

Global and Iraqi Infodemiology Surveillance of Paranasal Sinusitis and Anatomical Anomalies: A Two-decade Spatio-temporal and Time-series Analysis

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Abstract

Objectives: To analyze global and Iraqi search trends for five topics on paranasal sinusitis and relevant anatomical anomalies: maxillary sinusitis, sphenoid sinusitis, Schneiderian membrane, concha bullosa, and Onodi cells, focusing on their geographic distribution, temporal trends, and seasonal variations.

Methods: We retrieved monthly Google Trends data (2004–2025) for the five topics, analyzed global and Iraqi search volumes, mapped geographic hotspots, compared temporal trends and evaluated seasonality using Holt-Winters exponential smoothing. Analyses were performed using SPSS v.26 and JMP v.18.

Results: Maxillary sinusitis and concha bullosa consistently received the greatest attention over time, whereas interest in the Schneiderian membrane, sphenoid sinusitis, and Onodi cells remained markedly lower. Sphenoid sinusitis searches clustered in France and its former colonies (North-West Africa), and some Latin nations, while maxillary sinusitis queries were concentrated in post-Soviet states. Arab and Middle Eastern countries also accounted for the search volumes across all topics. Holt-Winters exponential smoothing revealed annual seasonality for maxillary sinusitis ($p < 0.001$), Schneiderian membrane ($p = 0.035$) and Onodi cells ($p = 0.003$); biannual peaks for sphenoid sinusitis ($p = 0.021$); and quarterly cycles for concha bullosa ($p < 0.001$), with maxillary sinusitis seasonality notably disrupted during the COVID-19 pandemic. In Iraq, search activity was confined to concha bullosa (Erbil, Sulaymaniyah, Baghdad) and the Schneiderian membrane (Baghdad).

Conclusions: Google Trends analysis showed regional hotspots and seasonal peaks in searches for sinusitis-related topics, notably maxillary sinusitis and concha bullosa, with topic-specific disruptions during the pandemic. In Iraq, interest was limited to concha bullosa and the Schneiderian membrane, suggesting physicians or specialist-driven searches. These trends highlight the potential role of digital surveillance in informing medical research and guiding public health communication.

Keywords: Concha Bullosa; Digital Epidemiology; Google Trends; Infodemiology and Infoveillance; Onodi Cells; Chronic Rhinosinusitis; Schneiderian Membrane; Sino-Nasal Pathology; Spatio-Temporal Analysis; Triple Exponential Smoothing.

Introduction

The paired paranasal sinuses (maxillary, frontal, ethmoid, and sphenoid) develop as outpouchings of the nasal cavity during embryogenesis between the third and fifth months of fetal life. Postnatal maturation continues, with the maxillary and ethmoid sinuses reaching functional size in early childhood and the frontal and sphenoid sinuses maturing during adolescence.^{1,2} Disruptions in this developmental process may predispose individuals to anatomical variants and related pathologies, including sinusitis. Several hypotheses have been proposed to explain the function of the paranasal sinuses. The anti-gravity theory suggests that sinuses reduce skull weight,³ whereas the evolutionary theory proposes that they developed through natural selection to enhance vocal

resonance and phonation.⁴ Additional hypotheses emphasize roles in respiratory humidification, thermal insulation, and olfaction.^{4,5} Anatomical variations of the paranasal sinuses, shaped by ethnicity, geography, and demographic factors such as age and sexual dimorphism, may influence the prevalence, severity, and laterality of paranasal sinusitis and other sinus pathologies.

The maxillary sinus is unique as it drains "uphill" because its natural ostium lies above the sinus floor, requiring mucociliary transport rather than gravity for mucus clearance.⁶ Ford et al. (2011) showed that passive drainage in cadaveric maxillary sinuses was significantly more efficient with a 90° forward head tilt than in the upright position ($p < 0.01$), suggesting a possible evolutionary mismatch in ostial placement.⁷ This configuration may increase susceptibility to maxillary sinusitis and, together with population differences in sinus and ostiomeatal complex morphology, may contribute to geographic variation in relevant infodemiological signals such as Google Trends search volumes. The Schneiderian membrane, a specialized respiratory mucosa lining the maxillary sinus, is essential for mucociliary clearance and barrier function. Trauma during dental implant procedures, particularly sinus lifts, can perforate this membrane, increasing the risk of maxillary sinusitis.⁸ Baseline variation in Schneiderian membrane thickness may also influence the severity of maxillary sinusitis and susceptibility to injury during dental or sino-nasal procedures.

A global meta-analysis of 28 population-based studies (237 million participants) found the prevalence of chronic rhinosinusitis (CRS) to be 8.71% (95% CI: 6.69–11.33%). Prevalence was higher in adults, smokers, and individuals with comorbidities, and increased from 4.7% (1980–2000) to 19.4% (2014–2020), indicating a rising global burden.⁹ National prevalence often differs by country, region, and perhaps, ethnicity, and this could be mirrored in corresponding variations in online information-seeking patterns. Such infodemiological insights can guide and inform subsequent regional or national prevalence studies on specific subtypes of sinusitis. On another note, climatic factors such as temperature extremes, low humidity, atmospheric pressure fluctuation, and airborne particulates exacerbate sinus mucosal inflammation.^{10,11} In the Middle East (especially in Iraq, UAE, Iran, and Saudi Arabia), frequent dust storms, arid conditions, and extreme summer temperatures have been associated with elevated rates of acute exacerbations and chronic sinusitis,¹² highlighting the need for region-specific environmental health strategies. It remains unclear how extrinsic climatic factors (temperature, humidity, wind speed, and atmospheric pressure) interact with intrinsic ethno-demographic variables to influence the prevalence (or severity) of paranasal sinusitis.

Specific sino-nasal anatomical variants, such as concha bullosa (CB) and Onodi cells (OCs), may predispose individuals to paranasal sinusitis. Concha bullosa is the pneumatization of the middle turbinate, which could reach up to 53% of individuals in specific populations.¹³ Morphological variants include lamellar, bulbous, and extensive forms, each with a distinct radiologic appearance and potential to obstruct the ostiomeatal complex, thereby predisposing to rhinosinusitis.¹⁴ In contrast, others (Calvo-Henríquez et al., 2019) may categorize CB according to the axial extension of pneumatization of the middle turbinate.¹⁵ Digital epidemiological surveillance may, or may not, reveal a correlation between search volumes for sinusitis and CB, potentially mirroring the clinical prevalence in a given country. Concerning OCs, these are posterior ethmoid air cells that pneumatize superolaterally to the sphenoid sinus, found in up to 65% of patients on CT imaging.^{16,17} The proximity to the optic nerve, internal carotid artery, and cavernous sinus stresses the importance of preoperative recognition to avoid neurovascular injury during endoscopic sinus surgery; inflammatory extension risks optic neuropathy or carotid artery complications.¹⁸⁻²⁰ While OCs themselves may not directly cause sinusitis, their location can promote drainage impairment of the sphenoid sinus, potentially contributing to sphenoid sinusitis or sphenoiditis.²¹ Analysis of online information-seeking for OCs and sphenoid sinusitis may reveal correlations that mirror their clinical association.

Digital epidemiology uses online data logs (such as web queries, social media posts, and online forums) to monitor patterns in real time. Infodemiology and infoveillance involve analyzing health-related information-seeking behavior, such as using Google Trends, to gauge public interest and complement classical epidemiological surveillance systems.²² These approaches can be applied not only to internet search engines' datasets but also to social media platforms (including online drug forums),^{23,24} and they have been successfully employed across medical research disciplines, including clinical psychiatry and mental health,^{25,26} neuropharmacology,²⁷⁻²⁹ dentistry,^{30,31} anatomy and surgery,^{32,33} rheumatology,³⁴ and dermatology,^{35,36} among others. Google Trends provides relative search volume (RSV) indices stratified by geography and time, allowing investigators to track interest in specified terms (or topics) over time (weeks, months, or years).³⁷ Its accessibility and good temporal resolution make it a good proxy for online information-seeking behavior.²² Compared to traditional surveillance (classical epidemiology), digital methods offer broader population reach

(including those who do not seek medical care) and cost efficiency. They are particularly valuable in low-resource settings where reporting infrastructure is often limited.

Time series analysis and seasonal forecasting methods model sequential data points to uncover trends and seasonal patterns. Common models include the autoregressive integrated moving average (ARIMA), exponential smoothing (single, double, and triple), among others, each suited to different data structures and research aims.^{38,39} The Holt-Winters exponential smoothing method applies triple components (level, trend, and seasonality) to analyze and forecast time series with recurring patterns.^{40,41} Its relative computational simplicity and ability to adapt to changing trends make it ideal for modeling health data with pronounced seasonality, such as sinusitis exacerbations. On another note, it remains unknown whether seasonal patterns exist in online information-seeking related to paranasal sinusitis and anatomical anomalies, or whether such patterns persisted during the Coronavirus disease 2019 (COVID-19) pandemic.^{42,43} According to Émile Durkheim's theory of social anomie, periods of rapid change (such as wars, crises, famines, or pandemics) can disrupt social norms, leading to normlessness, confusion, and weakened social bonds, which may give rise to deviant behaviors,⁴⁴ potentially including those of online information-seeking.

The current study aims to analyze a two-decade longitudinal Google Trends dataset to characterize global and Iraq-specific online information search behaviors for five topics on paranasal sinusitis (maxillary and sphenoid sinusitis), relevant sino-nasal anatomical anomalies (CB and OCs), and the Schneiderian membrane, by mapping their geographic distribution, assessing temporal trends, and evaluating potential seasonal fluctuations to elucidate periodic (cyclic) variations in public interest.

Methods

The current study examines global and national (Iraq) online search behaviour related to paranasal sinusitis and associated anatomical anomalies or entities (OCs, CB, and the Schneiderian membrane) using Google Trends data. Google Trends captures the popularity of search queries entered by millions of internet users worldwide via the Google search engine. Google Trends provides insights across four main domains: interest over time (temporal trends), interest by region (geographic distribution), related search topics, and related queries.³⁷ We analyzed five search topics: OCs, CB, Schneiderian membrane, sphenoid sinusitis, and maxillary sinusitis. The data spans from 2004 to 2025, with monthly intervals resulting in 259 data points per topic. Search interest is reported on a scale from 0 to 100, reflecting relative popularity over time.

The present study relates to the discipline of infodemiology and infoveillance. Data from Google Trends reflect online information-seeking behaviour at global (≈ 8.2 billion) and national scales (≈ 47 million for Iraq), based on 2025 census data.⁴⁵ Although the theoretical sampling frame could include the entire population, the analysed data are restricted to internet users who searched for paranasal sinusitis and related topics; the underlying population cannot be quantified because the platform (Google Trends) reports RSV on an ordinal scale rather than absolute counts. Further, the dependent variable (Google Trends' RSV) represents a proxy of uncertain validity, as it does not measure clinically confirmed disease incidence. Rather, RSV reflects population-level online health information-seeking behaviour.

Data from Google Trends was compiled and visualized in Microsoft Excel 2016 for temporal and spatial (geographic) mapping. Statistical analyses were performed in IBM SPSS v.26, including descriptive statistics and Spearman's bivariate correlation matrices. The time-series analysis, performed in JMP Student Edition v.18, used the Holt-Winters exponential smoothing model (triple exponential smoothing) and was evaluated by mean absolute error (MAE). Statistical significance was defined by a two-tailed alpha level of 5% ($\alpha=0.05$).

For the Holt-Winters exponential smoothing model, diagnostic checks confirmed that model assumptions were met; the residuals were evaluated for independence using partial and complete autocorrelation function (ACF/PACF), for normality by distributional inspection and Q-Q plots, and for homoscedasticity by plots of residuals versus time and fitted values. The Ljung-Box test found no significant autocorrelation ($p>0.05$).

We conducted a systematic search across MEDLINE and EBSCOhost databases using Medical Subject Headings (MeSH) terms related to paranasal sinusitis and specific anatomical entities (e.g., OCs, CB, Schneiderian membrane), retrieving case reports and series, reviews and systematic reviews, research papers,

and meta-analytic studies. We applied the same search criteria to the national Iraqi Academic Scientific Journals and the University of Baghdad Digital Repository.

The current study used only publicly available, open-access data and, due to its observational nature, was exempt from ethical approval by the Research Ethics Committee, College of Medicine, University of Baghdad. Informed consent was not required, and all data were fully anonymized. All study procedures were conducted per the World Medical Association's Declaration of Helsinki and the 1997 Framingham Consensus.

Results

Worldwide, and concerning the geographic mapping [Figure 1], the top 10 countries from which data signals originated included: Togo, Nepal, India, Pakistan, Malaysia, Singapore, Philippines, Australia, Nigeria, and the UAE (OCs), Dominican Republic, Puerto Rico, Lebanon, Austria, Jordan, Italy, United Arab Emirates, Nepal, Kuwait, and Romania (CB), Nepal, South Korea, Armenia, Jordan, Libya, Lebanon, Philippines, India, Honduras, and Ecuador (Schneiderian membrane), Réunion, France, Cuba, Dominican Republic, Côte d'Ivoire, Tunisia, Morocco, Algeria, Colombia, and Paraguay (sphenoid sinusitis), and Ukraine, Kazakhstan, Kyrgyzstan, Russia, Belarus, Turkmenistan, Tajikistan, Moldova, Uzbekistan, and Armenia (maxillary sinusitis).

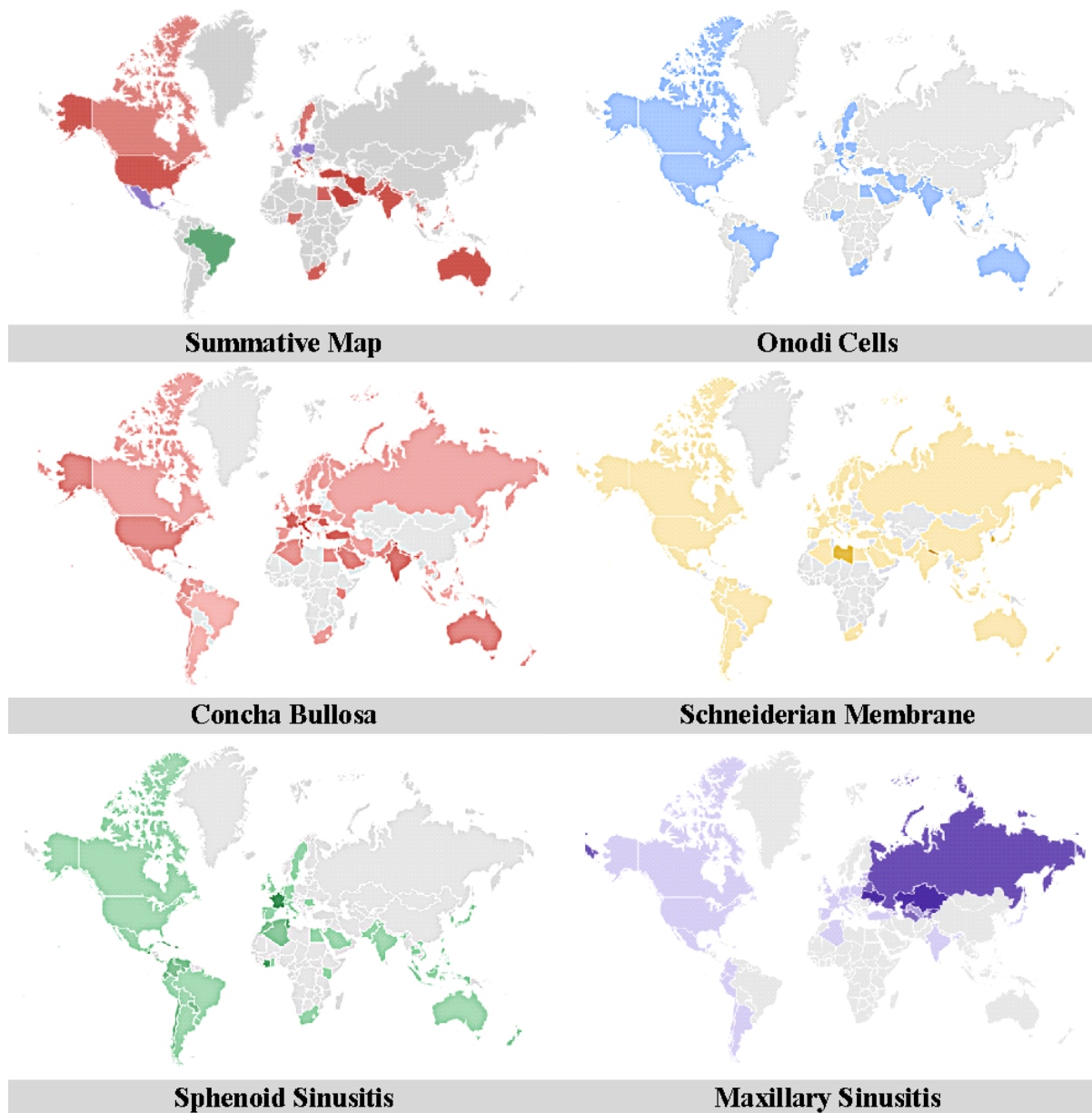


Figure 1: Global geographic mapping of online information search behavior. Summative map (upper left) with comparative search volumes.

Countries across the Arab and Muslim world (particularly in the Middle East and North Africa) also represented a good share of searches for almost every topic. For OCs (19.23%), the top contributors were Egypt, Iraq, Saudi Arabia, Turkey, and the United Arab Emirates. Concha bullosa queries (17.91%) stemmed primarily from Egypt, Iran, Iraq, Jordan, Lebanon, Morocco, Palestine, Qatar, Saudi Arabia, Tunisia, Turkey, and the UAE. Schneiderian membrane searches (17.91%) originated from Algeria, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Palestine, Saudi Arabia, the UAE, and Turkey, with Jordan and Libya leading those countries. Sphenoid sinusitis interest (12.28%) was highest in Tunisia, Morocco, and Algeria, followed by Egypt, Palestine, Saudi Arabia, and the UAE. Finally, maxillary sinusitis queries (8.11%) were also driven, and to a lesser extent, by Algeria, Palestine, and Turkey.

Search interest in sphenoid sinusitis was highest in France and its former colonies, including some West African and North African Arab countries (e.g., Réunion, Côte d'Ivoire, Tunisia, Morocco, Algeria), as well as a few nations of the Caribbean (e.g., Cuba, the Dominican Republic), which share historical ties with the French colonization of West Africa and the infamous trans-Atlantic slave trade. Réunion, a French Indian Ocean territory with strong cultural and migratory links to France and the Francophone zone of West Africa, led all regions in search volume. Cuba and the Dominican Republic also ranked highly.

Concerning OCs, data signals were concentrated in Togo (West Africa), Nepal, and Nigeria, as well as in Southeast Asian countries, with additional contributions from Gulf Arab nations like the UAE and Saudi Arabia, which are linked commercially to India and Nepal. A common feature in search trends for both OCs and sphenoid sinusitis is the notable involvement of West African countries. In contrast, search activity for maxillary sinusitis was primarily concentrated in former states of the Union of Soviet Socialist Republics (USSR), including Ukraine, Kazakhstan, Kyrgyzstan, and Russia, among others.

Temporal mapping

Temporal mapping [Figure 2] revealed that the median search volumes were highest for the maxillary sinus (12; IQR 5–32) and CB (5; IQR 5–6), intermediate for OCs (2; IQR 1–2), and lowest for the Schneiderian membrane (1; IQR 0–1) and sphenoid sinusitis (0; IQR 0–1). High-end outliers were observed for CB in January 2004, December 2004, and April 2005; for the Schneiderian membrane in November 2005; and for maxillary sinusitis in October 2017 and from September 2021 through January 2022.

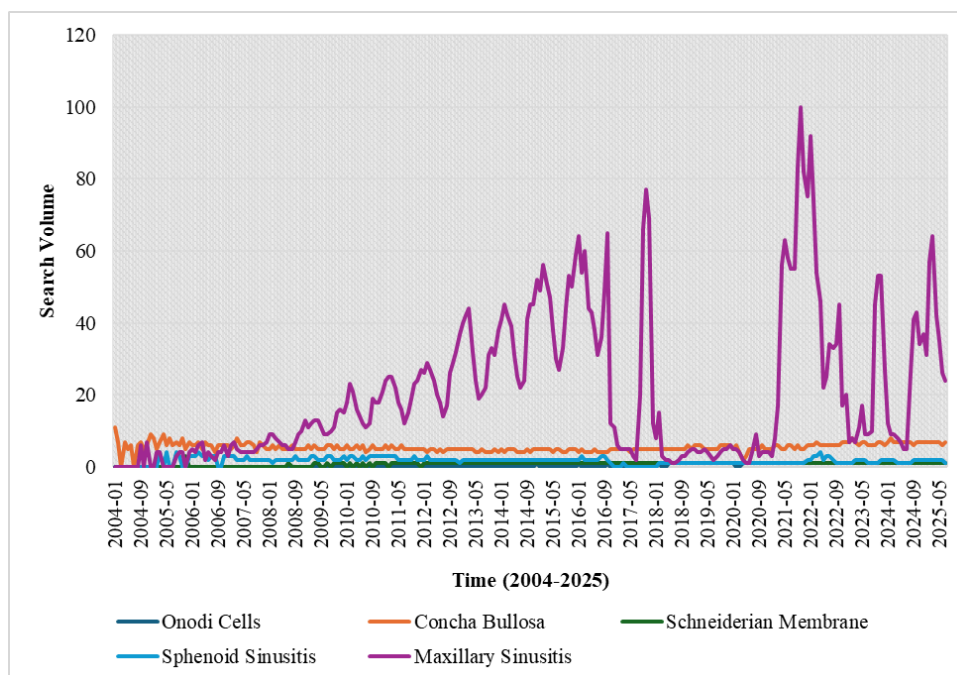


Figure 2: Global temporal mapping of online information search behavior.

Bivariate Spearman's correlations demonstrated that OCs and the Schneiderian membrane exhibited the strongest positive association (Spearman's rho=0.736, p-value<0.001). Moderate positive correlations were also found between OCs and CB ($\rho=0.376, p<0.001$) and between sphenoid and maxillary sinusitis ($\rho=0.327, p<0.001$), as well as a moderate negative correlation between Onodi cells and sphenoid sinusitis ($\rho=-0.342, p<0.001$). Weaker, yet still significant, associations included CB with Schneiderian membrane ($\rho=0.165, p=0.008$) and Schneiderian membrane with maxillary sinusitis ($\rho=0.272, p<0.001$), alongside negative correlations of CB with maxillary sinusitis ($\rho=-0.212, p=0.001$) and Schneiderian membrane with sphenoid sinusitis ($\rho=-0.224, p<0.001$).

We conducted a time-series analysis using the Holt-Winters exponential smoothing to evaluate whether online information-seeking exhibited statistically significant seasonality. There were no significant trends ($p>0.05$); however, significant seasonality existed (Table 1; Figure 3). Time series analysis confirmed evident seasonal patterns in online information-seeking, particularly for maxillary sinusitis, with annual peaks occurring almost every February until the onset of the COVID-19 pandemic; the seasonality may have been disrupted in association with the emergence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).

Table 1: Time series analysis.

Model Parameters		Onodi Cells	Concha Bullosa	Schneiderian Membrane	Sphenoid Sinusitis	Maxillary Sinusitis	
Model Parameters	LoS	12	4	12	6	12	
	Month	February	N/A	March	April/October	February	
	df	50	251	221	249	111	
	MAE	14.996	5.266	6.884	10.024	3.851	
Components	Level	Estimate	0.22	0.14	0.19	0.38	0.25
		SE	0.07	0.08	0.06	0.06	0.06
		p-value	0.003	0.062	<0.001	<0.001	<0.001
	Trend	Estimate	0.03	0.01	0.00	0.00	0.00
		SE	0.09	0.03	0.00	0.02	0.00
		p-value	0.773	0.845	0.892	1.000	0.962
	Seasonality	Estimate	0.67	0.50	0.14	0.13	0.93
		SE	0.22	0.10	0.07	0.05	0.12
		p-value	0.003	<0.001	0.035	0.021	<0.001

Degrees of freedom (df); length of seasonality (LoS); mean absolute error (MAE); not applicable (N/A); SE (standard error).

For maxillary sinusitis (excluding the COVID-19 period), online search interest exhibited significant annual seasonality, peaking each February ($p<0.001$). The Schneiderian membrane web queries likewise showed a significant yearly peak in March since 2008 ($p=0.035$). Similarly, interest in OCs demonstrated a significant February peak annually from 2016 onward ($p=0.003$). On another note, and for sphenoid sinusitis, search interest exhibited significant biannual peaks in April and October since 2016 ($p<0.021$), with pandemic-related disruptions that were less pronounced than those seen for maxillary sinusitis. Finally, CB queries displayed a significant quarterly cycle, peaking almost every season of the year since 2004 ($p<0.001$). We may infer that significant annual seasonality was observed for only three queries: maxillary sinusitis, the Schneiderian membrane, and OCs. The SARS-CoV-2 pandemic was associated with a disrupted seasonal cycle of maxillary sinusitis, with a milder perturbation seen for sphenoid sinusitis; however, a causal association cannot be inferred concerning the pandemic from the current study.

In summary, nations in the Middle East, North-West Africa, post-USSR states, and some Latin countries represented a substantial share of global queries. Temporally, interest in maxillary sinusitis and CB far exceeded that for the other three topics. Correlation analysis revealed strong positive associations between searches for OCs and the Schneiderian membrane, with moderate associations among other topic pairs. Seasonal modeling showed that maxillary sinusitis, Schneiderian membrane, and OCs each followed an annual cycle with predictable peaks in late winter to early spring; sphenoid sinusitis demonstrated twice-yearly peaks in spring and autumn; and CB displayed a four-season cycle. These regular patterns were notably disrupted in association with the COVID-19 pandemic, particularly for maxillary sinusitis.

In Iraq, regional mapping revealed online search signals only for CB and the Schneiderian membrane. CB queries originated from Erbil, Sulaymaniyah, and Baghdad (in descending order), while Schneiderian membrane searches were limited to Baghdad. Temporal mapping possessed too few data points for statistical or time-series analyses, including seasonality assessment. Related web queries centered on radiologic aspects of these topics imply that Iraqi radiologists and other medical professionals, especially in the Kurdistan region, may predominate in this information-seeking.

In summary, Iraqi searches appeared only for CB (Erbil, Sulaymaniyah, Baghdad) and the Schneiderian membrane (Baghdad). The data were too sparse for statistical or time-series analysis. The radiologic focus suggests Kurdistan-region medical professionals drive these queries, warranting larger and more rigorous studies for proper statistical inference.

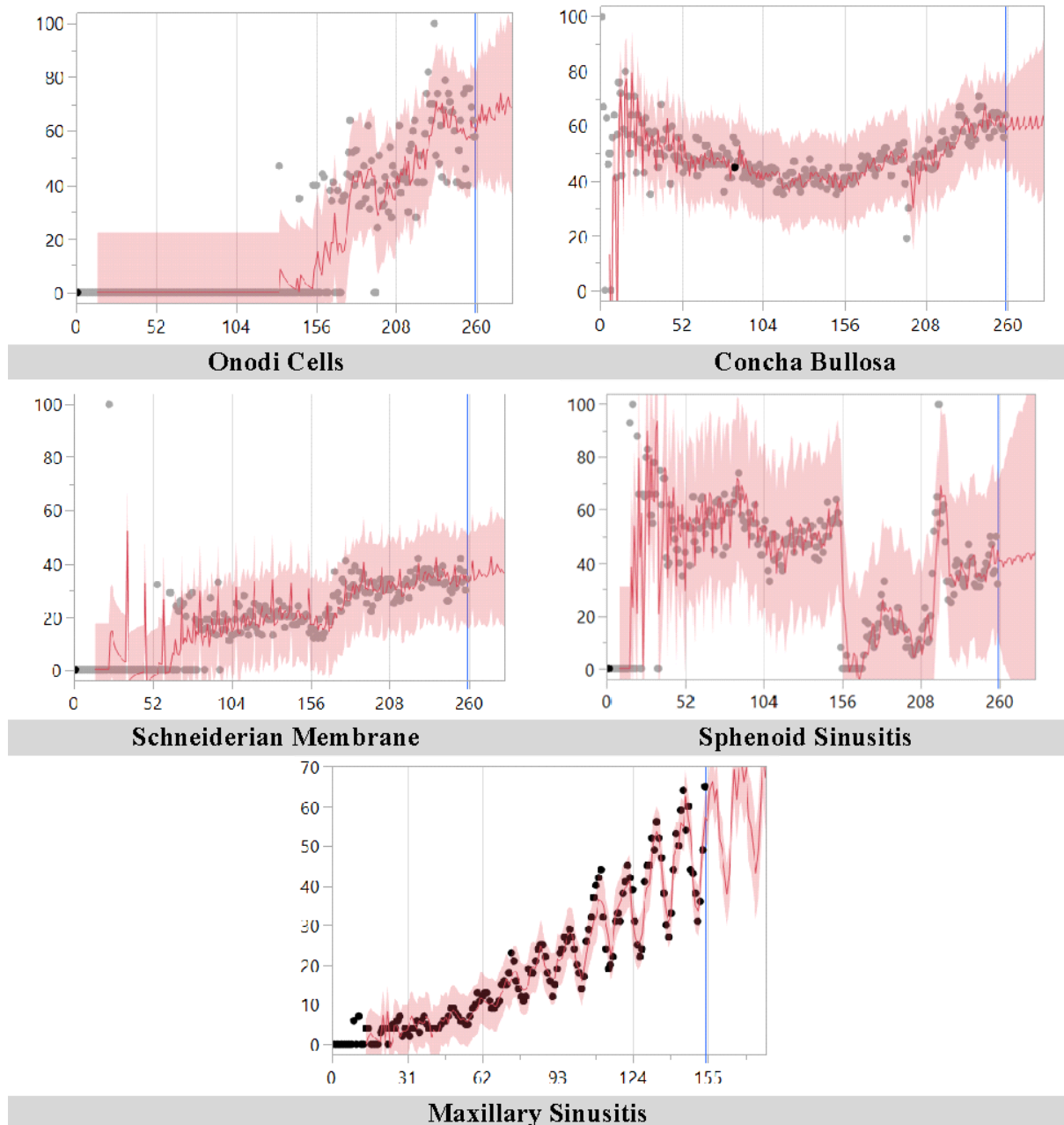


Figure 3: Time series analysis of search topics. The x-axis (time) and y-axis (search volume).

Discussion

Global online search trends for paranasal sinusitis and relevant anatomical anomalies revealed distinct geographic and temporal patterns that might be shaped by historical, cultural, and regional forces, potentially including the French colonization of North-West Africa and the trans-Atlantic slave trade during the Americas' colonization. Sphenoid sinusitis queries clustered in France, the Francophone zones of West Africa, some Latin nations of the Caribbean, and North African Arab states, suggesting possible ethnic and migratory influences. Onodi cell searches peaked in Togo (West Africa) and Nepal, with additional interest from some Arab Gulf states tied to Nepal through trade and proximity. CB volumes were highest in Caribbean nations (Dominican Republic and Puerto Rico), which are also historically linked to West Africa via the post-Columbian trans-Atlantic slave trade. In contrast, maxillary sinusitis searches clustered in post-Soviet countries with minimal engagement from Arab and Middle Eastern nations, unlike other search topics.

Maxillary sinusitis and CB were the most frequently searched topics, while OCs and the Schneiderian membrane showed lower levels of interest. Correlation analysis indicated strong associations between OCs and the Schneiderian membrane, alongside moderate relationships among other topics. Seasonal patterns showed annual peaks for maxillary sinusitis, Schneiderian membrane, and OCs; biannual peaks for sphenoid sinusitis; and a quarterly periodicity for CB, with notable disruptions following the onset of the COVID-19 pandemic, especially for maxillary sinusitis.

In Iraq, search activity was limited to CB and the Schneiderian membrane, originating mainly from Baghdad and Kurdistan, with a focus on radiologic content, suggesting a potential professional interest among local radiologists and medical professionals. On another note, the time series analysis was not applicable. Time-series analysis beyond the available observation window (2004 to 2025) was not feasible. Although the sampling frame could theoretically be extended, Google Trends provides RSVs only starting from January 2004.

Our finding of evident (statistically significant) winter-peaking seasonality for maxillary sinusitis searches mirrors several infodemiological investigations that used Google Trends and other online search platforms. For example, Liu et al. (2022) applied cosinor time-series analysis to rhinosinusitis-related search terms ("sinusitis", "mucus", "nose", among others) across both hemispheres and consistently observed wintertime peaks, lending support to viral-triggered exacerbations of acute and chronic rhinosinusitis.⁴⁶ Similarly, Sharma et al. (2020) found that United States search volumes for "sinusitis" and related terms – derived from the SNOT-22 and the authors' clinical experience (e.g., "postnasal drip" and "nasal congestion") – cycle seasonally, peaking in January–February and dipping in summer.⁴⁷ Our results extend these observations globally and reveal novel topic-specific seasonality (biannual peaks in sphenoid sinusitis and quarterly cycles in concha bullosa) previously undocumented in digital surveillance studies.

In contrast to the well-established infodemiology of clinical sinusitis, very few studies have explored online interest in purely anatomical variants such as CB and OCs. Our identification of CB as the second-highest searched topic (after maxillary sinusitis) complements radiologic prevalence data. CT-based studies report CB in roughly 35–53% of patients, depending on imaging modality and population (e.g., 53% in a Saudi cohort; 49% in Omani adults).^{13,48} Our digital search peak for CB may parallel clinical relevance, emphasizing the potential of Google Trends to approximate underlying anatomic-variant epidemiology.

For OCs, Tomovic et al. (2012) reported a 65.3% prevalence of OCs on high-resolution CT in a North American cohort (83.3% in Asians, 73.1% in Whites, 62.7% in Hispanics, and 57.0% in African Americans),¹⁷ whereas an Iranian CBCT series (2021) reported a lower prevalence of 38.8%, likely due to differences in ethnic focus or research protocols, including imaging planes and techniques.¹⁶ Our data reveal more modest, but seasonally significant, interest in OCs, peaking each February, and a strong correlation with Schneiderian membrane searches ($\rho=0.736$, $p<0.001$), a relationship not previously quantified in digital-behavior studies.

Geo-spatially, interest in sphenoid sinusitis was concentrated in France and former Francophone regions of North-West Africa, while maxillary sinusitis was prominent in post-Soviet states. In contrast, Min et al. (2025) reported higher CRS prevalence in Europe (8.7–19.4%) compared to other regions worldwide.⁹ The divergence between digital search "hotspots" and clinical prevalence maps may reflect differences in health information-seeking behavior, internet penetration, language use, and specialist-community engagement rather than actual disease burden.

In summary, our findings confirm and extend prior infodemiological research on paranasal sinusitis, validating seasonal patterns and identifying new trends related to specific sino-nasal anatomical anomalies. These patterns likely reflect the interplay between clinical prevalence, educational attention, and public information-seeking behavior shaping Google Trends signals.

Study limitations and recommendations

An important limitation is language bias. The study did not distinguish online searches by language, which prevents analysis of populations with different languages and their distinct information-seeking behaviours (including within Iraq). Future research can implement broader multilingual search strategies using a customizable thesaurus of search terms, which can include medical names, anatomical and lay terms, abbreviated terms, and language (or dialect) variants, combined with Boolean operators and truncation to explore more detailed and population-specific online information search behaviours.

Another important limitation is that Google Trends RSVs are conditioned by internet penetration and Google market share, and therefore, they may not represent the underlying disease burden. Populations with limited or no internet access, including older adults, individuals with disabilities, and socioeconomically disadvantaged groups (e.g., people experiencing poverty, homelessness, or living in remote rural areas), are underrepresented. Internet access also varies within and between countries, and between high-income and low- and middle-income settings, owing to differences in infrastructure, economics, and culture. Where possible, future studies can adjust for local internet penetration and search engine market share and combine online data with complementary sources.

Another limitation is that Google Trends supplies normalized, aggregated temporal and spatial metadata, rather than raw, individual user-level figures, reflecting collective search behaviour for a given query.³⁷ Early data (around 2004) may be inconsistent, as Google has continuously refined its "web crawling" and aggregation algorithms.

Web users may obscure their geographic location via virtual private networks (VPNs), internet protocol (IP) masking, Tor anonymous web browser, or other privacy-focused browsers, such as DuckDuckGo, potentially affecting data accuracy.^{49,50} In China, private internet infrastructures, alternative browsers, and domestic search engines (e.g., Baidu) limit the visibility of Google Trends data.⁵¹ Similarly, Iraq's sparse data may reflect language barriers, low English language RSV, and diverse Arabic and Kurdish dialects, compounded by the post-Saddam (post-2003) collapse of an already underdeveloped internet infrastructure.

Seasonal patterns in online search behaviour can vary by region due to differences in climate and geography, which can influence sinusitis and relevant online search behaviours. Future research can therefore analyse country-specific time series. Additionally, our analysis indicates that the COVID-19 pandemic was associated with a reduced search interest in paranasal sinusitis, especially maxillary sinusitis, highlighting the need for longer, pandemic-free datasets to more accurately characterize underlying seasonal trends without the societal or norms disruptions.

The time series analysis for the Iraqi data was not applicable, and unfortunately, time-series exploration beyond the available observation window was not feasible. Although the sampling frame could theoretically be extended, Google Trends provides metadata only from January 2004 to 2025, and data prior to 2004 are not accessible through the platform. Earlier raw search logs were either not retained or are not comparable because of differences in sampling procedures, privacy issues, and data collection methods, rendering pre-2004 Google Trends estimates unreliable.

Emerging digital technologies, particularly automation based on artificial intelligence (AI) and generative artificial intelligence (GenAI), and the anticipated artificial general intelligence (AGI),^{52,53} promise to overcome many of the previously detailed barriers. Further, integrating AI with infodemiology could revolutionize modern medical education by exploring real-time surveillance and predictive analytics to tailor relevant personalized learning strategies.^{54,55}

Conclusion

In this study, infoveillance revealed distinct geographic and temporal patterns in online information-seeking for paranasal sinusitis and relevant sino-nasal anatomical anomalies. Globally, countries in the Middle East,

North-West Africa, South Asia, some Latin countries, and former Soviet republics contributed disproportionately to search activity, potentially reflecting regional clinical interest, or potentially, ethnic, historical, and migratory ties influencing the search behavior. Temporally, maxillary sinusitis and CB consistently attracted the most attention, while interest in Schneiderian membrane, sphenoid sinusitis, and OCs was much lower. Correlation analyses suggest that searches for specific anatomical variants tend to co-occur, which could mirror clinical or educational linkages among those topics. Seasonal modeling demonstrated reliable annual or multiannual peaks for several search topics; seasonal patterns were perturbed during the COVID-19 pandemic, notably concerning maxillary sinusitis. At the national level in Iraq, search signals were limited to CB and the Schneiderian membrane, concentrated in Baghdad and the Kurdistan region, and could be driven by physicians or radiology professionals. Together, these findings illustrate how digital surveillance can explore global and local patterns of health information-seeking, inform public health policy, and guide future research into the underlying drivers of online engagement with sinus-related topics.

Disclosure

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