Accurate MR cardiac perfusion analysis by using a multiresolution B-splines registration algorithm

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SYNOPSIS

We acquire MR cardiac perfusion in free-breathing mode. Along the whole sequence, we observe large variations in the position of the left ventricle on short-axis views. We evaluate here an automatic and freely available registration algorithm for performing an accurate perfusion analysis. This algorithm automates the otherwise tedious and time-consuming shift of the different regions of interest, which is needed to reach sufficient accuracy in the perfusion analysis. We validate the accuracy of this algorithm by calculating the geometric residual displacements of the left ventricle and by fitting the data to a compartment model with 2 parameters.

INTRODUCTION

After injection of a contrast media, the myocardial perfusion can be measured from the transit time curves obtained by MRI. The registration of the dynamic images of MR perfusion study is the first step of this analysis, which is usually done manually. This work describes an automatic registration process that overcomes the difficulty related to time-dependent intensity variations inside the heart section to be registered.

MATERIALS & METHODS

We have validated the registration method with cardiac perfusion MRI exams (2 slices per study) of 8 patients. The registration is based on a fully automated registration algorithm [1] that uses the original grey levels as feature space and that considers a Euclidean least-squares criterion for the determination of a general 3D affine transform that we restrict here to 2D data. It is based on B-splines in a multiresolution context. The registration process requires only one region of interest (ROI) that is centred on the left ventricle. The left ventricular cavity itself, where image intensities vary the most in reason of the perfusion of the contrast medium, must be removed from this ROI.

We have determined the accuracy of the automatic registration algorithm by monitoring the position of the Left Ventricle (LV) inside the myocardium. We have obtained three series of transit time curves inside the myocardium, one from the raw images, one from the images after automated registration, and one from the images after manual registration. We have used the latter in the role of the gold standard. The transit time curves were fitted to the compartment model to estimate the myocardial perfusion parameters [2]: the blood-to-myocardium transfer constant (*K1*) and the Gd-DTPA distribution volume (*Vd*). We have calculated the relative variation (in % of the gold standard) of *K1* and *Vd* for the raw data sets and for the registered images. We report the goodness of the fit as the sum of the squared differences between the model and the original data.

RESULTS

We have successfully implemented the registration on eight patients. This allows for a reduction in the positional variations of the center of mass of the LV from 1.98±0.68 mm to 0.56±0.18 mm in the x-direction, and from 4.05±2.00 mm to 0.49±0.14 mm in the y-direction (Table 1, Figure 1). On short-axis views, free breathing is clearly dominant in the Anterior-Inferior direction. The degree to which gold standard transit time curves correlate with transit time curves obtained with or without registration differs sensibly: a low correlation (r=0.84, P<0.01) is obtained with non-registered images, whereas a high correlation (r= 0.99, P=0.47) is obtained with registered ones. We present in Table 2 the variability obtained in the perfusion parameters with or without registration. We observe a large variability of the perfusion parameters when they are obtained from unregistered images. This leads to measurements that are statistically different from those obtained from the gold standard. Taking adavantage of automatic registration, we reduce this variability and obtain perfusion values that are very close to those obtained with the gold standard.

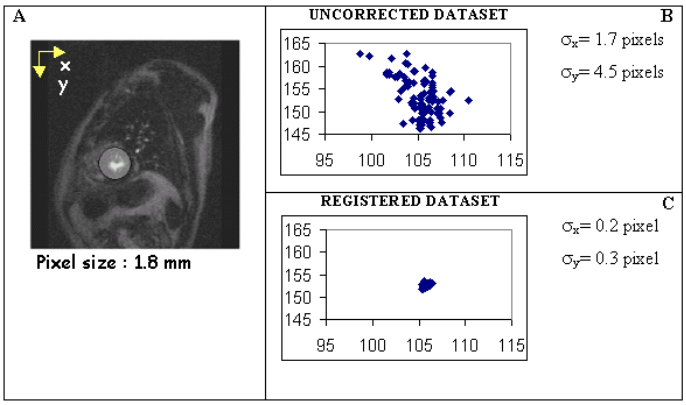

Figure 1: We estimate the accuracy of registration by monitoring the position of the left ventricle inside the myocardium (region of interest in **A**). Without registration, we observe large variations in the LV position (**B**). We obtain better results with automatic registration (**C**).

Table 1
Registration accuracy: summary of the results obtained on eight patients

Registration technique	Variation of the position of the center of mass of the LV (in pixels)			
	X		Y	
	min mean	max stdev	min mean	max stdev
No registration	0.25 1.10	1.85 0.38	0.28 2.25	4.48 1.11
Automatic registration	0.18 0.31	0.51 0.10	0.15 0.27	0.46 0.08

LV: left ventricle, stdev: standard deviation. Pixel size: 1.8 mm

Table 2
Variability of the model fit and value of the t-test associated to the raw images and the automatically registered images from 8 patients (4 sectors each; *K1*, *Vd*)

Variability (%)	Raw images		Registered images	
K1	(46 ± 103) %	*P*=0.07	(5 ± 4) %	*P*=0.58
Vd	(18 ± 21) %	*P*=0.01	(5 ± 5) %	*P*=0.73

CONCLUSION

The automatic registration algorithm [1] integrates a robust multiresolution approach based on B-splines. It corrects for most of the in-plane motion induced by physiology and by free breathing, which allows us to perform simpler perfusion analysis by avoiding the tedious and time-consuming manual shift of the ROIs over each image of a dynamic sequence. The accuracy of this algorithm is demonstrated by the improvement in the determination of the perfusion parameters.

REFERENCES

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