

## Quantitative perfusion and diffusion weighted magnetic resonance imaging of pancreatic adenocarcinoma: a pilot study

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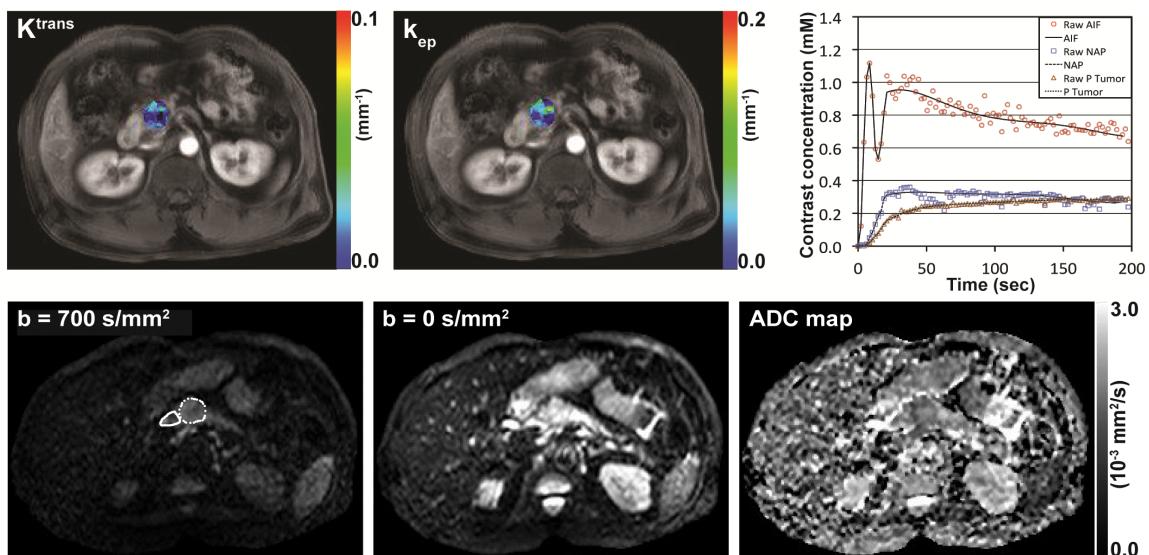
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**Purpose:** To assess the feasibility of obtaining quantitative physiologic parameters using magnetic resonance imaging (MRI) in patients with treatment-naïve pancreatic adenocarcinomas.

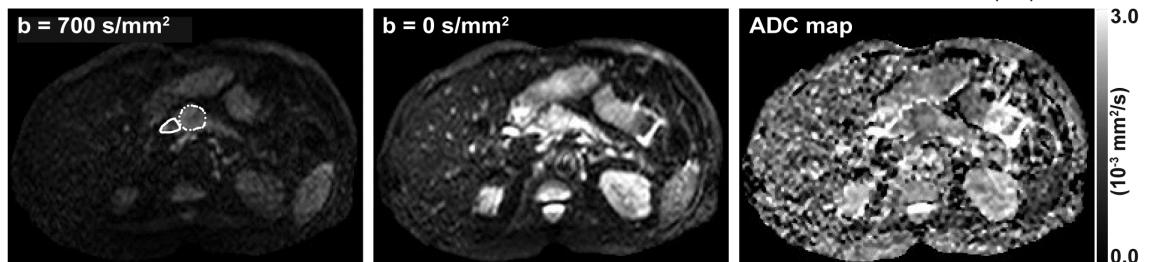
**Materials and Methods:** Sixteen subjects with a mean age of 64 years were accrued. All subjects had newly diagnosed, biopsy-proven pancreatic adenocarcinomas, and agreed to undergo pre-treatment MRI. All subjects were examined on a single 3T clinical MR system. Breath-hold DW single-shot echo-planar imaging (DW-SS-EPI) was performed with two  $b$  values of 0 and 700  $\text{s/mm}^2$  with following parameters: TR/TE = 3666/65 ms, FOV = 38×26 cm, NEX = 1, thickness/gap = 4/1 mm, matrix = 128/102 (interpolated to 256×256), and EPI factor = 37. A total of 24 slices were obtained during 20 seconds of breath hold. T1 maps were created by performing three separate breath-hold 3D spoiled gradient echo T1 weighted axial sequences with flip angles of 5, 10, and 15 degrees, respectively, with following parameters: TR/TE = 5/2.3 ms, FOV = 40×40 cm, NEX = 1, thickness/gap = 6/0 mm, matrix = 192/154 (interpolated to 256×256), and SENSE factor = 2. A total of 10 slices were obtained during 20 seconds of breath hold for imaging with each flip angle. DCE-MRI employed the same acquisition parameters as those for creating T1 maps, but with a fixed flip angle of 15 degree. A total of 92-96 images were continuously acquired with temporal resolution of 2.1 seconds after intravenous injection of 0.1 mmol/kg of gadoteridol with 20-ml saline flush at the rate of 2 ml/s. During DCE-MRI, patients were instructed to perform breath-hold in maximal end inspiration for as long as possible, and then repeat similar breath-holds as feasible. For correcting motion in DCE-MR images, three post image-processing techniques were employed: unwarping, median filtering, and curve fitting. For unwarping, the boundary of a patient's body above the paravertebral muscle and abdominal aorta was determined in each DCE-MR image, then the boundary in each DCE-MR image was unwarped to match with the boundary in the baseline image. All pixels within the boundary were relocated accordingly. Thereafter, median filtering and curve fitting were applied. T1 maps were also unwarped as described above, and co-registered with DCE-MR images. A two-compartment pharmacokinetic model was employed to calculate volume transfer constant ( $K^{\text{trans}}$ ) and reverse reflux rate constant ( $k_{\text{ep}}$ ). In DWI analysis, the ADC value was calculated by finding the best fitting curve to the equation,  $S = S_0 e^{-bD}$ , where  $S$  is the intensity of DW images,  $S_0$  is a constant, and  $D$  is ADC value.

**Results:** Figure 1 shows a representative motion-corrected DCE-MR image (gray-scale) of a 59-year-old man with a resectable pancreatic adenocarcinoma at 30 seconds after initiating gadoteridol injection superimposed with  $K^{\text{trans}}$  and  $k_{\text{ep}}$  maps (color-scale) in the tumor region, and contrast-enhancement curves averaged in the abdominal aorta (i.e., AIF), non-tumor adjacent pancreatic parenchyma (NAP), and pancreatic tumor. Figure 2 shows representative DW images obtained with two  $b$  values of 700 and 0  $\text{s/mm}^2$  and ADC maps of a 50-year-old man with a resectable pancreatic adenocarcinoma.  $K^{\text{trans}}$ ,  $k_{\text{ep}}$ , and ADC values of primary pancreatic tumors were  $0.0073 \pm 0.0042$  (mean±SE)  $\text{mm}^{-1}$ ,  $0.030 \pm 0.009 \text{ mm}^{-1}$  and  $0.0013 \pm 0.0002 \text{ mm}^2/\text{s}$ , while those of liver metastases were  $0.0081 \pm 0.0059 \text{ mm}^{-1}$ ,  $0.052 \pm 0.020 \text{ mm}^{-1}$  and  $0.0011 \pm 0.0001 \text{ mm}^2/\text{s}$ . Both the  $K^{\text{trans}}$  and  $k_{\text{ep}}$  values of primary pancreatic tumors and liver metastases were significantly lower than those of NAP ( $0.0258 \pm 0.0149$  and  $0.074 \pm 0.031 \text{ mm}^{-1}$ ) or normal liver tissues ( $0.0451 \pm 0.0156$  and  $0.121 \pm 0.028 \text{ mm}^{-1}$ ) ( $p < 0.05$ ), but the  $K^{\text{trans}}$  and  $k_{\text{ep}}$  values of primary pancreatic tumors were not statistically different from those of liver metastases ( $p > 0.05$ ). The ADC values of pancreatic tumors were significantly lower than those of NAP ( $0.0016 \pm 0.0003 \text{ mm}^2/\text{s}$ ) ( $p = 0.0022$ ), but not different from those of normal liver tissues ( $0.0011 \pm 0.0001 \text{ mm}^2/\text{s}$ ) or liver metastases ( $p > 0.05$ ).

**Discussion:** 3T breath-hold quantitative physiologic MRI is a feasible technique that could be applied to patients with pancreatic adenocarcinomas and liver metastases, although the small Z-axis coverage (6 cm) is limiting in regard to full coverage of the liver for metastasis evaluation. Quantitative DCE-MRI has been recently reported for pancreatic tumors (1, 2), but the mean  $K^{\text{trans}}$  values were significantly different from one another. Thus, the standardization of imaging protocols incorporating DCE-MRI would be a necessary step to improve the reproducibility of quantitative measures for evaluation of therapeutic response.



**Figure 1.** Representative DCE-MR image of a 59-year-old man with pancreatic cancer at 30 seconds after contrast injection with  $K^{\text{trans}}$  and  $k_{\text{ep}}$  maps (color-scale) in tumor region, and contrast enhancement curves in the abdominal aorta, NAP and pancreatic tumor.



**Figure 2.** Diffusion weighted images of a 50-year-old man with pancreatic cancer at two different  $b$  values of 700 and 0  $\text{s/mm}^2$  with constant gray scale, together with ADC map. The regions of tumor and non-tumorous adjacent parenchyma are indicated with dotted and solid lines, respectively.

### Reference:

1. Kim JH, Lee JM, Park JH, et al: Solid pancreatic lesions: characterization by using timing bolus dynamic contrast-enhanced MR imaging assessment—a preliminary study. Radiology 266:185-196, 2013
2. Yao X, Zeng M, Wang H, et al: Evaluation of pancreatic cancer by multiple breath-hold dynamic contrast-enhanced magnetic resonance imaging at 3.0T. European journal of radiology 81:e917-922, 2012