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"Computational Fluid Dynamics Evaluation of Sinonasal Flow During Respiration and Nasal Irrigation Following Transnasal Endoscopic Surgery"

BACKGROUND: During transnasal endoscopic sinus surgery (TNES), surgeons remove diseased tissue, polyps, and other obstructions to restore normal sinus ventilation and enhance mucociliary function. The extent of the surgery can significantly affect a patient's nasal airflow and mucus clearance. However, excessively removing healthy tissue may disrupt airflow patterns and damage the protective mucosal lining, potentially causing dryness, crusting, and changes in sensitivity. In some cases, patients may develop empty nose syndrome—an issue likely caused by impaired neurosensory feedback and mucosal function—resulting in a persistent sensation of nasal obstruction despite having widely open nasal cavities. Additionally, variations in the TNES technique and the extent of dissection can influence a patient's ability to maintain adequate sinonasal hygiene during postoperative nasal irrigation.

METHODS: Using CAD software, representative models were fitted with an inlet at the pyriform aperture to simulate nasal irrigation flow. In a separate study, we modified a normal sinonasal airway model to simulate flow alterations in the maxillary sinus after isolated surgical changes to the osteomeatal complex and lateral nasal wall. Qualitative flow changes were evaluated by examining flow streamlines and visualizing penetration into the nasal and sinus cavities. Quantitative parameters included airway resistance, airway pressure, and lateral wall shear pressure. Computational fluid dynamics (CFD) were used to simulate changes in sinonasal aerodynamics and postoperative irrigation patterns following TNES. We analyzed 11 three-dimensional sinonasal models constructed from CT scans, representing normal anatomy, standard functional endoscopic sinus surgery (FESS) with ethmoidectomy and maxillary sinusotomy, FESS with extended maxillary sinusotomy (FESS-EMS), and FESS with a modified EMS that preserves the anterior inferior turbinate (FESS-MEMS).

RESULTS: Our findings indicate a significant increase in inspiratory flow into the maxillary sinus cavities, with a corresponding potential for environmental irritant and pathogen deposition that grows proportionally to the extent of TNES. Airway resistance and pressure decrease in relation to the extent of lateral wall resection. The inspiratory velocity profiles are altered, displaying reduced flow around the sinus cavity openings. Sinus wall shear forces remain low in normal and postoperative simulations, suggesting they do not contribute to sinus mucosal changes or mucociliary dysfunction. Intraluminal pressures are highest in the FESS-MEMS cases, followed by FESS-EMS and standard FESS. Irrigant penetration into the maxillary sinus appears similar in FESS-EMS and FESS-MEMS cases and is substantially greater than in normal and standard FESS models.

CONCLUSIONS: Our findings elucidate changes in aerodynamics and irrigation patterns in the postoperative sinonasal cavity. These results give insight into potential postoperative complications and the efficacy of postoperative irrigations specific to the degree of the maxillary sinus surgery performed, allowing surgeons to further tailor endoscopic sinus surgery to patient pathology and symptomatology.