CORRESPONDENCE OF CMR SCANS FROM MULTIPLE VISITS

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Abstract and Background

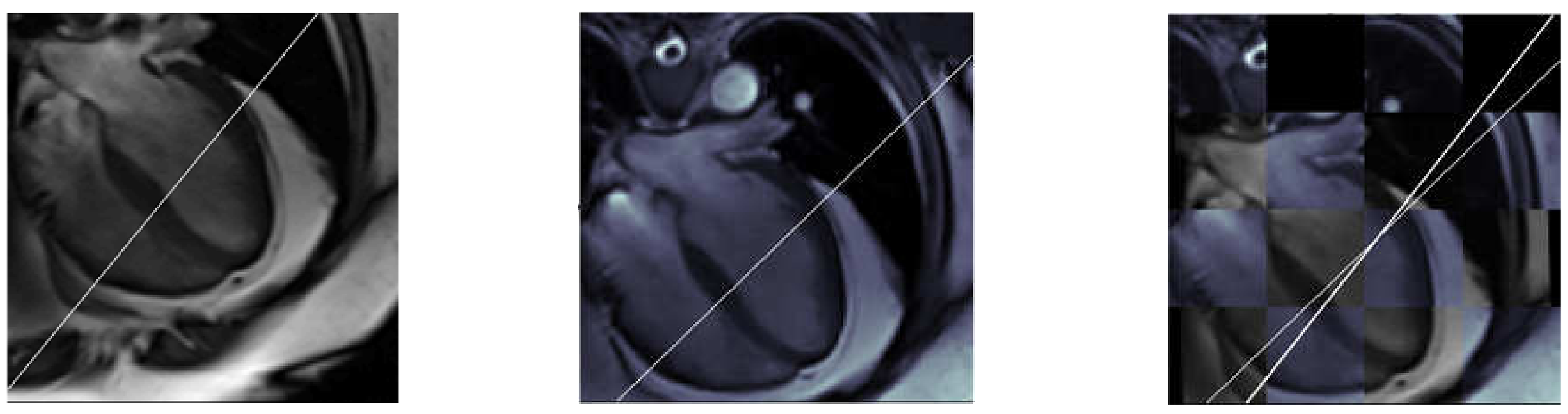
Longitudinal dynamic changes of myocardial tissue composition following ischemic injury determine left ventricular (LV) remodelling. Conventional manual 2D registration of clinical cardiovascular magnetic resonance (CMR) images acquired at different times aids the comparison of imaging findings, improving assessment of the effects on LV remodelling. Here we firstly show that discrepancies in the selection of short- (SA) and long-axis (LA) planes leads to significant differences in location and angle between slices manually identified as corresponding in two studies of the same patient. As a result, we propose a registration algorithm that overcomes this challenge by performing a full 3D registration using a combination of short- and long-axis images. In addition, due to the potential intensity differences between MRI studies, that may preclude the use of conventional intensity based registration methods, our proposed approach uses a similarity metric based on local phase. Encouraging results were obtained from tests carried out on a phantom volume showing a mean Dice coefficient of 0.96 ± 0.02 for LV alignment as well as superior performance compared with an equivalent intensity based approach. Qualitative validation of results obtained on real data show clear improvement in the alignment of the main cardiac structures.

Misalignment of 2D SA slices

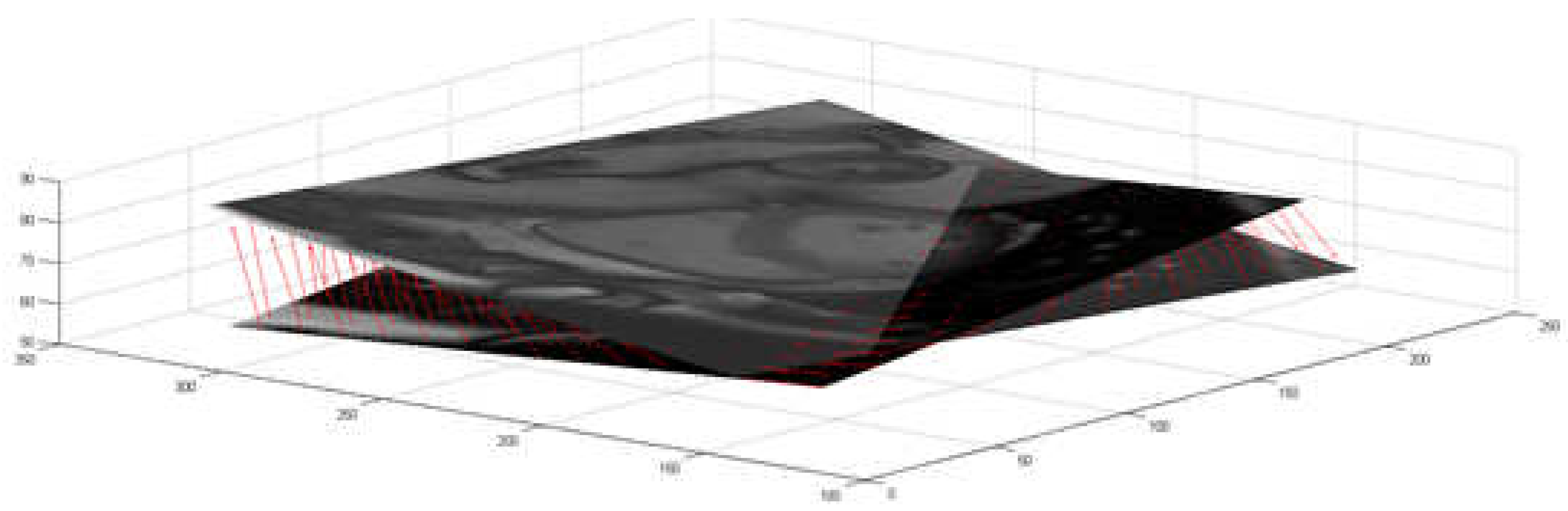
Methods

The steps used in the analysis were:
- bring LA slices into same plane and perform 2D point based registration
- transform all slices according to registration result
- measure angular difference and z-offset between SA slices

Results



Corresponding LA slices from the two visits, where the white lines represent the intersection of the selected SA slices. Finally, the result of the co-registration is shown, with the two images occupying alternate squares in a checkerboard pattern.



The SA slices after applying the co-registration above. The misalignment is represented by the vertical arrows.

	Entire Plane	Region of Interest
Angular Difference	8.34 ± 7.47°	
Z-direction Offset	8.16 ± 8.54mm	6.50 ± 6.53mm

Discussion

For all patient data sets tested there was a substantial misalignment between the SA slices, with offset values comparable to inter-slice spacing. This might have an important effect on the accuracy of longitudinal studies using individual slices, and suggest a 3D approach is necessary. For areas of oedema, this error may be important, especially for lesions with irregular shapes or sizes similar to the calculated error values.

3D Registration

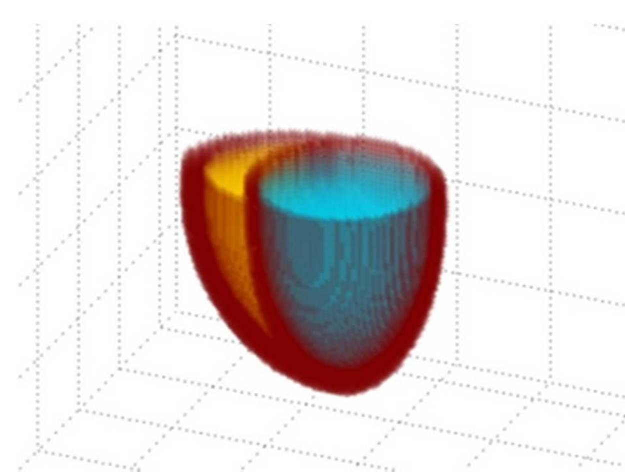
Methods

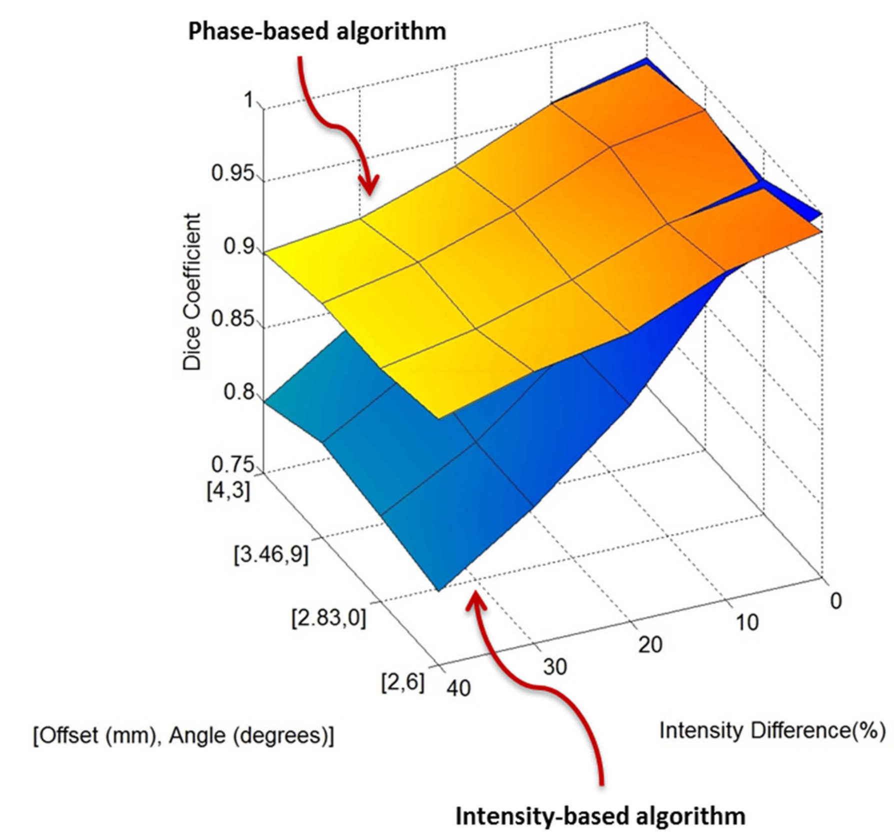
Our proposed variational registration approach for cardiac MR images consists of the following steps:
- intensity correction between SA and LA images for volumetric reconstruction of tissue volume
- registration of 3D volumes using the approach proposed in [1] adapted to the use of local phase

$$E = \iiint \left(w^T J_\rho(\nabla_4 \varphi) w\right) + \alpha \left(\|\nabla v_x\|^2 + \|\nabla v_y\|^2 + \|\nabla v_z\|^2\right)\, dxdydz$$

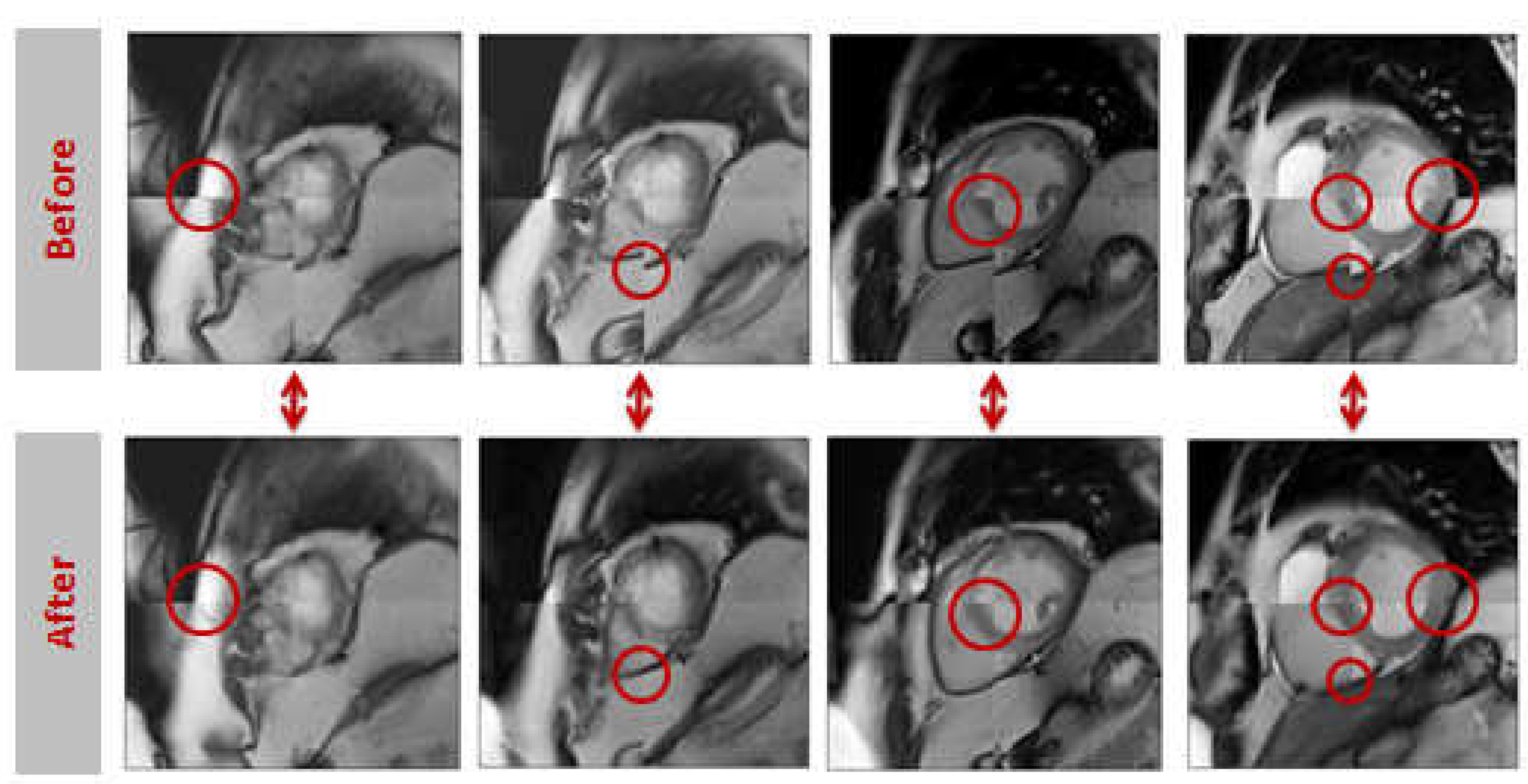
Phase is used due to its intensity invariance - intensity variation that can exist between cardiac MR data sets. The phase values are calculated using 9 directional quadrature filters (see reference [2]).

Results





Comparison for registration of a phantom image using both an intensity-based and a phase-based method with varying intensity differences.



Checkerboard results showing images before and after registration. Locations of visible improvement are highlighted via the red circles.

[1] Bruhn, Andrés, Joachim Weickert, and Christoph Schnörr. "Lucas/Kanade meets Horn/Schunck: Combining local and global optic flow methods", International Journal of Computer Vision.3 (2005): 211-231.
[2] Hemmendorff, Magnus, et al. "Phase-based multidimensional volume registration", Medical Imaging, IEEE Transactions on.12 (2002): 1536-1543.