Endoluminal In-Vivo High-Resolution MR Imaging of the Esophageal Wall with Histological Correlation

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Introduction: Esophageal cancer is the eighth most common cancer in the world. In the United States, the overall incidence is about 5 in 100,000. 5-year survival rate continues to be less than 10% despite advances in multimodality therapies [1]. Determining the depth of tumor invasion through the esophageal wall is central to assigning an accurate T-stage and thereby selecting an appropriate treatment regimen [2]. In this work, we sought to test the hypothesis that endoluminal high-resolution MR imaging can provide detailed depiction of the various layers of the esophageal wall and that MR findings will correlate with histology as would be required for a future role for MR in cancer staging.

Methods: Experiments were performed on 8 farm pigs under a protocol approved by the Institutional Animal Care and Use Committee. On a 1.5T open-configuration interventional MR system (Magnetom Espree, Siemens, Germany), a 12F actively detuned MR imaging catheter with an integrated single channel opposed solenoid coil (MR Eye®, Interventional Imaging, Inc., Cleveland, OH, USA) was introduced into the esophagus. Imaging sequences and parameters are listed in the table below. The animals were sacrificed and the corresponding esophageal segments were harvested for histological correlation. Images from various sequences were blindly evaluated by a board-certified radiologist on a 5-point scoring system to rate the performance of each sequence in each esophageal segment for 1) overall image quality and for the ability to visualize the 2) mucosa / muscularis mucosa; 3) submucosa; 4) muscularis propria; and 5) adventitia.

Sequence	Res (mm)	TE/TR (ms)	AVG	Tacq (min)	# SLC	BW (Hx/Px)	Dim	FA
	FOV (mm)	Matrix	THK (mm)	Turbo Fact				
T1W SE	0.16x0.16x3	16/500	6	9:38	9	90	2D	
	30x40	192x256	3					
T2W TSE	0.16x0.16x4	45/3500	6	9:52	9	90	2D	
	30x40	192x256	4	7				
PD TSE	0.17x0.16x4	22/3500	6	8:49	9	90	2D	
	30x40	175x256	4	7				
T1W VIBE	0.17x0.17x4	8.2/16.4	10	7:00	8	130	3D	10
	54x76	320x448	4					
HASTE	0.21x0.21x4	83/1130	32	5:25	9	160	2D	
	30x40	144x192	4	144				
TrueFISP	0.35x0.35x4	4.4/8.9	32	6:09	9	266	2D	70
	50x67	144x192	4					

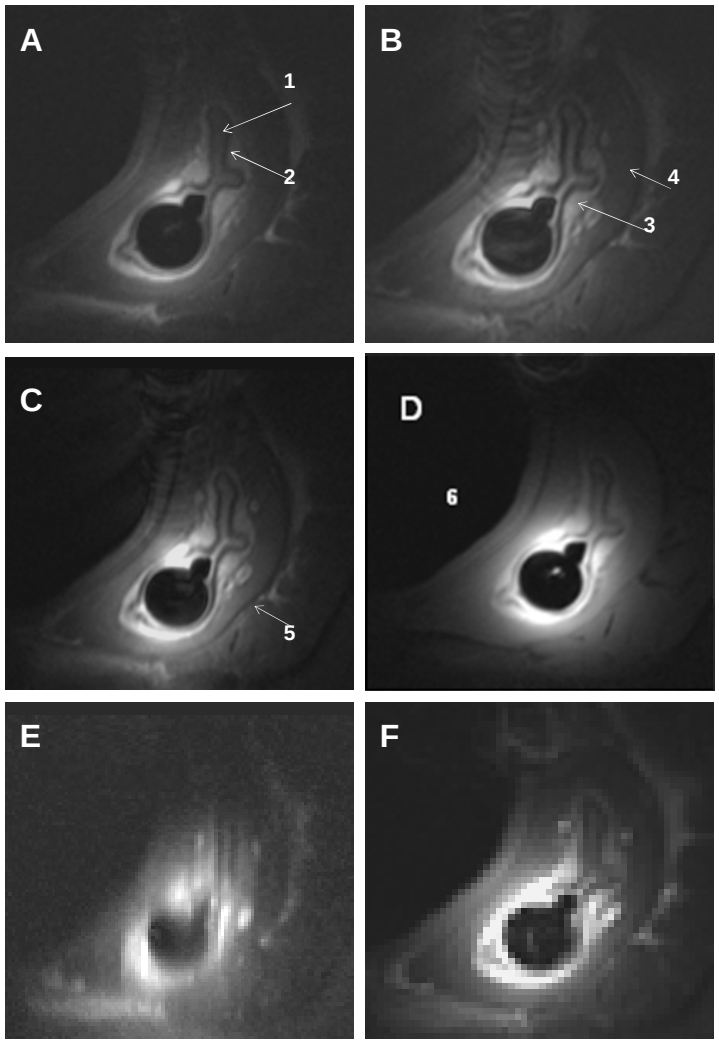

Fig1: In-vivo endoluminal MRI in the cervical esophagus demonstrating the various wall layers. (a)T1W SE; (b)T2W TSE; (c)PD TSE; (d)T1W VIBE; (e)HASTE; (f)True-FISP. (g)Cross sectional histology image of harvested esophagus showing high correlation to endoluminal MRI (the open lumen on histology is due to the rigid fixed specimen as opposed to the collapsed lumen on the in-vivo MR images). (1) superficial mucosa; (2) muscularis mucosa; (3) submucosa; (4) muscularis propria; (5) adventitia; (6) trachea.

Results: Endoluminal imaging was performed in 22 esophageal segments (12 *in-vivo*, and 10 *in-situ* postmortem). These included 12 cervical, 6 retrocardiac, and 4 distal esophageal segments. Overall ratings were highest for the cervical segment.

In-vivo imaging in the retrocardiac and distal esophagus was compromised by motion artifacts, although pulse-gated scans provided improved motion insensitivity. Combining the results from all cervical, retrocardiac and distal segments, the overall image quality was rated 4 or 5 (very good or excellent) in 42% of segments imaged with T1W, 32% on T2W, 35% on PD, 6% on VIBE, 0% on HASTE, and 20% on TrueFISP. Visualization of the mucosa was best on T2W (rated 4 or 5 in 50%). The submucosa was best visualized on true FISP (rated 4 or 5 in 40%) but was closely followed by PD, T1W, and T2W (at 36% for each). The musculosa was best visualized on T1W (rated 4 or 5 in 53%), and the adventitia on T1W (rated 4 or 5 in 53%). The individual wall layers as seen on T1W, T2W, and PD images demonstrated the highest correlation with histological layers of harvested specimens (Fig. 1).

Conclusions: This investigation demonstrates the feasibility of acquiring *in-vivo* high-resolution MR images of the esophageal wall with commercially available catheter-mounted receiver coils placed in the esophageal lumen in a manner analogous to endoscopic ultrasound. Distinct visualization of the individual esophageal wall layers is shown to highly correlate with histology particularly on T1W, T2W, and PD images. The rigorous tissue details shown here by these technologies render endoluminal MRI a viable candidate for a future primary role in local staging of esophageal carcinoma.

References: **[1]** Pickens A & Orringer MB. Ann Thorac Surg. 76:S1367-S1369 (2003) **[2]** Diederich S. Cancer Imaging.1;7 Spec No A:S63-6 (2007)