IMPROVING IVIM DERIVED F-MAPS OF PANCREATIC TUMORS WITH AUTOMATIC DUCT AND VESSEL SEGMENTATION

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INTRODUCTION: The Intravoxel Incoherent Motion (IVIM) model derived perfusion fraction *f* was recently shown to be significantly lower within pancreatic adenocarcinoma tumors than in healthy pancreatic tissue and to be quantitatively superior to diffusion parameters including the apparent diffusion coefficient (ADC) and the IVIM diffusion coefficient (D) for characterizing pancreatic lesions [1]. Thus, maps of perfusion fraction *f* (*f*-maps) of the pancreas are potentially of high diagnostic value for identifying pancreatic tumors. In *f*-maps pancreatic adenocarcinoma tumors appear as hypointense (low perfused) lesions with high contrast in the surrounding tissues and vessels. Unfortunately, since bile and pancreatic ducts appear as hypointense in *f*-maps, their presence adjacent to tumors can lead to errors in tumor delineation. This paper presents a novel approach which addresses this issue by color coding vessels and ducts in the *f*-maps based on integrated diffusion coefficient D data.

MATERIALS AND METHODS: Forty-three patients with histologically confirmed adenocarcinoma of the pancreas were examined with echo-planar MR diffusion-weighted imaging (DWI) using eleven different b-values ranging from 0-800 sec/mm^2 using a 1.5 T scanner (MAGNETOM Avanto, Siemens Medical Solutions, Erlangen, Germany) with a maximum gradient strength of 45 mT/m, a 6-element body-phased array coil and a 24-channel spine array coil (Res.: 100x78 pixels, FOV: 350x273mm2, 14 slices, slice thickness/gap:5/0.25mm, spectral fat saturation, 4 averages, BW: 2940Hz, TR: 1300ms, TE: 60ms, k-space based parallel imaging technique *GRAPPA* acc. factor of 2, total scan time: 12min). Data was fitted to the IVIM model [2] yielding maps of the perfusion fraction *f* and of the diffusion constant D. The pseudo Diffusion Coefficient D* was inferred from preliminary experiments and fixed to 20 µm²/ms [1], since a stable 3 parameter fit would have required a considerably higher SNR than available with our experimental setup. For comparison, ADC maps were calculated using a linear fit of the multiple b-value DWI data. Two radiologists identified regions of interest (ROIs) within the lesion (*Tumor*), the gallbladder or major bile duct (*Duct*), and the aorta, renal- or vertebral artery (*Vessel*) on several axial slices of the DW images. Receiver operating characteristics (ROC) analysis was utilized to determine *f* and D cutoffs for tissue segmentation. Results were used to automatically color code vessels and ducts on *f*-maps for all patients.

RESULTS: Figure 1 shows the two-parameter (*f*,D) histograms for the three tissue types in all patients. In all vessel measurements, D was low close to zero. ROC analysis identified *f*=0.28 as the cutoff for *Vessels* (AUC=0.901) vs *Tumor+Duct* and D=1.85 for separating *Duct* from *Tumor* tissue (AUC=0.988). Figure 2 shows a sample ADC (2a) and corresponding *f*-map (2b) for a patient with adenocarcinoma of the pancreas. Figure 2c is the same *f*-map with color coding of vessels (red) and ducts (blue). The tumor's anterior extent was not visible in the ADC map (2a), while its posterior and medial borders were not clearly visible in the *f*-map (2b). Color coding of vessels and ducts in the *f*-map (2c) permitted clear tumor delineation and resulted in a diagnostically superior image to either the ADC or *f-map*. Similar results were obtained in the remaining 42 patients. The plausibility of the results was confirmed on pre-existing standard CT and MRI exams.

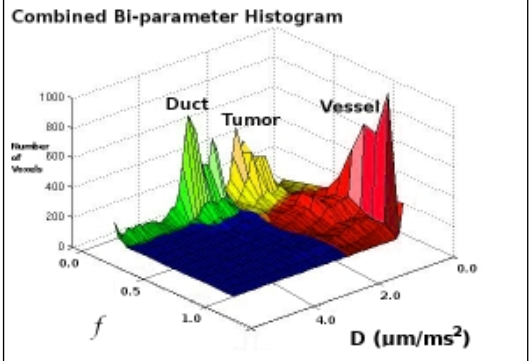

Fig.1: Bi-parameter (f,D) Combined histogram for Duct (green), Tumor (yellow), and Vessels (red) tissue categories. Considering both parameters permits clear separation of all three peaks which would not be possible if only f or D were considered. ROC analysis defined an f cutoff of 0.28 and a D cutoff of 1.85 (refer to text for details).

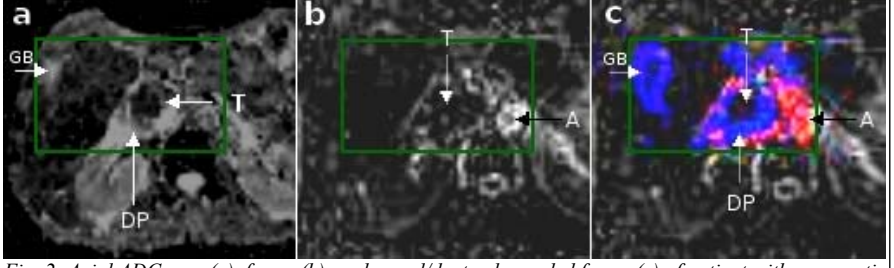

Fig. 2: Axial ADC map (a), f-map (b), and vessel/duct color coded f-map (c) of patient with pancreatic carcinoma. In the color coded image (c), a color mask is used to segment vascular (red) and ductal (blue) voxels according to f and D ranges as described in the text. Note that the tumor (T) is best delineated in the f-map if the pancreatic duct, which due to its curved path almost completely surrounds the tumor, is color coded. To avoid image clutter, color coding was limited to a user selected region of interest (green rectangle) including the tumor containing head of the pancreas and surrounding tissues. Also note the highlighted Gallbladder (GB). (T=tumor; GB=gall bladder; DP=ductus pancreaticus; A=aorta)

DISCUSSION: By combining both the diffusion and perfusion information extracted from DWI using the IVIM model, it is possible to successfully identify ductal and vascular structures. By color coding these structures in *f*-maps of the pancreas, tumor delineation is greatly improved. Color coded *f*-maps show potential for improving pancreatic tumor diagnostics when used alone or in conjunction with other MR imaging techniques. As a non-invasive, non contrast agent imaging modality, they also show promise for use in patients with contrast agent intolerance and in a possible screening program for pancreatic cancer. This study was limited to the segmentation of blood vessels and ducts from pancreatic cancer tissue. Future studies incorporating large data sets of other tissue types may lead to improved *f*-map imaging of other pathologies.

References: 1. Lemke A. et al, Invest Radiol. Oct.2009. 2. Le Bihan D., Radiology 1986;161:401-407.