Quantifying Nasal Airway Changes Associated with Decongestion

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Abstract

Introduction:

This study is aimed at investigating the effect of decongestion on nasal airway dimensions in normal subjects. High resolution 3T MRI scanning was employed in order to asses the effect of decongestion on nasal airway dimensions in normal subjects. Erectile Tissue Volume (ETV) changes in the nasal cavity are known to be profound but it is impossible to quantify the complete airway caliber changes endoscopically. It was found that high resolution 3T MRI scans serve as a fast, non-invasive means to obtain detailed 3D geometrical measures. Acoustic rhinometry (AR) was used for comparison with the MRI data. AR has previously been shown to correlate well with MRI data, however, it only provides reliable information on the overall changes in the anterior portion of the nose.

The findings of this study are being used to propose metrics to quantify localised effects of decongestion which will help enhance our understanding of changes in nasal morphology. MRI was found to be an excellent modality to study mucosal changes within the nose as it images the air mucosa interface directly.

Methods:

Seven healthy volunteers (ranging in age from 21-38 years, mean 28) were selected for inclusion in this study. The subjects were screened to ensure they had no nasal complaints and no obvious rhinoscopic abnormalities. AR and nasal peak inspiratory flow measurements (SNOT-22, VAS, PNIF and AR) were performed on all subjects by a single trained operator in accordance with published protocols.

Each subject underwent two MRI scans in a GE Discovery MR750 series scanner producing a series of 120 1.2mm thick slides, taking 3 minutes each. 3-D volume imaging

was carried out using a new isotropic three-dimensional fast spin Echo sequence called 3-D cube. The 3-D cube images were obtained in the coronal imaging plane with scan parameters: TR of 2500, TE 122, 1.2 mm thick slices and bandwidth of plus or minus 62.5kHz, matrix 288 x 288. All images were carried out at 3 Tesla in this study. All subjects remained immobilised following the scan and were decongested in a standardised way with Xylometazoline spray. A second MRI scan was taken after 10 minutes allowing time for the decongestant to take effect and acoustic rhinometry and PNIF measures were repeated. Once these image cubes were obtained, images were resampled, reducing the size of the stepped finishes in the original image of 512 x 512 and producing a fine grained image of double the resolution 1024 x 1024. Resampling is a common operation in all signal and image processing applications, with the available methods varying in their computational complexity, speed, and quality. For this work a sinc-based algorithm included as part of the IRTK package was employed. The resampled images were then registered using non-rigid registration algorithms. Non-rigid registration is used on both the pre- and post-decongestion MRI scans as it aligns rigid structures such as bone and septum from both scans, enabling change in the soft tissues inside of the nasal cavity of each subject to be delineated.

After the process of resampling and non-rigid registration the nasal geometries were segmented using ITK Snap. The segmentation process uses snake-growing algorithms to fill regions of interest from seed point. The resulting geometries were then analysed using MATLAB providing numerical data allowing us to map changes within the nasal cavity including the airway, the inferior turbinate, middle turbinate and the septum. This method has not been used before to analyse such data.

Results:

Decongestion had the greatest effect in three sites: the inferior turbinate, middle turbinate and the septum. The greatest change in Erectile Tissue Volume (ETV) was observed in the inferior turbinate. Changes were also seen in ETV of the middle turbinate and septal mucosa to a significantly lesser extent.

To highlight mucosal changes the volume of the airways was calculated from 2cm to 5cm along a path approximating the locus of airway cross-section centroids, corresponding to that recorded in by AR. The AR measurements indicated a mean increase of 42% and 27% of the right and left nasal passage cross-sectional area , respectively. This equated to a 57% and 33% decrease in the surface area to volume ratio on the right and left respectively with decongestion. We found a good correlation between acoustic rhinometry and MRI measurement for minimal cross sectional area and volume in the first 5cm of the path defined as above.

Discussion:

This preliminary study was intended to test the success of the imaging modality chosen and the associated means to derive nasal mucosal volumetric changes. The sequence used proved to be efficient in mapping changes within the nasal mucosa using a fast spin Echo to provide contrast and does not rely on the much lower soft tissue contrast produced by gradient Echo sequences which can also carry out isotropic 3-D volumes. This sequence allows data to be obtained in a single scan plane but the data can then be reconstructed into multiple other planes because of the isotropic nature of the Voxel acquisition. Each MRI scan took approximately 3 minutes, whilst each total exam time lasted 20 minutes. The geometries were then resampled, registered and segmented taking approximately 20 hours per subject. It is feasible to use this method on a larger cohort .

The study thus far shows that high resolution 3T-MRI is an excellent modality to quantify ETV changes and can provide detailed 3D-geometric data. Our results demonstrate the significant effect of decongestion on ETV, with the greatest result seen in the inferior turbinate. The methods employed are effective in measuring volume change within the soft tissues of the nasal airway, however it is the effect of decongestion on the airway which is most consequence for the physiology of transport and exchange processes in the airways. Future work will examine the robustness of the methods and the consequences for airway caliber and flow of inter- and intra- subject variability.