The objective of this study was to analyze the impact of nasal septal perforation (NSP) size on nasal physiology using computational fluid dynamics (CFD) simulations. A radiologically normal CT scan was imported into Mimics™ 12.0 imaging software (Materialise, Plymouth, MI) and a 3-dimensional reconstruction of the nasal airway was made. Ovoid anterior NSPs of 1, 2, and 3 cm length were virtually created on the anterior-to-posterior axis. Planar surfaces at the nostrils and trachea were constructed for specifying inlet and outlet conditions on simulated airflow. Computational meshes of the model airways and the original trachea were constructed for specifying inlet and outlet conditions on simulated airflow. CFD meshes were created using the FLOW-3D CFD™ software (Materialise, Plymouth, MI) and a grid independence study was carried out to select the optimal grid size for the three perforation sizes. A radiologically normal CT scan was used for visualization.

Methods

A radiologically normal CT scan was imported into Mimics™ 12.0 imaging software (Materialise, Plymouth, MI) and a 3-dimensional reconstruction of the nasal airway was made. Ovoid anterior NSPs of 1, 2, and 3 cm length were virtually created on the anterior-to-posterior axis. Planar surfaces at the nostrils and trachea were constructed for specifying inlet and outlet conditions on simulated airflow. Computational meshes of the airspaces, consisting of approximately 4 million unstructured, graded tetrahedral elements, were created. Steady-state, inspiratory airflow was simulated using the CFD software package Fluent™ 14.0 (ANSYS, Inc., Canonsburg, PA) under pressure-driven, laminar conditions. Heat and water vapor transport were simulated using the airflow simulation as input. Fluent™ was used for analysis of simulations and the post-processing software package Fieldview™ 14.0 (Intelligent Light, Lyndhurst, PA) was used for visualization.

Results

Increased perforation size correlated with increased airflow crossover through the perforation (4.2-12.2%), lower resistance (0.039-0.034 Pa/(ml/s)), and decreased humidification (97.7-96.4%). The posterior wall of each perforation exhibited the greatest water and heat flux. Highest total heat and water flux among the NSPs was noted in the 3 cm perforation. The water and heat flux averaged over all four perforation walls was slightly higher in the 2 cm perforation compared to the 1 and 3 cm perforations.

Conclusions

Our study is the first to suggest a unique effect of NSP on total water and heat flux in the vicinity of the perforation which is not directly proportional to perforation size. Additionally, we depict velocity changes around perforations which have not previously been described in the literature. Consistently high heat and water vapor flux in the posterior regions of all three perforations may explain the highest incidence of crusting noted on the posterior edges of NSPs.

Future Directions

CFD analysis of true NSPs using CT scans of individuals with perforations with comparison to demonstrated virtual NSP data

CFD analysis of physiologic changes after perforation repair by comparing models based on pre-operative and post-operative imaging

References


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