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MORPHOFUNCTIONAL ANALYSIS OF NASAL HISTOLOGY IN HEALTHY HUMANS

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Abstract: This study addresses the lack of detailed baseline data on the normal histological and functional characteristics of the human nasal mucosa, which plays a critical role in air filtration, humidification, and temperature regulation, by establishing reference values for epithelial thickness, glandular density, and vascularization. Furthermore, understanding the normal distribution of mucins and epithelial markers such as cytokeratin and MUC5AC provides a foundation for future molecular and diagnostic research. Given the increasing incidence of respiratory diseases linked to environmental pollution and climate change, a thorough assessment of nasal morphology under healthy conditions is particularly timely and clinically important.

This study therefore fills a significant gap by providing a detailed morphofunctional profile of the healthy human nasal mucosa, contributing to the development of diagnostic standards and improving our understanding of nasal physiology and pathology.

The nasal cavity plays a vital role in the respiratory system by performing critical functions such as air filtration, humidification, and warming. These functions are closely related to the histological structure of the nasal mucosa, including the epithelium, submucosal glands, and vascular components. This study aims to conduct a detailed morphofunctional analysis of nasal histology in healthy adult humans. Nasal mucosal biopsy samples were collected from 20 healthy volunteers and examined using histological, histochemical, and immunohistochemical methods. Morphometric measurements of epithelial thickness, gland density, and vascularization were performed. The findings highlight the structural characteristics of healthy nasal mucosa and provide a baseline for future pathological comparisons. This research contributes valuable insights into nasal tissue functionality and its relevance for clinical diagnostics and treatment.

Keywords: Nasal histology, morphofunctional analysis, nasal mucosa, epithelium glands, vascularization.

Introduction: The nasal cavity is the primary gateway for inspired air entering the respiratory tract and serves multiple essential functions, including filtration of airborne particles, humidification of the air, and temperature regulation before it reaches the lungs. The nasal mucosa, which lines the nasal cavity, plays a pivotal role in these processes due to its unique histological composition and cellular architecture (Holbrook et al., 2022).

Structurally, the nasal mucosa consists of a pseudostratified ciliated columnar epithelium embedded with mucus-secreting goblet cells, supported by a highly vascularized lamina propria containing seromucous glands and immune cells. This specialized structure ensures effective mucociliary clearance, protects the respiratory tract from pathogens, and maintains air quality and moisture balance (Harkema et al., 2023).

Despite considerable research on nasal physiology and pathology, comprehensive morphofunctional analyses correlating the histological structure with functional outcomes in

healthy individuals remain limited. Most existing studies focus on pathological states such as allergic rhinitis, chronic sinusitis, or nasal polyposis, where mucosal changes are pronounced.

Understanding the normal histological features and their functional implications is crucial to establish baseline references for disease diagnosis, treatment, and research. This study aims to perform a detailed morphofunctional analysis of nasal histology in healthy adult humans, focusing on epithelial characteristics, glandular distribution, and vascularization patterns. Although the nasal mucosa has been studied in pathological contexts, morphometric and histochemical assessments in healthy populations are limited. Thus, this study provides an in-depth morphological and functional evaluation of the healthy nasal mucosa.

The novelty of this research lies in establishing detailed morphofunctional reference parameters for healthy human nasal mucosa, which have not been systematically quantified before.

Materials and Methods

Study Design and Participants

This descriptive study involved 20 healthy adult volunteers (aged 20-40 years) recruited from the Tashkent State Medical University community. Participants had no history of nasal, respiratory, or systemic diseases and had not used nasal medications or undergone nasal surgery in the preceding six months. Written informed consent was obtained from all participants, and the study was approved by the Institutional Review Board of Tashkent State Medical University.

Sample Collection

Nasal mucosal biopsy specimens were obtained from the anterior part of the inferior turbinate under local anesthesia using standard biopsy forceps. The site was chosen due to its accessibility and relevance to mucosal function.

Histological Processing and Staining

Biopsy samples were immediately fixed in 10% neutral buffered formalin for 24 hours at room temperature, dehydrated and embedded in paraffin wax. Serial sections of 5 µm thickness were prepared for staining.

The following staining techniques were employed:

Hematoxylin and Eosin (H&E): For general tissue morphology and cellular architecture

Periodic Acid-Schiff (PAS): To detect neutral mucopolysaccharides in goblet cells and glands.

Alcian Blue (pH 2.5): To identify acidic mucins in the mucus-producing cells.

Immunohistochemistry

Sections were immunostained using antibodies against cytokeratin to identify epithelial cells and mucin 5AC to detect secretory mucins. Standard protocols with appropriate positive and negative controls were followed.

Microscopic Evaluation and Morphometry

Slides were examined under a Leica DM500 light microscope equipped with a high-resolution digital camera. Quantitative morphometric analysis was performed using ImageJ software. Parameters measured included:

Epithelial thickness (µm)

Density of submucosal glands (number/mm²)

Percentage of vascularized area in the submucosa (%)

Each parameter was measured in five random high-power fields per specimen, and mean values were calculated.

Statistical Analysis

Data were analyzed using SPSS version 25. Results were expressed as mean ± standard deviation (SD). The significance level was set at $p < 0.05$.

All procedures were conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Tashkent State Medical University.

Results

Histological Structure

Microscopic examination of H&E-stained sections revealed a well-preserved pseudostratified ciliated columnar epithelium with interspersed goblet cells. The epithelial thickness averaged 50 ± 5 µm. Cilia were well-organized and abundant on the apical surface, contributing to effective mucociliary clearance.

Mucin Distribution

PAS staining highlighted abundant neutral mucopolysaccharides in goblet cells and submucosal glands. Alcian Blue staining confirmed the presence of acidic mucins, particularly in glandular secretions.

Immunohistochemical Findings

Strong cytokeratin positivity was noted throughout the epithelial layers, confirming epithelial cell integrity. Mucin 5AC was expressed prominently in goblet cells and seromucous glands, indicating active mucus production.

Morphometric Analysis

The mean density of submucosal glands was 120 ± 15 glands/mm². Vascularization assessed by capillary density occupied approximately 18% ± 3% of the submucosal area.

Discussion

The nasal mucosa's structural and functional integrity is essential for respiratory health. This study presents a detailed morphofunctional analysis of the nasal mucosa in healthy adults, confirming findings from prior research and providing a normative baseline.

The pseudostratified ciliated columnar epithelium observed is critical for mucociliary clearance, effectively removing inhaled particles and pathogens. The epithelial thickness and cilia density are consistent with data reported by Holbrook et al. (2005), who emphasized their role in airway defense.

Mucins secreted by goblet cells and submucosal glands, visualized by PAS and Alcian Blue staining, form a protective mucus layer. The dual presence of neutral and acidic mucins ensures optimal viscosity and pathogen trapping, corroborating Lee et al.'s (2015) observations.

Immunohistochemical expression of cytokeratin and mucin 5AC confirms epithelial integrity and active secretory function. The gland density and vascularization percentages observed reflect a highly active mucosal environment supporting thermoregulation, humidification, and immune defense (Harkema et al., 2006).

Comparison with pathological states reveals significant deviations from this baseline. For example, allergic rhinitis shows epithelial disruption and glandular hyperplasia leading to increased mucus production and impaired clearance (Bousquet et al., 2001). Chronic sinusitis involves glandular hypertrophy and fibrosis, affecting mucosal function (Ponikau et al., 2003).

Limitations include the modest sample size and absence of functional assays such as mucociliary clearance measurements. Recent studies (e.g., Chen et al., 2021; Patel et al., 2022) have emphasized the role of epithelial integrity and glandular activity in maintaining nasal immune defense, which supports our findings. Future studies incorporating advanced molecular techniques and functional assessments will enrich understanding. These observations reinforce the importance of maintaining epithelial and glandular balance for optimal nasal function and provide a basis for early pathological screening.

These findings can be applied in clinical histopathology to distinguish early mucosal alterations in inflammatory nasal diseases.

Conclusion

This study provides detailed morphofunctional parameters of the healthy human nasal mucosa, including epithelial thickness, gland density, and vascularization. The obtained normative data

can serve as a reference for histopathological evaluations in nasal diseases. The results have both theoretical and practical significance for improving diagnostic precision in otorhinolaryngological practice and for further morphological research. Thus, this research establishes a histological reference framework for future comparative and pathological investigations of the nasal mucosa.

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