Imaging Operated and Unoperated Human Paranasal Sinuses Using Hyperpolarized Gas MRI

M. Ishii[1], J. Yu[2], M. L. Kashima[1], M. C. Fischer[2], K. Emami[2], S. Kadlecek[2], R. R. Rizi[2]

[1]Department of Otolaryngology, Johns Hopkins University, Baltimore, MD, United States, [2]Department of Radiology, University of Pennsylvania, Philadelphia, PA, United States

Introduction

HP ^{3}He MRI has been used to study gas exchange in porcine sinuses(1). Gas exchange in healthy sinuses was found to be a slow process driven by diffusion. It is surmised that this is by design to prevent the efficient introduction of disease-causing bacteria and allergens into the sinuses. We therefore suggest that patients who receive endoscopic surgery to improve sinus drainage, but maintain the diffusion limited exchange of gases between the nasal and paranasal sinuses may have the greatest chance for surgical success. The proof of this hypothesis is paramount to developing a predictive, functional test of sinus physiology. In the following study we show that dynamic HP ^{3}He MRI can be used measure the temporal behavior of human sinus ventilation after endoscopic sinus surgery. These results suggest that dynamic HP ^{3}He MRI may play a role in the clinic management of chronic sinusitis.

Method

Experiments were conducted on human cadaver heads under an IRB-approved protocol. Fresh human cadaver heads were acquired from the morgue and prepared for surgery. Unilateral endoscopic sinus surgery was performed using the Messerklinger approach. The heads where then placed in a birdcage coil and positioned within a 1.5-T whole-body imager (Sonata, Siemens). The paranasal sinuses were localized in space using a series of proton images. At the start of a helium imaging experiment nitrogen gas was circulated throughout the nasal cavity at a rate of 300 ml per minute for 15 minutes to deplete the paranasal sinuses of oxygen. After the nitrogen flush, 60 cc to 150 cc of hyperpolarized ^{3}He/N_2 gas with net activity of 0.4 to 2.0 mmole was injected into the nasal cavity at a constant rate of 2 cc to 10 cc per second. The hyperpolarized helium was generated via the spin exchange optical pumping method using a commercial polarizer (Amersham Health, Durham, NC). MRI imaging began 10 seconds prior to the injection of ^{3}He using a sequentially encoded 2D fast gradient-echo pulse sequence with the following imaging parameters: nominal constant flip angle of 3° to 5°, TR/TE 6.4 msec/2.92 msec, 128 x 128 matrix size, slice thickness 3 mm to 11 mm, and FOV 16 cm x 16 cm. Images were obtained at 1 to 10 second time intervals. A nitrogen flush was selectively used to capture wash out kinetics and to determine the effects of relaxation due to imaging.

Results and Discussion

Figure 1 depicts sample ^{3}He images and the roughly corresponding proton and computed tomographic images. An anterior ethmoidectomy and maxillary antrostomy were performed on the head's right side between images B and C and images D and E. Note that there is high signal intensity in the operated sinuses, since the ostial sizes are larger and allow for greater diffusion of HP ^{3}He gas into the sinus. Figure 2 shows signal kinetics for the supply line, and right and left frontal and maxillary sinuses. Note that the right frontal sinus has increased aeration compared to the left denovo state, and that gas exchange is still in the diffusion limit in both frontal sinuses suggesting the potential for a good surgical response.

Conclusion

Dynamic HP ^{3}He MRI can be used to study gas exchange kinetics after endoscopic sinus surgery. Sinuses that have improved aeration but remain in the diffusion limit may have increased likelihood of good surgical outcome based on current understandings of intranasal sinus gas exchange. The demonstrated ability to measure gas transport suggests the HP ^{3}He MRI may be useful in predicting surgical response.

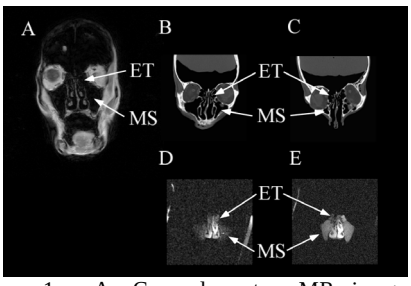

Figure 1. A. Coronal proton MR image of paranasal sinuses corresponding to the ^{3}He MR image plane. Note that the air-filled spaces contiguous with the nose are devoid of signal. Figures B and C represent coronal fine cut computed tomographic images through the osteomeatal complex. Image C was taken after an anterior ethmoidectomy and maxillary antrostomy were performed on the left side. Note that the uncinate process is no longer visible in figure C, but is present in figure B. The anterior-most section of the maxillary antrostomy is visualized in figure C as well. Figures D and E are HP ^{3}He MR images, taken prior and post endoscopic surgery respectively. Note that there is greater filling of the maxillary sinuses and ethmoid labyrinth on the left due to the surgery. 50 cc of ^{3}He gas with net activity of 0.4 mmoles were injected at a rate of 10 cc/sec. Note that the signal intensity on subject's unoperated side is higher in figure E, since more gas was available to diffuse into the sinuses. ET: ethmoid, MS: maxillary sinus.

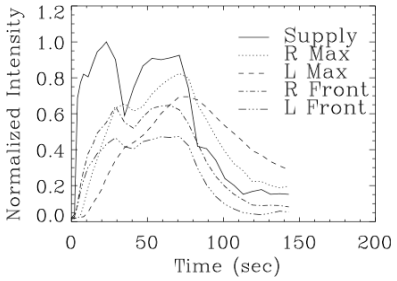

Figure 2. Time-dependent signal intensities for the supply line, right and left maxillary sinuses, and right and left frontal sinuses. The nitrogen flush was on from 30-45 and 70-82 seconds. The tail ends of curves show relaxation effects due to imaging. Note the slow nature of gas exchange processes, suggesting gas transport in the diffusion limit. Sinuses that were operated on show higher signal intensities and faster wash in kinetics, but still remain in the diffusion limit.

Acknowledgments

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References:

[1] Ishii, M. et.al., Acad. Radiol. 2003 10(4) 373-8