Effects of Anterior Ethmoidectomy with and without Antrotomy and Uncinectomy on Nasal and Maxillary Sinus Airflows: a CFD Study

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Abstract

The effects of anterior ethmoidectomy, alone or combined with antrotomy and uncinectomy, on nasal and sinus airflow patterns were investigated using computational fluid dynamics (CFD) analysis of computed tomography scan-based three-dimensional nasal model reconstructions. The velocity, pressure, and airflow distribution, and airflow pathlines were evaluated. In model I, operated and non-operated airways were compared. In model II, the maxillary sinus was artificially sealed to evaluate the effects of ethmoidectomy alone. For both models, CFD simulations showed that post-op middle meatus airflow patterns were strongly affected, with higher air velocity, lower pressure, and larger-sized vortices, and the overall middle meatus airflow was redistributed laterally into the sinus cavities and away from the septum and superior meatus. Airflow rates at other intranasal sites were unaffected. The increase in post-op maxillary ventilation is larger than those in normal sinuses and sinuses with accessory ostia. Uncinectomy and antrotomy affect only local airflow within the antrum. In conclusion, middle meatus endoscopic sinus surgery (ESS) increases air exchange between sinuses and the nasal airway, increases middle meatus airflow at the expense of superior meatal flow, and produces vortices in the antrum and ethmoid. However, both ethmoidectomy and antrotomy/uncinectomy affect only local airflow, with negligible influence far from the operation site. These computed changes help us understand where dryness and mucus crusting is likely to occur following middle meatus ESS.

Keywords: Endoscopic sinus surgery (ESS), Ethmoidectomy, Uncinectomy, Antrotomy, Maxillary sinus, Computational fluid dynamics (CFD)

1. Introduction

Endoscopic sinus surgery (ESS), proposed by Messerklinger [1], has become the primary technique for treating sinonasal diseases such as mucocele, sinusitis, and nasal polyps. However, after decades of surgical operations, there are still lingering debates regarding the physiological effects of ESS. For example, the question of whether to preserve the middle turbinate is still controversial [2-4], and the question of whether it is better to preserve or enlarge the maxillary sinus ostium remains unanswered [5]. In particular, although both antrotomy with uncinectomy and maxillary balloon catheter dilatation attempt to increase sinus ventilation by enlarging maxillary ostia, neither the effects of these two operations on sinonasal functions, nor the differences between them, are fully understood [6]. Airflow patterns in nasal cavities have been well reported [7-10], but sinus physiology and the effects of ESS interventions are still quite limited due to the poorly accessible location of the sinuses and the lack of noninvasive techniques for studying sinus physiology in living persons. For example, during ESS, uncinectomy is usually performed when the ostiomeatal complex is affected by disease, and anterior ethmoidectomy is frequently added to optimally decompress the ostiomeatal complex [11]. However, the effects of these combined operations on sinonasal functions, such as sinus ventilation, are not known. Since air flow, air filtration,