4D Flow MRI for non-invasive assessment of Mesenteric Ischemia

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Target Audience: Those interested in abdominal MR Angiography and/or MR flow imaging.

Purpose: Investigate the use of 4D flow MRI to improve diagnosis of mesenteric ischemia by providing simultaneous anatomical depiction and functional assessment of the hemodynamics before and after a meal challenge.

Background: A variety of diseases can cause chronic mesenteric ischemia (CMI), which describes a pathology of abdominal pain that appears about 15-60 mins after a meal. The most common cause is atherosclerosis where a narrowing of the celiac artery limits blood flow to the intestines. However, other causes exist such as median arcuate ligament syndrome, superior mesenteric syndrom, clots, venous thrombus, among others. Evaluation of mesenteric ischemia is complicated by the rich network of mesenteric collaterals available from the superior (SMA) and inferior (IMA) mesenteric artery, which in some patients, may compensate for decreases in flow through the celiac axis [1]. In this pilot study, we investigate the use of 4D flow MRI to improve diagnosis by providing simultaneous anatomical depiction and functional assessment of the hemodynamics in the entire upper abdomen. The 4D flow MRI exam is repeated before and after a meal challenge as introduced by Li et al. with 2D PC MRI [2].

Subject	Ao (%)	SMA (%)	SMV (%)
1	8.8	32.0	-45.2
2	-1.7	166.6	66.4
3	-8.5	7.2	122.2
4	12.3	20.6	9.1
5	6.8	29.6	28.8
6	17.3	282.7	87.1
7	-23.8	57.9	225.8
8	-2.3	17.3	20.3
Mean	**1.1**	**76.7**	**64.3**
STD	**13.1**	**97.5**	**83.0**

Table 1: Flow increase in % after the meal challenge in all 8 subjects in 3 vessels..

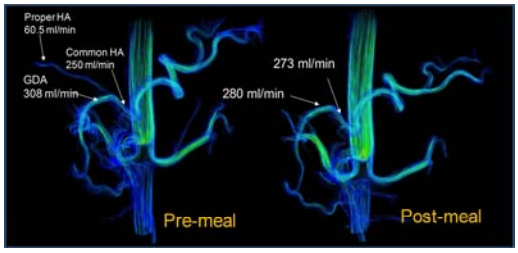

Fig.1: Patient with celiac trunk stenosis. The flow through the common HA and GDA does not increase after the meal challenge.

Methods: In this IRB-approved and HIPAA-compliant study, eight patients were imaged on a clinical 3T scanner (Discovery MR 750, GE Healthcare, Waukesha, WI). The patients were referred from Vascular Surgery because of suspicion for mesenteric ischemia (n=7) and an aortic dissection (n=1) suspected to cause insufficient blood supply to the mesenteric artery. 4D PC MR data were acquired before and after a meal using a radially undersampled acquisition, 5-point PC VIPR, [3,4] with large coverage: imaging volume: 32x32x20cm^3; 1.25mm acq. isotropic spatial resolution; TR/TE=6.4/2.2m; intravsacular contrast agent (0.03mmol/kg of gadofosveset trisodium (Lantheus, N. Billerica, MA)), free breathing acquisition with ~11 min scan time. All imaging was performed after at least 5 hours of fasting. After the first scan, subjects orally ingested 574 mL EnSure Plus® (Abbot Laboratories, Columbus, OH; 700cal) orally. Scanning was resumed 20 min after the meal challenge. The 4D PC VIPR data were analyzed for anatomy (PC angiogram) as well as flow measures and pathways using a combination of commercial and customized software packages for segmentation, visualization, and quantitative analysis.

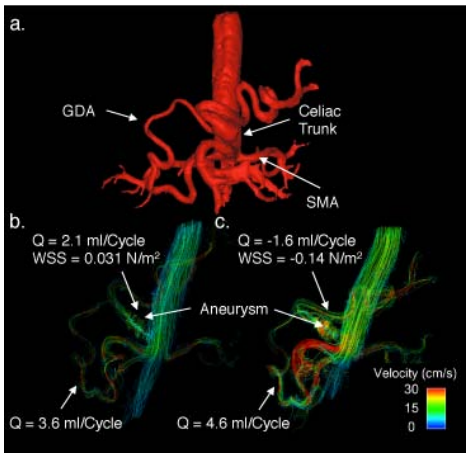

Fig.2: Patient with celiac trunk stenosis and poststenotic aneurysm. The volume rendered PC angiogram (a) and streamline visualization with peak systolic flow before (b) and after (c) a meal challenge.

Results and Discussion: 4D MR flow data were successfully obtained from all 8 subjects. The flow changes in the aorta, superior mesenteric artery, and superior mesenteric vein in response to the meal challenge are shown for all subjects and as average and standard deviation in Table 1. As can be seen, the aortic flow did not change substantially, while the SMA and SMV flow varied significantly for the patients. The heterogeneous flow changes indicate the individual differences in disease state and collateral flows that were observed across the patient population. Fig.1 shows a patient with a celiac trunk stenosis. To illustrate the range of conditions observed, one of the patients will be discussed in more detail. In this patient, stenosis of the celiac trunk as well as a post-stenosis aneurysm were identified as illustrated in Figure 2. Flow in the gastroduodenal (GDA) artery was reversed and increased by 28% after the meal while WSS within the aneurysm increased 4.5 fold after the meal.

Conclusion: This pilot study demonstrates the capabilities for PC VIPR to characterize and quantify complex vessel anatomy and hemodynamics in the entire hepatic and mesenteric circulation from a single free breathing scan. Not surprisingly, we did encounter very patient-specific responses to the meal challenge. Mesenteric ischemia typically occurs when two of the three vessels going to gut (celiac, SMA and IMA) are obstructed and the third is unable to meet demands after a meal. Since abdominal pain after a meal can occur for other reasons, some of which are listed above, it is often difficult to diagnose this condition. Based on these encouraging initial results, 4D MR Flow imaging has great potential to improve diagnostics and assist in therapeutic decision making in the challenging diagnosis of mesenteric ischemia.

REFERENCES: [1] W Oldenburg et al., Ann Arch Intern Med. 2004: 164(10):1054-1062 [2] KC Li et al., Radiology 1994: 190(10:175-9 [3] T Gu et al., AJNR 2005: 26(4):743-9 [4] KM Johnson et al., MRM 2008: 60(6):1329-36.

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