A Groupwise Non-Rigid Registration Approach for Accurate Quantification of DCE-MRI in Characterizing Ovarian Cancers

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Target Audience: Engineers and physicists interested in artifact correction in DCE-MRI

Introduction: Ovarian cancer is the primary indication for gynecological surgery and quantitative Dynamic Contrast Enhanced MRI (DCE-MRI) has been shown beneficial to differentiate malignant and benign tumors based on the measured enhancement characteristics. One of the major assumptions in quantification of DCE-MRI in abdominal organs is spatially-fixed region of interest over the time course of contrast agent passage **[1]**. However, there are two types of motion occurring in the image series, which could invalidate this assumption and thus the quantification outcome: one of them from complex motion resulting from breathing, pulsation and the natural movement of the organ of interest, and the another one from the motion of the contrast agent **[2]**. Thus, accurate quantification of DCE-MR image series highly depends on minimization of motion artifacts. The traditional methods only register the post-contrast images to the pre-contrast image, regardless of contrast changes in the post-contrast images. Calculation of mean image in the post-contrast images could suppress the image artifacts and severe contrast changes. Here, we proposed a registration approach for accurate quantification of DCE-MRI in ovary, employing elastic non-rigid registration in a group-wise setting to account for spatially-varying intensity changes within the registration framework.

Material and methods: Data Acquisition: DCE-MR images of eighteen patients (10 benign and 8 malignant patients with histological assessment) diagnosed with solid or solid/cystic ovarian masses were acquired on a 3T MR scanner (Siemens MAGNETOM Tim TRIO) using a surface phased-array coil, TE/TR = 1.74/5*m*sec, flip angle = 60°, image matrix = 156×192, FOV =23×23cm^2, slice thickness = 5mm, number of measurements = 52 at 6sec/volume, number of slices = 16. The acquisition was performed before and immediately after injection of 0.2mL/kg of Gadolinium (DOTAREM; Guerbet, Aulnay, France), followed by injection of 20cc normal saline solution with 3mL/min injection rate. Image registration: In our group-wise registration approach, at first, the pre-contrast image is taken as the reference and the consequent images are aligned with the reference image, and consequently, in order to improve the registration result all images are registered to the group mean image. We employed elastic registration algorithm, in which the geometric transformation is a local affine model with a global smoothness constraint. Intensity variations are modeled with local changes in brightness and contrast. The mean squared error metric was applied to the intensity values to correct the nonlinear distortion. A least-squares technique was used to minimize the error function [3]. For further assessment, the proposed group-wise elastic registration (GW-Reg) approach was compared to the simple elastic registration algorithm (E-Reg), in which we select the pre-contrast image as a reference image and register all post-contrast images to the reference, and unregistered images (UnReg). Quantification: As proposed in **[4]**, time-to-peak (*TTP*) and wash-in-rate (*WIR*), defined as $(SI_{max}\text{-}SI_0)/TTP$, can be used to distinguish between benign and malignant ovarian masses.

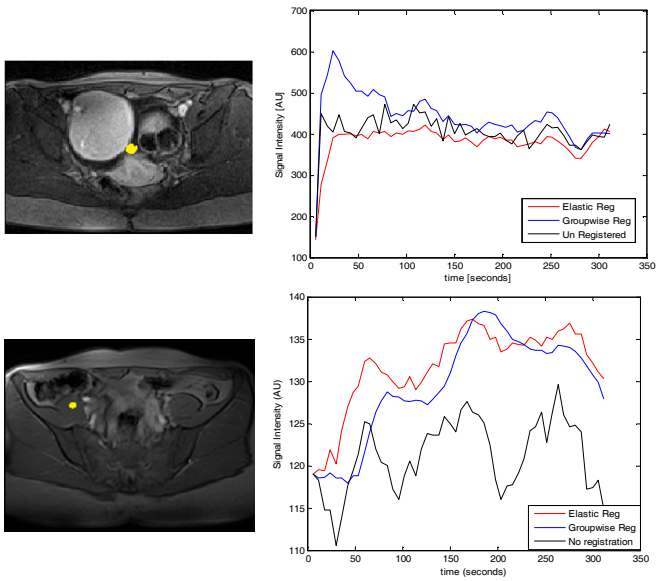

Fig. 1 Signal Intensity-Time curves from unregistered, registered images by E-Reg and GW-Reg algorithms in a patient with malignant ovarian mass: (upper row) Psoas: (bottom row).

Results and Conclusions: Fig. 1 clearly shows the impact of two registration methods on the selected regions-of-interest (ROIs) located in solid part of the tumor and psoas (normal tissue) in two of the cases. As can be observed, the group-wise algorithm significantly improves the signal intensity curves, especially in psoas that inhibited much distortion. In addition, the mean and the median of the standard deviation within the ROIs selected on tumor and psoas over the time courses of contrast agent passage were computed (**Table 1**), which suggests that elastic and group-wise registration methods significantly improve the signal intensity-time courses in contrast to the unregistered images**.** Similar results are obtained for the other data sets. Also, quantitative parameters were calculated for unrigestered, elastic registered and group-wise registered images, as summarized in **Table 2**. It can be inferred that the value of mean to standard deviation ratio of the parameters increased after registration with elastic method, and further by groupwise registration approach, which would improve the characterization of benign from malignant ovarian masses. From the results attained in this work, it can be concluded that the outcome of ovarian cancer characterization could benefit from group-wise registration approach and hence this method can be reliably used for quantification of DCE-MR images of ovarian tumors.

Table 1. Evaluation of unregistered, E-Reg, and GW-Reg

		Benign (n=10)		Malignant (n=8)	
		Mean	Standard Deviation	Mean	Standard Deviation
WIR	UnReg	6.58	5.18	24.73	29.77
	E-Reg	4.91	4	15.3	15.11
	GW-Reg	5.66	3.77	21.18	16.56
TTP	UnReg	273.6	43.56	130.5	71.91
	E-Reg	286.2	38.37	156	88.58
	GW-Reg	283.2	42.21	110.21	63.1

Table 1. Parameter calculations for Benign and Malignant ovarian masses

		Dataset 3 (Benign)		Dataset 10 (Malignant)	
		Psoas	Tumor	Psoas	Tumor
UnReg	mean	12.72	88.44	135.13	67.73
	median	13.72	81.91	130.19	66.98
E-Reg	mean	5.97	60.26	89.51	14.84
	median	4.68	59	86.66	14.74
GW-Reg	mean	4.66	50.21	80.97	13.78
	median	4.69	55.23	82.55	13.41

References: **[1]** Dilks P *et al.*, *EUR Radiol* 20, 2176 (2010). **[2]** Zöllner F *et al*, *CMIG* 33, 171 (2009). **[3]** Periaswamy *et al.*, *IEEE Trans Med* 22:865–874 (2003). **[4]** Thomassin-Naggara I *et al*., *Radiol* 248 (1), 148-59 (2008).