MRI of Hyperpolarized He-3 Gas in Porcine Paranasal Sinuses

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Synopsis: Determining paranasal sinus ostial patency plays an important role in managing sinus disease. We hypothesize that hyperpolarized 3He MRI can be used to determine paranasal sinus ostial patency. We tested this hypothesis on a porcine animal model. Our results show that He3 MRI can be used to infer ostial patency. This suggests that 3He MRI may lead to a novel diagnostic tool for treating sinus disease.

Introduction: Sinusitis is a significant health problem in the United States affecting 33 million Americans. Despite its impact on health care, no practical functional tests of sinus physiology exist for guiding medical therapy. Recently, dynamic 3He imaging techniques have been introduced to study the ventilation of lungs. We propose that these techniques can be modified to study the aeration of the paranasal sinuses. This may lead to a novel test for measuring sinus physiology. In order to test this hypothesis we have developed an animal model where we surgically alter, in a precise fashion, the connection between the nasal cavity and paranasal sinuses. This model allows us to evaluate the effectiveness of dynamic hyperpolarized helium techniques in measuring sinus aeration under controlled conditions.

Methods: Experiments were conducted under an IACAC approved protocol. Five, 50 kg, Yorkshire pigs were sacrificed, exsanguinated, and decapitated. Frontal sinusotomies, ethmoid labyrinthectomies, and maxillary antrostomies were then performed at random. The sizes of the antrostomies were measured endoscopically. The porcine heads where then placed in a double tuned birdcage coil, tuned to the 3He and proton frequencies, and positioned within a 1.5-T whole-body imager (Signa, Ge Medical Systems, Milwaukee, WI). The paranasal sinuses were localized in space using a series of proton images. At the start of an imaging experiment nitrogen gas was circulated through the nasal cavity at a rate of 600 ml per minute for 20 minutes to deplete the paranasal sinuses of oxygen. After the nitrogen flush, 100 cc of hyperpolarized 3He/N2 gas, net activity of 2.5 mmole, was injected into the nasal cavity at a constant rate of 10 cc per second. The hyperpolarized helium gas was generated via the spin-exchange optical pumping method using a commercial polarizer (Amersham Health, Durham, NC). MRI imaging began 40 seconds prior to the injection of the 3He using a sequentially encoded 2D fast gradient-echo pulse sequence with the following imaging parameters: a nominal constant flip angle of 90, TR/TE 9 msec/2.2 msec; 256X128 matrix size; slice thickness 5mm; FOV 16 cm x 16 cm; 1 echo per excitation; and no interslice spacing. After 110 seconds the nitrogen infusion was restarted at 600 cc per minute to capture washout kinetics.

Results and Discussion: Figure 1 depicts sample 3He images and the corresponding proton images. Aggressive sinus surgery was performed on the right, while a limited ethmoid labyrinthectomy was performed on the left. Note how sinuses with largest ostia display highest signal intensity. Figure 2 shows normalized signal intensities as function of time for the supply line and the left and right maxillary sinuses. These figures demonstrate that gas exchange is a function of ostial size and gas exchange occurs most rapidly in ostia with larger sizes.

Conclusion: These results suggest that 3He MRI may be useful in identifying the anatomic configuration of the paranasal sinuses as well as assessing sinus aeration.

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