Feasibility Of Fast Dynamic MRI As A Tool To Investigate Swallowing

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Introduction: Swallowing involves an intricate coordination of various muscular organs such as the soft palate, epiglottis, glottis, and esophagus. Dysphagia refers to a condition where swallowing is impaired. It is prevalent in several stroke, dementia, head injury, oral cancer, and gastro-esophageal reflux disease patients. Current diagnostic tools to assess swallowing include dynamic captures of a bolus using X-ray video fluoroscopy, or flexible endoscopy. While these tools provide sufficient frame rates to capture swallows, they are limited by several factors such as high ionization (with X-rays), limited spatial view of swallowing events due to lack of depth resolution with X-rays, and restricted view by endoscopy. In this study, we demonstrate a novel flexible, and fast dynamic magnetic resonance imaging (MRI) scheme that allows capturing swallowing of a bolus in three simultaneously acquired planes at a nominal time resolution of 18ms/frame.

Materials and Methods: In contrast to X-rays, and endoscopy, MRI is non-invasive, provides excellent soft tissue contrast, and is flexible to image in arbitrary slice orientations. However, conventional MRI methods based on Nyquist sampling have been challenged with slow imaging speeds. In this work, we perform accelerated dynamic MRI at a rate of ~21 fold utilizing a scheme that combines variable density spirals, parallel imaging via a head and neck coil, and a sparsity based temporal finite difference regularization prior. Imaging was performed with a gradient echo sequence with parameters TR=6.0 ms; flip angle = 15^0; 3 concurrent sagittal slices with thickness of 10 mm; spatial resolution of 2.4x 2.4 mm^2 ; time resolution of 18ms/frame. We designed a bolus comprising of either water, blueberry juice (BJ), or pineapple juice (PJ) mixed with a unflavored thickener in a 3 tsp: 4 oz ratio. PJ and BJ contains high levels of manganese, which is paramagnetic in nature and offers a natural high contrast in MRI. We also designed a syringe apparatus to approximately deliver 15 mL of the bolus to the subject in a supine position. Imaging were performed on two healthy subjects swallowing the three bolus contrasts in separate scans. We qualitatively evaluated the dynamic MRI movies to identify key swallowing events. Image contrast between the soft tissue and the bolus with the three boluses was quantified in terms of the Contrast-to-Noise Ratio(CNR). Finally, to evaluate how the bolus would breakup between slices, the volume of bolus within each slice was quantified.

Results and Discussion: Six key phases of swallowing were effectively identified in all 3 boluses for both subjects. The bolus provides an inherent bright contrast and the high time resolution of 18 ms ensured capture of the six key phases with good temporal fidelity. In both the subjects, we observed an average high CNR with pineapple juice, and blueberry juice as boluses compared to water (CNR_{PJ} = 44.08; CNR_{BJ} = 38.8; CNR_{water} = 18.8). The gain in CNR with PJ over BJ was expected due to higher level of manganese in PJ. Adding the thickener did not seem to dilute the manganese present. We observed the mid-sagittal slice only captured 20-40% of the total bolus delivered. In contrast, the 3 slices captured volume of the bolus in the range of 13-16 ml indicating that the total delivered bolus was effectively captured.

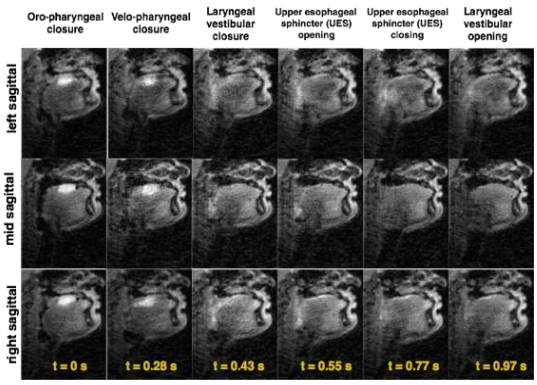

Figure 1. Fast dynamic MRI of a subject swallowing pineapple juice. The bolus is shown as bright intensity. The three sagittal slices effectively capture the six key swallowing dynamic phases.

Conclusions: We successfully demonstrated feasibility of fast dynamic MRI to capture dynamics of swallowing in two normal subjects. The temporal resolution of 18 ms/frame ensured the identification of the key swallowing phases and multi slice imaging allowed for imaging the entire delivered bolus. A simple syringe apparatus was developed to deliver a predetermined amount of bolus. Pineapple juice was the most effective bolus in terms of CNR. Swallowing in supine position was tolerated well by the subjects. Future studies include more trial on healthy subjects, and trials on studies involving dysphagia patients and comparison against X-ray video fluoroscopy, and endoscopy.