In vivo intravascular MRI: evaluation of vessel wall conspicuity obtained in multiple contrast imaging protocols

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Introduction: MR based intravascular imaging for identification and characterization of vascular diseases such as atherosclerosis, may play an import role towards reducing morbidity and mortality in the future. It is recognized that catheter-based intravascular coils are required to attain adequate signal to noise ratio for imaging of internal vessels and achieving the goals of disease characterization. Even with advances in antenna design, many *in vivo* endovascular MRI studies in the literature still utilize classic imaging sequences resulting in poor image quality from respiratory, cardiac, vessel and device motion as well as from blood flow artifacts during the long measurement times normally necessary to achieve the required resolution and SNR. This is unfortunate because the quality of fast imaging techniques, such as EPI, TrueFISP and HASTE has been greatly improved in the last few years. We have adapted these sequences for intravascular imaging applications to demonstrate ability to reduce artifacts while clearly depicting different aspects of the vasculature through a variety of contrast mechanisms [1]. This study utilizes expert observer evaluations and statistical analyses to determine the capability of these sequences to provide clinically relevant identification of vessel wall structures.

Material and Methods: High resolution MR imaging of the abdominal aorta and iliac artery was performed in 13 healthy domestic farm pigs using a clinical 1.5T Siemens Sonata scanner. All procedures were performed in accordance with approved institutional animal care and use committee protocols. Custom catheter-based, opposed solenoid RF coils were used for intravascular imaging [2,3]. For each trial, 10 specific imaging protocols previously identified as suitable for intravascular imaging were employed at the same location in the abdominal aorta. Imaging protocols are summarized in Table 1. Six experienced clinical raters evaluated each acquired image with respect to the following questions: 1. Is the wall visible (Yes/No), 2. Wall to lumen contrast (scale of 1-5; 5=best), 3. Surrounding tissue contrast (scale of 1-5; 5=best), 4. Number of visible vessel wall layers, 5. Clinical usefulness (scale of 1-5; 5=best), and 6. Overall image quality (scale of 1-5; 5=best). Responses to questions 2-4 were coded as zero by default when the rater could not see the vessel wall. Average scores across raters were calculated for each question for each image. Differences between sequence types across the 13 trials were tested using a repeated measures analysis of variance (ANOVA), with sequence type as the repeated measures factor. Planned contrasts were performed that compared the mean of the sequence with the highest score to the means from the 9 remaining sequences. The null hypothesis rejection criteria was $p<0.05$, 2 tailed.

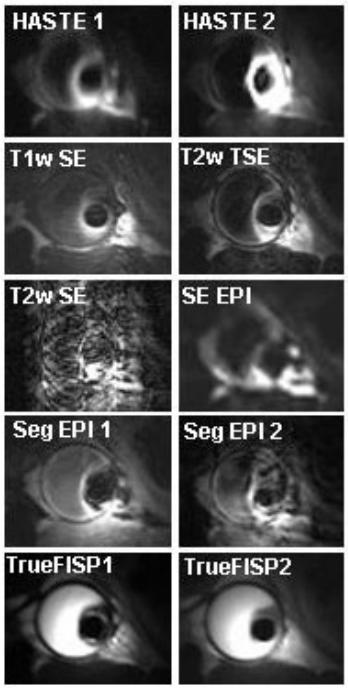

Figure 1: *Comparison of images obtained from the abdominal aorta using the protocols summarized in Table 1.*

Results and Conclusions: Figure 1 shows a representative example of all imaging sequences obtained from a single pig. Table 2 presents a summary of the raters evaluations sorted in order of average rank across all six questions. Sequences that were statistically significantly poorer than the highest rank within category are indicated by (*). Salient results are as follows: TrueFISP (BW=370Hz/Pixel) was the highest ranked on four of the six measures (i.e., vessel wall visibility, lumen-wall contrast, clinical usefulness and image quality). HASTE 2 showed the best contrast between vessel wall and surrounding tissue. TrueFISP (BW=370Hz/Pizel) was ranked second on this measure and was not statistically significantly different from HASTE2. When considering the number of visible layers in the vessel wall, T2w TSE was ranked best. Raters typically reported seeing only a single layer in TrueFISP images which was statistically significantly fewer than seen in the T2w TSE acquisitions. The two TrueFISP images were not statistically different from each other on any measure. Basic vessel wall visibility was high in all but four of the protocols and even so, TrueFISP images showed the best vessel wall visibility, the improvement over the other 5 protocols was not statically significant. The ability to identify multiple layers is associated with both dark blood and T2 contrast as found in the HASTE and T2wTSE methods, and shown in Figure 1 (note the TrueFISP vessel signal is high while TSE and HASTE is quite low). We conclude that TrueFISP imaging sequences provide the best overall image quality and acquisition speed but need to be modified to provide T2w black blood contrast in order for reliable identification of vessel wall structures.

Table 1. Summary of sequence and sequence parameters used in intravascular imaging experiments.

Sequence type	TE [ms]	TR [ms]	TA/slice [min]	BW [Hz/Pizel]	Matrix	FOV [mm]	SL [mm]	NA	
Haste 1	114	2000	2:16	130	192*256	30*40	3	8	FS, SAT
Haste 2	69	2000	1:38	130	92*128	30*40	3	8	FS, SAT
T1w SE	12	521	9:59	90	192*256	30*40	3	6	SAT
T2w TSE	97	4400	8:18	90	187*256	30*40	3	6	ETL 11, FS, SAT
T2w SE	76	2400	1:29	10	192*256	30*40	3	2	FS, SAT
SE-EPI	184	1500	1:34	750	44:87	64*128	3	10	FS, SAT
seg EPI 1	38	2400	2:14	130	94*128	30*40	3	4	ETL 7, FS, SAT
seg EPI 2	27	2400	2:14	345	94*128	30*40	3	4	ELT 7, FS, SAT
TrueFISP 1	6	12	0:09	130	96*128	30*40	3	8	
TrueFISP 2	3.8	7.5	0:06	370	96*128	30*40	3	8	

Table 2. Summary means. Qualitative ratings for each rating element with corresponding ranks within rating item. Highest rank is in bold font with backshading. Statistically significant differences from highest rank within columns are indicated by (*)

Sequence type	Vessel Wall Visible?	Contrast Lumen vs. Wall	Contrast Tissue vs. Wall	Number of Layers	Clincal Usefulness	Image Quality
TrueFISP1 (BW 370Hz/Pixel)	**0.97 (1)**	**3.50 (1)**	2.69 (2)	1.19 (7) *	**2.95 (1)**	**3.23 (1)**
TrueFISP2 (BW 130Hz/Pixel)	0.97 (2)	3.41 (2)	2.60 (4)	1.18 (8) *	2.95 (2)	3.03 (2)
T2w TSE	0.95 (3)	2.58 (3) *	2.65 (3)	**1.86 (1)**	2.54 (4)	2.33 (6) *
HASTE 2 (TE 69ms)	0.87 (6)	2.42 (5) *	**2.71 (1)**	1.63 (4) *	2.54 (3) *	2.68 (3) *
seg EPI 1 (BW 376 Hz/Pixel)	0.94 (4)	2.46 (4) *	2.53 (5)	1.81 (2)	2.46 (6) *	2.35 (5) *
T1w TSE	0.90 (5)	2.14 (6) *	2.50 (6)	1.86 (3)	2.49 (5) *	2.54 (4) *
seg EPI 2 (BW 130Hz/Pixel)	0.83 (7) *	1.97 (7) *	1.94 (8) *	1.60 (5)	2.06 (7) *	1.80 (8) *
HASTE 1 (TE 114ms)	0.81 (8) *	1.74 (8) *	1.95 (7) *	1.15 (9) *	1.82 (8) *	1.95 (7) *
T2w SE	0.74 (9) *	1.41 (9) *	1.69 (9) *	1.24 (6) *	1.55 (9) *	1.37 (9) *
SE-EPI	0.53 (10) *	1.15 (10) *	0.95 (10) *	0.79 10) *	1.37 (10) *	1.32 (10) *

References: [1] C. M. Hillenbrand et al. Proc ISMRM 2003. p1650. [2] G. C. Hurst et al., MRM 24: 343-57 (1992). [3] A. J. Martin al, JMRI 2, 421-9 (1992).