurmountable barrier for surgery [10].

Another milestone that dominated laryngological oncology for nearly half a century was the publication by L.G. Öhngren from Sweden in 1933. He proposed a departure from simple horizontal lines in favor of an oblique plane running from the inner canthus of the eye (medial canthus) to the angle of the mandible (gonion). This famous "malignancy plane" divided the maxillo-ethmoidal complex into two sectors with vastly different prognoses. Tumors located in the antero-inferior sector (so-called external) were considered easier to remove and had a better prognosis due to less frequent metastasis and, more importantly, easier diagnosis associated with earlier symptoms visible in the oral cavity or on the face. Conversely, lesions located in the postero-superior sector, involving deep structures in the vicinity of the pterygopalatine fossa, were characterized by aggressive progression and were historically often categorized as inoperable. Öhngren attributed this unfavorable prognosis to the specifics of lymphatic drainage. He indicated that lymph from this area drains to the retropharyngeal nodes, which, unlike the submandibular nodes draining the anterior sector, remain inaccessible to palpation and present a challenge for surgical resection [11].

In later years, however, the limitations of simple geometric divisions were recognized. In 1951, C.P. Wilson significantly revised Öhngren's concept, indicating that any classification based solely on the site of tumor origin is insufficient. He proposed a functional division—based on the direction of tumor spread—into tumors of the medial type (medial/ethmoidal group), originating from the lateral nasal wall and ethmoid cells, and the lateral type (lateral/antral group), originating from the recesses of the maxillary sinus. Wilson demonstrated that this topographic distinction determines a specific clinical picture—with a dominance of naso-orbital symptoms in the first group versus buccal-dental symptoms in the second—and also defines the vectors of infiltration towards the skull base [12].

With the development of radiation techniques, a need arose for even greater topographical precision, expressed in the work of François Baclesse from the Curie Institute (1952). Baclesse deemed the existing Sebileau lines too simplified for the needs of radiotherapy and proposed a complex system based on a grid of vertical and horizontal lines, distinguishing a total of ten anatomical regions (A, B-H, J, L). His key contribution to the development of classification was the isolation of orbital and pterygoid fossa involvement as independent and critical prognostic categories [13,14,15].

In 1959, G.D. Dodd et al. critically analyzed the clinical utility of Baclesse's system, pointing to its theoretical nature. The authors argued that at the time of diagnosis, the neoplastic process rarely remains confined to a single anatomical sector, making rigid geometric division difficult to apply in practice. They proposed a systematic protocol based on tomography, which allowed for precise tumor "mapping" within existing regions [16].

The "Transitional" Era: From Geometry to Anatomical Barriers and the TNM System

The 1960s and 1970s brought a fundamental paradigm shift in the classification of sinonasal tumors. With the advancement of surgical and radiotherapeutic techniques, simple lines projected onto the skull ceased to suffice. There was a gradual shift away from theoretical planes in favor of precise assessment of the involvement of specific anatomical structures and bony barriers.

A turning point, bridging the European tradition with the modern approach, was the classification presented in 1969 by Manuel Lederman. This British radiotherapist created the most complete "linear" system in history, which was a hybrid extension of the concepts of Sebileau and Öhngren. He proposed a classification system for upper jaw tumors aimed at unifying the description of sinus and nasal cavity tumors, treating them as an anatomical-clinical entity. Lederman based his division on two horizontal lines parallel to the hard palate: the first passing through the floor of the maxillary sinuses and the second through the floor of the orbits. By adding vertical lines, he obtained a precise topographical grid. He also presented his own proposal for TNM staging. Although this system was still based on geometry, its main goal was the optimization of radiation field planning, allowing for a more individualized approach to therapy [13,17].

Meanwhile, in America, the year 1963 (six years prior to Lederman) brought a fundamental redefinition of the diagnostic approach, signed by Sissona and Johnson. Through the implementation of the TNM system, these authors moved away from abstract skull geometry towards clinical anatomy. In their view, static division lines lost significance in favor of dynamic assessment of bony barrier destruction. This shift toward evaluating invasiveness and tumor pathomorphology marked the definitive end of the era of linear classifications and paved the way for contemporary, multidimensional prognostic models [18].

In the face of the growing discrepancy in oncological nomenclature between European and American schools, Philip Rubin attempted to integrate classification systems. His concept was based on the introduction of unified graphic schematization. Rubin developed sets of standardized anatomical diagrams, so-called "tumor maps," intended to function as a universal visual language enabling precise information exchange within interdisciplinary teams (radiologist–surgeon–radiotherapist). This initiative, a direct reaction to the terminological chaos of the time, became the foundation for modern standards of medical documentation and disease extent assessment [19].

The culmination of this transitional period, and simultaneously a revolution in surgical thinking, was the concept presented in 1976 by D.F.N. Harrison. Although Harrison did not create a tabular classification sensu stricto, his contribution to understanding the operability of these tumors was groundbreaking. He questioned the prognostic fatalism attributed to Öhngren's line, proving that tumors of the so-called suprastructure need not be a death sentence. He believed that the poor prognosis of tumors in this region resulted not from tumor biology, but from inadequate surgery. Surgeons feared operating in this region, leaving residual tumor at the skull base. Harrison emphasized that the true limit of operability is not an arbitrary line on the face, but the skull base, specifically the cribriform plate. His works provided theoretical foundations for the development of craniofacial resections, proving that the skull base barrier could be safely crossed by the surgeon [20].

The "Modern" Era: 3D Mapping and the Concept of Anatomical Compartments

The last decades of the 20th century brought a fundamental redefinition of classification systems, determined by the popularization of computed tomography and magnetic resonance imaging. The introduction of three-dimensional tumor visualization meant that historical lines and planes, once key determinants of prognosis and operability, lost their primary clinical significance, currently retaining mainly didactic and historical value.

A symbolic moment in history, marking a new stage in rhinological oncology, was the year 1977, when the American Joint Committee on Cancer (AJCC) published the first edition of the classification dedicated to paranasal sinus tumors. The codification of the TNM system represented a moment of global standardization of clinical language [21]. The evolution of the AJCC system was not a linear process but a dynamic reaction to clinical verification.

In the original 1977 classification (1st edition), invasion of deep structures such as pterygoid muscles, the infratemporal fossa, or the orbit defined the T3 stage. However, attempts at prognostic validation of this model failed, forcing a revision of criteria. Despite introducing significant modifications in 1997 (5th edition), key vectors of tumor spread, including infiltration of the infratemporal fossa, were still left in the T3 category. It was not until the 2002 system (6th edition) that a fundamental correction reflecting the actual weight of these anatomical barriers was made. This edition introduced a distinction in the assessment of orbital infiltration and dura mater involvement, and invasion of the infratemporal fossa was finally reclassified as a T4 feature, recognizing these as indicators of advancement that critically worsen prognosis [22]. In 2017 (8th edition), melanoma was separated, which does not have T1 and T2 features, meaning that every melanoma in the sinus begins immediately as T3, reflecting its malignancy [23].

Since then, therapeutic decisions have ceased to be determined by the tumor's relationship to the historical lines of Öhngren or Lederman, giving way to objective assessment of the degree of anatomical structure involvement, the lymphatic system, and the presence of distant metastases.

Concurrently, a significant contribution to the evolution of topographical systems was made by the Asian school, a direct consequence of the much higher incidence of maxillary cancer in this population [24]. In 1966 and 1971, S. Sakai presented his own classification proposal [25,26,27]. Based on progress in imaging, he introduced the concept of subsegmentation, dividing the maxillary sinus into a series of smaller sectors based on its specific walls. Japanese researchers, possessing extensive clinical material, demonstrated that such meticulous mapping allows for the prediction of tumor spread pathways with significantly higher accuracy than Western systems of the time [25].

The "Contemporary" Era: Endoscopic Classifications and Limits of Resectability

The contemporary therapeutic paradigm crystallized at the turn of the 20th and 21st centuries, being a direct consequence of the dynamic development of endoscopic skull base surgery (ESBS) and the work of pioneers such as G. Iannetti and Wolfgang Draf [28,29,30]. The widespread adoption of the endoscopic technique fundamentally reversed the operative perspective; traditional visualization from the external surface was replaced by assessment "from within."

This change in visualization perspective, supported by the implementation of intraoperative image-guided sinus surgery (IGSS) and high-resolution magnetic resonance imaging, forced a thorough re-evaluation of existing topographical schematics [31].

Under conditions of endoscopic assessment of the surgical field, static linear divisions lost their clinical justification. They were replaced by the concept of "compartment theory," based on dynamic vector analysis, where instead of geometric vertical stratification, an independent assessment of the degree of infiltration of each sinus wall is performed [32].

This strategy enabled a departure from the paradigm of en bloc resections in favor of tailored surgery, which allows for the optimization of the resection scope within the complex architecture of the skull base, guaranteeing the preservation of oncological margins while simultaneously minimizing trauma to surrounding tissues [33].

Discussion

The analysis of the evolution of classification systems—from simple geometric lines to modern staging—leads to the conclusion that this process is not yet complete. Currently, rhinological oncology is in a phase of deep transformation, where static topographic anatomy is gradually being integrated with molecular biology and advanced digital analysis [34]. It appears that the future of prognostic systems will rely on three pillars: radiomics, molecular profiling, and so-called hybrid navigation [35,36].

It should be noted that traditional systems, such as TNM or Lederman's classification, are based almost exclusively on macroscopic morphological assessment. Meanwhile, the future of diagnostics seems to belong to radiomics and the concept of "virtual biopsy".

The utilization of artificial intelligence (AI) algorithms to extract thousands of image features allows for the detection of phenomena remaining beyond the perception of the human eye. AI systems are capable of generating predictive maps, indicating tumor subregions with the highest biological aggressiveness or potential chemoresistance, as well as demonstrating the risk of recurrence [35,37,38]. This means that instead of relying on rigid division lines, future algorithms will identify areas that, despite being located in a theoretically safe anatomical zone, exhibit a high-risk biological signature.

Parallel to the progress in preoperative imaging, new technologies are redefining the concept of intraoperative precision. Augmented reality (AR) and hybrid navigation systems aim to visualize resection boundaries in real-time through image fusion and the superposition of three-dimensional models of critical structures (e.g., the internal carotid artery) directly onto the surgical field [39].

Ultimately, however, in the era of precision oncology, a gradual marginalization of pure anatomy in favor of molecular profiling is observed. Confirmation of this paradigm shift is the 5th edition of the WHO Classification (2022), which redefines the systematics of sinus tumors based on their genetic signatures. Anatomical location (T feature), which for decades formed the basis of therapeutic decisions, is becoming secondary in many cases to the tumor's genetic profile (including HPV status, NUT gene mutations, IDH2 expression, c-MET expression) [40,41].

It is therefore to be assumed that future classification systems will evolve towards integrated models. They will likely combine location (anatomy), imaging phenotype (radiomics), and genetic profile (biology), creating multidimensional risk models that correlate with survival much more precisely than any single line or plane described in the past [42].

Conclusions

The historical analysis, from the geometric concepts of Pierre Sebileau and L.G. Öhngren, through the TNM system, to modern radiomic algorithms, reveals the remarkable evolution of oncological thought. The history of topographical divisions of the maxillo-ethmoidal complex is a process of striving for precision: from the macroscopic assessment of the skeleton, through microscopic tissue analysis, to digital data processing. Although historical eponyms have given way to functional endoscopic scales, the primary goal of classification remains unchanged: the precise delineation of the boundary between neoplastic and healthy tissue, aiming to optimize treatment outcomes and minimize complications.

Disclosure

Conceptualization: Michał Magiera
Methodology: Piotr Czwałga
Software: not applicable.
Check: Michał Magiera, Piotr Czwałga, Miłosz Sikora
Formal analysis: Miłosz Sikora
Investigation: Michał Magiera
Resources: Miłosz Sikora
Writing-rough preparation: Michał Magiera, Piotr Czwałga
Writing-review and editing: Piotr Czwałga, Miłosz Sikora
Visualization: Piotr Czwałga, Miłosz Sikora
Supervision: Michał Magiera
Project administration: Michał Magiera
Receiving funding: not applicable.

All authors have read and agreed with the published version of the manuscript.

Funding Statement: Not applicable.
Institutional Review Board Statement: Not applicable.
Informed Consent Statement: Not applicable.

Data Availability Statement: The authors confirm that the data supporting this study are available in the article’s references.
Conflict of Interest: Authors declare no conflict of interest.

References

1. Dutta R, Dubal PM, Svider PF, Liu JK, Baredes S, Eloy JA. Sinonasal malignancies: A population-based analysis of site-specific incidence and survival. Laryngoscope. 2015;125(11):2491-2497. doi:10.1002/lary.25465
2. Milano AF. Cancer of the Nasal Cavity, Middle Ear and Accessory Sinuses - 15 Year Comparative Survival and Mortality Analysis by Age, Sex, Race, Stage, Grade, Cohort Entry Time-Period, Disease Duration and Topographic Primary Sites: A Systematic Review of 13,404 Cases for Diagnosis Years 2000-2017: (NCI SEER*Stat 8.3.8). J Insur Med. 2024;51(2):77-91. doi:10.17849/insm-51-2-77-91.1
3. Szaleniec J, Hartwich P, Składzień J. Ocena przyczyn późnego rozpoznawania nowotworów jam nosa i zatok przynosowych. Otorynolaryngologia. 2009;8(1):23-27.
4. Zhu Q, Zhu W, Wu J, Zhang H. The CT and MRI observations of small cell neuroendocrine carcinoma in paranasal sinuses. World J Surg Oncol. 2015;13:54. Published 2015 Feb 15. doi:10.1186/s12957-015-0475-z
5. Singh V, Khalaf A, Nguyen GK, et al. Imaging evaluation of sinonasal tract neoplasms. *Mini-invasive Surg*. 2025;9:28. doi:10.20517/2574-1225.2024.75
6. Eggesbø HB. Imaging of sinonasal tumours. Cancer Imaging. 2012;12:136-152. Published 2012 May 7. doi:10.1102/1470-7330.2012.0015
7. Jongbloed WM, Tessema B. Egyptian dynasties to biologics: a historical review of nasal polyposis. Otolaryngol Head Neck Surg. 2024;171:625-629. doi:10.1002/ohn.786
8. Mavrodi A, Paraskevas G. Evolution of the paranasal sinuses' anatomy through the ages. Anat Cell Biol. 2013;46(4):235-238. doi:10.5115/acb.2013.46.4.235
9. Howard DJ, Stell PM. Historical aspects of surgery in the sinonasal area. In: Lund VJ, Howard DJ, Wei WI, eds. Tumors of the Nose, Sinuses, and Nasopharynx. Thieme; 2014. doi:10.1055/b-0034-91538
10. Sebileau P. Les formes cliniques du cancer du sinus maxillaire. Ann Maladies d'Oreille Larynx Pharynx 1906; 32: 430–50.
11. Ohngren LG. Malignant tumors of the maxillo-ethmoid region. Acta Otolaryngol (Stockholm) 1933; 19(Suppl): 101–6.
12. Wilson CP. Malignant disease of the superior maxilla. Ann R Coll Surg Engl. 1954;14(5):285-302.
13. Lederman M. Tumours of the upper jaw: natural history and treatment. J Laryngol Otol. 1970;84(4):369-401. doi:10.1017/s0022215100072005

14. Baclesse F. Les cancers du sinus maxillaire de l'ethmoïde et des fosses nasales [Cancer of the maxillary sinus, of the ethmoid, and of the nasal fossae]. Ann Otolaryngol. 1952;69(8-9):465-485.
15. Jing BS. Roentgen diagnosis of malignant disease of paranasal sinuses and nasal cavity. Ann Otol Rhinol Laryngol. 1970;79(3):584-591. doi:10.1177/000348947007900323
16. Dodd GD, Collins LC, Egan RL, Herrera JR. The systematic use of tomography in the diagnosis of carcinoma of the paranasal sinuses. Radiology. 1959;72(3):379-393. doi:10.1148/72.3.379
17. Lederman M. Cancer of the upper jaw and nasal chambers. Proc R Soc Med. 1969;62(1):65-72. doi:10.1177/003591576906200137
18. Sisson GA, Johnson NE, Amiri CS. Cancer of the maxillary sinus: clinical classification and management. Ann Otol Rhinol Laryngol. 1963;72(4):1050-1059. doi:10.1177/000348946307200418
19. Rubin P. Cancer of the head and neck: nose and paranasal sinuses. Cancer. 1973;31(4):963-968. doi:10.1002/1097-0142(197304)31:4<963::aid-cncr2820310431>3.0.co;2-j
20. Harrison DFN. Critical analysis of present classifications and proposal for improvement of classification of carcinoma of the maxillary sinus. Ann Otol Rhinol Laryngol. 1978;87(1):3-9. doi:10.1177/000348947808700102
21. Grose E, Carrau RL, Snyderman CH, et al. TNM classification of malignant tumors of the maxillary sinus: a study of the new 1997 and 2002 systems. Eur J Surg Oncol. 2006;32(2):221-224. doi:10.1016/j.ejso.2005.04.001
22. Lee CH, Hur DG, Roh HJ, et al. Survival rates of sinonasal squamous cell carcinoma with the new AJCC staging system. Arch Otolaryngol Head Neck Surg. 2007;133(2):131-134. doi:10.1001/archotol.133.2.131
23. Thawani R, Kim MS, Arastu A, et al. The contemporary management of cancers of the sinonasal tract in adults. CA Cancer J Clin. 2023;73(1):72-112. doi:10.3322/caac.21752
24. Praveena NM, Maragathavalli G. Carcinoma of the Maxillary Antrum: A Case Report. Cureus. 2018;10(5):e2614. Published 2018 May 13. doi:10.7759/cureus.2614
25. Sakai S, Hamasaki Y. Proposal for the classification of carcinoma of the paranasal sinuses. Acta Otolaryngol. 1967;63(1):42-48. doi:10.3109/00016486709128728
26. Sakai S, Masaki N. Proposals for the TNM classification and its extended application for malignant tumours of the head and neck regions. Acta Otolaryngol. 1971;72(5):370-376. doi:10.3109/00016487109122496

27. Sakai S, Shigematzu Y, Fuchihata H. Diagnosis and TNM classification of maxillary sinus carcinoma. Acta Otolaryngol. 1972;74(1):123-129. doi:10.3109/00016487209128431
28. Shah J, Cappello ZJ, Roxbury C, et al. Prevalence and Clinical Significance of Radiographic Sinus Disease on Preoperative Computed Tomography Imaging in the Endoscopic Skull Base Surgery Population. Am J Rhinol Allergy. 2021;35(2):239-244. doi:10.1177/1945892420949130
29. Castelnuovo P, Giovannetti F, Bignami M, Ungari C, Iannetti G. Open surgery versus endoscopic surgery in benign neoplasm involving the frontal sinus. J Craniofac Surg. 2009;20(1):180-183. doi:10.1097/SCS.0b013e318191cf04
30. Draf W. Die Endoskopie der Nasennebenhöhlen--Diagnostische und therapeutische Möglichkeiten [The endoscopy of paranasal sinuses. Diagnostic and therapeutic possibilities (author's transl)]. Laryngol Rhinol Otol (Stuttg). 1975;54(3):209-215.
31. Al-Qudah M. Image-Guided Sinus Surgery in Sinonasal Pathologies With Skull Base/Orbital Erosion. J Craniofac Surg. 2015;26(5):1606-1608. doi:10.1097/SCS.0000000000001841
32. Al-Qudah M. Endoscopic sinus and skull base surgery: the compartment concept. J Otolaryngol ENT Res. 2017;6(4):00173. doi:10.15406/joentr.2017.06.00173
33. DeConde AS, Suh JD, Mace JC, Alt JA, Smith TL. Outcomes of complete vs targeted approaches to endoscopic sinus surgery. Int Forum Allergy Rhinol. 2015;5(8):691-700. doi:10.1002/alr.21541
34. Meerwein CM, Mauthe T, Soyka MB, Holzmann D. Current concepts in sinonasal tumors: from pretherapeutic assessment to patient-tailored treatment. Rhinology. 2025;63(5):534-542. doi:10.4193/Rhin25.073
35. Migliorelli A, Manuelli M, Ciorba A, Stomeo F, Pelucchi S, Bianchini C. Role of MRI-Based Radiomics in Sinonasal Cancer Management: A Scoping Review. Cancers (Basel). 2025;17(20):3313. Published 2025 Oct 14. doi:10.3390/cancers17203313
36. Taverna C, Agaimy A, Franchi A. Towards a Molecular Classification of Sinonasal Carcinomas: Clinical Implications and Opportunities. Cancers (Basel). 2022;14(6):1463. Published 2022 Mar 12. doi:10.3390/cancers14061463
37. Waters C, Deshwal A, Cuddihy TO, et al. Role of Radiomics to Predict Malignant Transformation of Sinonasal Inverted Papilloma: A Systematic Review. Cancers (Basel). 2025;17(13):2175. Published 2025 Jun 27. doi:10.3390/cancers17132175
38. Gu J, Yu Q, Li Q, et al. MRI radiomics-based machine learning model integrated with clinic-radiological features for preoperative differentiation of sinonasal inverted papilloma

and malignant sinonasal tumors. Front Oncol. 2022;12:1003639. Published 2022 Sep 23. doi:10.3389/fonc.2022.1003639

39. Sahovaler A, Chan HHL, Gualtieri T, et al. Augmented Reality and Intraoperative Navigation in Sinonasal Malignancies: A Preclinical Study. Front Oncol. 2021;11:723509. Published 2021 Nov 1. doi:10.3389/fonc.2021.723509
40. Agarwal A, Bhatt AA, Bathla G, et al. Update from the 5th Edition of the WHO Classification of Nasal, Paranasal, and Skull Base Tumors: Imaging Overview with Histopathologic and Genetic Correlation. AJNR Am J Neuroradiol. 2023;44(10):1116-1125. doi:10.3174/ajnr.A7960
41. Robinson H, Green M, Radkar G, Ready N, Strickler J. Targeting MET Amplification with Crizotinib in a Case of Sinonasal Undifferentiated Carcinoma. Cancer Invest. 2021;39(3):235-239. doi:10.1080/07357907.2021.1884695
42. Stabile AM, Pistilli A, Mariangela R, Rende M, Bartolini D, Di Sante G. New Challenges for Anatomists in the Era of Omics. Diagnostics (Basel). 2023;13(18):2963. Published 2023 Sep 15. doi:10.3390/diagnostics13182963