

# Motion correction of high temporal 3T Dynamic Contrast Enhanced MRI of pancreatic cancer - preliminary results

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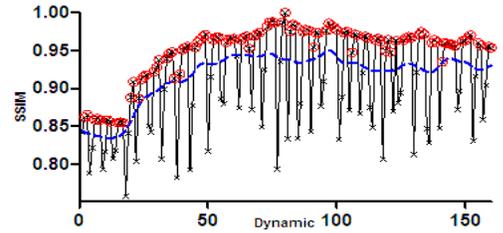
**Introduction** Despite advances in multimodality treatment options, pancreatic ductal adenocarcinoma still ranks 4<sup>th</sup> on the list of cancer-related deaths. Treatment resistance is induced, among others, by poor vascularisation of pancreatic tumours. Non-invasive characterization of tumour vascularization could aid in the selection of patients who would benefit from (neo-)adjuvant chemo(radiation) therapy. Dynamic Contrast Enhanced Magnetic Resonance Imaging (DCE-MRI) allows for the assessment of the passage and distribution of a contrast agent through organs. Pharmacokinetic quantification of this distribution has been shown to provide valuable information on pancreatic tumour characteristics such as microcirculation and microvasculature<sup>1</sup>. However, the pancreas is prone to movement due to breathing, cardiac motion and bowel peristalsis causing misalignment of the dynamic images and distortion of the quantification. Here we present a complete image acquisition and post-processing approach to minimize the effects of movement on the quantification of DCE-MRI of the pancreas.

**Methods Subjects:** 3 male subjects with histologically proven pancreatic adenocarcinoma (age 56-66) participated in the study. The study was approved by the local ethics committee and all subjects gave written informed consent.

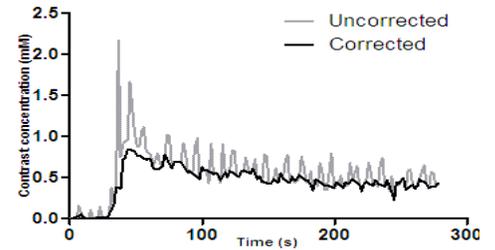
**Image acquisition:** Imaging was performed on a Philips Ingenia 3T MR scanner (Philips Healthcare, Best, The Netherlands). The DCE protocol comprised a dynamic series consisting of a 3D FFE sequence with 30 slices; slice thickness 2.5mm (5mm non-interpolated), FOV 400x400mm, matrix size 160x160, TR/TE/FA 3.2/2.0ms/20° and a temporal resolution of 1.75s. Baseline T1 in the pancreas was determined prior to the dynamic series using four scans with increasing flip angles of 2°, 5°, 10° and 20°. For anatomical correlation a mDIXON sequence was performed. To minimize peristaltic movement during the dynamic scan 1ml of 20mg/ml Buscopan® (Boehringer Ingelheim) was administered just before start of the dynamic image acquisition. 0.1mmol/kg of 1.0mmol/ml Gadovist® (Bayer) was administered 15s after start of the dynamic series at a rate of 5ml/s followed by a 15ml saline flush. Scanning was continued for 4.5min.

**Post processing:** First, the dynamic image signal intensity was converted in contrast agent tissue concentration using the baseline T1 measurements. The arterial input function was fitted to the average pixel values in a drawn ROI on the superior mesenteric artery in one slice, using the method described by Parker et al.<sup>2</sup>. From the dynamic series the breathing cycle was detected by calculating the structural similarity<sup>3</sup> (SSIM) of each 3D dynamic volume relative to one selected dynamic. Next, the dynamic volumes were assigned to an inspiratory or expiratory phase by using the low-pass moving average of the similarity index as divider. The phase containing the most dynamics was assumed to represent expiration and the volumes assigned to this phase were used for further analysis (Figure 1). These volumes were then registered to one dynamic using Elastix<sup>4</sup>, first rigidly followed by an affine transformation.  $K^{trans}$  values were calculated for all pixels in the pancreas for both the corrected and uncorrected data for comparison, using the two compartment model described by Tofts et al.<sup>5</sup> and projected on the anatomical images. ROIs of both healthy and tumorous pancreas were drawn based on the anatomical images.

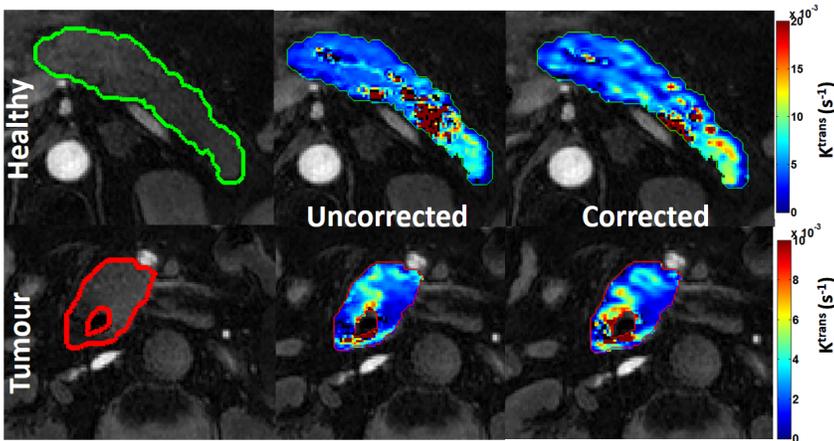
**Results** Figure 2 shows the difference in contrast medium concentration before and after motion correction in a region of interest in the pancreatic tail, near an artery. Figure 3 shows the  $K^{trans}$  map before and after motion correction for a typical patient in a normal tail and in a tumour in the head of the pancreas. Note the better correlation with anatomical structures of the  $K^{trans}$  map after correction, e.g. the visualization of the pancreatic duct. The median  $K^{trans}$  for normal pancreas before motion correction was  $11.9 \times 10^{-3} s^{-1}$  vs.  $11.0 \times 10^{-3} s^{-1}$  after correction. Median  $K^{trans}$  for tumour tissue before motion correction was  $4.0 \times 10^{-3} s^{-1}$  vs.  $4.3 \times 10^{-3} s^{-1}$  after correction (Figure 4).



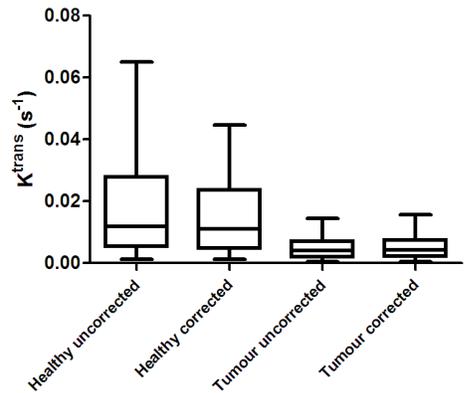
**Figure 1** SSIM of each dynamic image relative to the middle dynamic (SSIM=1). Blue: moving average. Red: detected expiratory phase



**Figure 2** Contrast concentration in normal pancreatic tail tissue before and after motion correction



**Figure 3** Corrected and uncorrected  $K^{trans}$  ( $s^{-1}$ ) of healthy tail (green) and tumorous head (red) of the pancreas



**Figure 4** Box and whisker plot of  $K^{trans}$  values in the healthy and tumour ROI. 5-95% percentile, outliers not shown

**Discussion & Conclusion** We showed the feasibility to perform motion correction in quantitative DCE-imaging of the pancreas. The DCE-MRI imaging protocol and post processing methods described in this study provide a valuable approach for future assessment in a larger patient group. Future research will show if motion correction favours the capability of DCE-MRI to discriminate between tumour and healthy tissue and if it increases reproducibility between scans.

**References** <sup>1</sup>Bali MA, et al. *Radiology*. 2011;261(2):456-66. <sup>2</sup>Parker GJM, et al. *Magn. Reson. Med*. 2006;56(5):993-1000. <sup>3</sup>Wang Z, et al. *IEEE Trans. Image Process*. 2004;13(4):600-12. <sup>4</sup>Klein S, et al. *IEEE Trans. Med. Imaging*. 2010;29(1):196-205. <sup>5</sup>Tofts PS, et al. *J. Magn. Reson. Imaging*. 1999;10(3):223-32.