Quantification of Arterial-Phase Perfusion Kinetics in the Liver

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Introduction: Gadolinium-enhanced arterial phase images of the liver are critical for distinguishing vascular tumors. Timing is commonly affected by variable arterial transit times. One current method for ensuring reproducibility of optimal image contrast is using a fluoroscopic MR technique for real-time bolus-tracking. This method is highly efficient since it does not require an additional scan for a test bolus, and can be designed to trigger the subsequent 3D gradient echo arterial phase scan when contrast appears in a region-of-interest, such as the celiac axis. Even though contrast can be tracked to the celiac axis, there is uncertainty concerning the delay time from this point to maximum tumor-to-liver image contrast. Moreover, the temporal relationship between tumor, liver, portal venous, and hepatic venous enhancement has not been fully described in terms of defining optimal imaging windows. These relationships are important in arterial phase imaging since early or late imaging may compromise accurate tumor delineation.
Purpose: The purpose of this study was to describe the temporal relationships between aorta, tumor, liver, portal and hepatic vein.
Methods: This study's protocol was HIPPA compliant and approved by the institution's internal review board, and informed consent was obtained from all subjects. Nine subjects were included in the analysis (5 FNH, 2 HCC, 1 carcinoid, 1 benign adenoma), and perfusion studies were performed on a 1.5T Siemens Avanto system. Following the routine liver examination, which revealed an arterial-enhancing tumor, an additional volumetric perfusion scan was performed in a transverse plane encompassing the tumor, liver, and portal vein using at least 35 slices of 3.5mm thick. Additional parameters were TR/TE/flip = 2.3ms/0.7/25, 192 matrix (60% phase resolution), 300 FOV, BW=1300Hz, IPAT = 3, 1.6-2.4sec temporal resolution (depending on volumetric coverage), 50 dynamics. This resulted in a perfusion imaging time of approximately 100seconds. The sequence was initiated simultaneously with an injection of 0.1mmol/kg Gd-DTPA-BMA with the subject instructed to breathe quietly. Perfusion data was exported off-line for analysis (Osiris 4.19, Geneva, Switz) where individual dynamic slices containing tissues of interest were isolated. Signal measurements were acquired from aorta (at the level of the celiac axis), tumor, remote liver, portal vein, and hepatic vein using a region-of-interest (ROI) tool propagated to all dynamic images. Compensation for motion was achieved by manually moving individual ROIs as needed. The specific time points extracted from the perfusion curves included time-to-peak signal (TTP) for each tissue, along with time to peak tumor-to-liver contrast (TPC). Both of these measurements were expressed relative to peak aorta signal, which is the time point real-time bolus tracking would be halted in practice. This adjustment places emphasis on the time to peak tumor enhancement following bolus arrival in the celiac axis. Other temporal relationships recorded were arterial phase window (peak aorta to peak hepatic vein), and commencement of the portal venous phase. A cumulative average of temporal measurements was conducted for all nine subjects.
Results: Figure 1 shows a sample perfusion plot from one subject, detailing the temporal relationships between the tissues of interest. The relationships featured in the plot were similar in all individuals. A summary of delay times are given in Table 1. From the data, tumor enhancement coincides closely with portal venous enhancement, judging by TTP times and perfusion curves. Since this trend was valid in all subjects, this finding suggests that the portal vein may be used as an indicator for optimal tumor enhancement. Moreover, the data suggests that arterial phase imaging should be commenced early after bolus detection in the celiac axis (~10 sec), despite the length of the "arterial window". In clinical practice, centric reordered arterial-phase 3D GRE sequences (THRIVE, VIBE, or LAVA), with ky = 0 near the beginning of the scan, should be implemented with a delay of ~7sec from bolus detection near the celiac axis, which allows adequate time for breath holding instructions. Non-centric sequences may require earlier triggering to ensure optimum tumor contrast.
Conclusions: This study details the temporal relationships between aorta, tumor, liver, portal, and hepatic vein enhancement due to gadolinium perfusion. There is a consistent delay time (~10sec) following bolus arrival in the celiac axis to peak tumor contrast with remote liver. Coincidentally, this enhancement follows portal vein enhancement closely, and is contained within the first 25% of the "arterial window". Knowledge of the time-to-peak tumor contrast following peak aortic enhancement will enable more reproducible acquisition of arterial phase liver examinations. This method may be expanded to include patients with cirrhosis to develop a better understanding of possible altered transit times in the setting of portal hypertension, where these relationships have not yet been fully evaluated in the current literature.

Table 1. Summary of Perfusion Delay Times (n=9)

	TTP Aorta (sec)	TTP relative to aorta (sec)				TPC (sec)	Arterial window (sec)
		Tumor	Portal	Liver	Hep vein		
Avg	22.5	10.9	13.9	33.6	43.6	10.1	43.6
SD	5.5	3.1	4.6	14.2	12.6	2.5	12.6

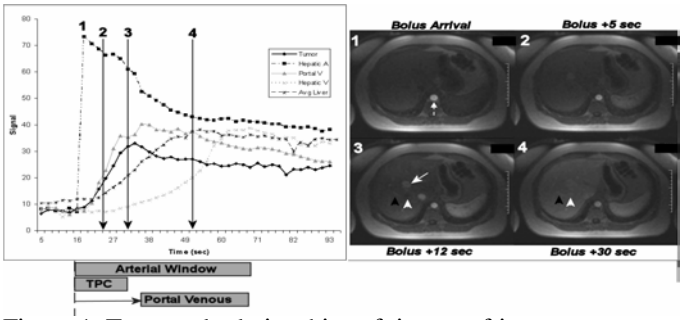

Figure 1. Temporal relationships of tissues-of-interest