Diffusion Tensor Imaging of The Pancreas

Noam Nissan[1], Talia Golan[2], Edna Furman Haran[3], Sara Apter[4], Yael Inbar[4], Dov Grobgeld[1], and Hadassa Degani[1]

[1]*Department of Biological Regulation, Weizmann Institue of Science, Rehovot, Israel,* [2]*Oncology Institute, Sheba Medical Center, Tel Hashomer, Israel,* [3]*Biological Services, Weizmann Institute of Science, Rehovot, Israel,* [4]*The Division of Diagnostic Imaging, Sheba Medical Center, Tel Hashomer, Israel*

Purpose: To characterize the complex water diffusion properties of normal pancreatic tissue by applying Diffusion Tensor Imaging (DTI) and to utilize this method for detecting early changes due to pancreatic ductal adenocarcinoma (PDAC).

Introduction: PDAC carries a poor prognosis and only a minority of patients are diagnosed with localized resectable tumors. Recent evidence supports a sufficient window of opportunity for early detection (1), and there is an unmet clinical need to diagnose this malignancy at earlier stages. The normal pancreas microstructure consists of exocrine units of acini and ducts and endocrine units of islets of Langerhans distributed within "lobules", ranging from 1 to 3 mm in diameter (2). Previous diffusion weighted imaging (DWI) in normal pancreas and in pathological conditions, predominantly of PDAC provided conflicting results for ADC values: Both lower and higher ADC values in PDAC as compared with normal pancreatic tissue (3-6), partially due to the non-standardized protocols and processing means. DWI studies at a broad range of b-values, including low b-values, analyzed by fitting to a biexponential decay suggested substantial contribution from intravoxel incoherent motion (IVIM) (3,7). Since water diffusion in pancreatic tissue is complex and anisotropic we have focused on developing DTI protocols and processing means with the aim of detecting changes in the tensor parameters upon malignant growth.

Methods: Images were acquired on a 3Tesla whole body MRI scanner: MAGNETOM Trio, Tim System (Siemens) equipped with a transmitting body coil and a receiving, multi-channel, body matrix and spine matrix coils. The MRI protocol included transversal T2weighted images with and without fat saturation, axial DTI with fat-saturation and respiratory triggering, b = 0, 100, 500 s/mm^2, TE/TR 74/6000 ms, 20 directions and spatial resolution of 2x2x2.5mm^3, or 3x3x4mm^3.

Data processing: The DTI datasets were analyzed pixel by pixel using propriety software applied previously to analyze breast DTI datasets (8). This analysis yielded three eigenvectors v1, v2, v3 and their corresponding eigen-values λ1, λ2 and λ3. The eigen-values were presented in color coded maps and v1 in vector map (Fig. 1).

Statistical Analysis: Means and S.D. of the three diffusion tensor parameters λ1, λ2 and λ3 were calculated for regions of interest in the head, body and tail of the pancreas. Unpaired, two tailed t-test were applied for evaluating statistical differences between the diffusion parameters in the different parts of the pancreas.

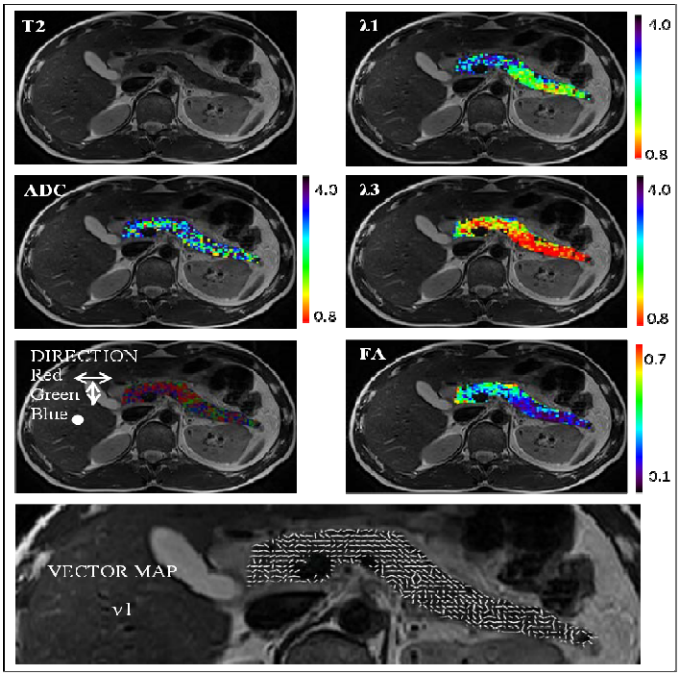

Fig. 1. *A T2 weighted image and the corresponding parametric and vector maps of the pancreas of a healthy male (age: 38).An Axial view is presented. Maps are overlaid on the T2 weighted image. λ1, λ3 and ADC units: (mm^2/s)x10^{-3}.*

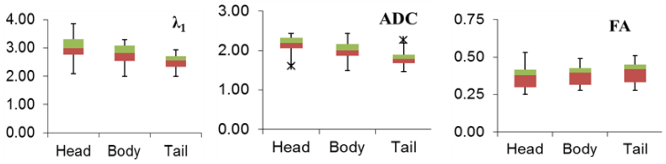

Fig. 2. *The cohort's diffusion parameters in the different parts of the pancreas: λ1 and ADC values were significantly higher ($p<0.05$) in the head as compared with the tail. λ1 and ADC units: (mm^2/s)x10^{-3}.*

Results: 18 healthy volunteers, 11 males and 7 females (age range 24-38) and one patient with pathology confirmed PDAC were scanned. Results clearly indicated that due to the complex nature of the microstructure and micrvascularization of the pancreas, the MRI experimental parameters, such as b-values and diffusion times, need to be carefully selected. In these studies we have employed a spatial resolution which is of approximately the dimensions of a pancreatic lobule (see Introduction).We found a difference in the diffusion coefficients (λ1, λ2,λ3 and ADC) of the head, body and tail with a similar fractional anisotropy and maximal anisotropy indices in these regions (Fig. 2). The results suggest that the contribution of the ductal elements in each lobule is predominantly determined by the water diffusion in the exocrine fraction , where there is free diffusion parallel to the walls of the ducts. This is further verified in the λ1 vector maps showing the main direction of the ductal elements per lobule (Fig.1), indicating a possibility for tracking the pancreatic ductal system. Since the fraction of the Langerhans islets in the healthy pancreas is low, 1-3%, their water diffusion contribution per pixel is negligible. However, as the microvascular fraction and blood flow of the islets are ~5 times higher than in the exocrine system, this microcirculation can generate an IVIM measured as a fast diffusion decay component at low b-values (b< 100 s/mm^2). DTI experiments with two initial b values (0 or 100 s/mm2) and a similar second b-value suggested the presence of IVIM and a reduction in ADC values by 29±4 % (n=5) when IVIM is eliminated by using initial b=100 s/mm2 and eliminating the IVIM contribution. In a study of a single patient with confirmed PDAC we found a reduction of 30% in λ1 and 16% in λ1- λ3.

In summary The diffusion tensor parameters of the pancreas varied significantly between healthy subjects and within different parts of the pancreas. Based on our preliminary results we predict that DTI may help detecting changes in the normal pancreatic tissue caused by malignant growth.

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