AN EVALUATION OF GLOBAL VERSUS LOCAL IN-PLANE RIGID REGISTRATION IN DYNAMIC CONTRAST-ENHANCED BREAST EXAMINATIONS

Araminta E. W. Ledger[1], Marco Borri[1], Romney Pope[2], Erica Scurr[1], Toni Wallace[1], Cheryl Richardson[2], Marianne Usher[2], Robin Wilson[2], Steven Allen[2], Karen Thomas[3], Nandita deSouza[1], Martin O. Leach[1], and Maria A. Schmidt[1]

[1]*CR-UK and EPSRC Cancer Imaging Centre, The Institute of Cancer Research and Royal Marsden NHS Foundation Trust, Sutton, Surrey, United Kingdom,* [2]*Department of Radiology, Royal Marsden Hospital, Sutton, Surrey, United Kingdom,* [3]*Clinical Research and Development, Royal Marsden Hospital, Sutton, Surrey, United Kingdom*

Introduction

The analysis of breast dynamic contrast-enhanced (DCE) examinations is susceptible to error due to subject movement, which may impact on the classification of contrast agent (CA) uptake curves. Post-processing by using rigid registration of the breast volume is sometimes used to compensate for this motion. Since an in-plane resolution of <1 mm is recommended [1], an evaluation of image registration effectiveness on small enhancing structures is particularly pertinent, as the use of high resolution images presumes correct registration between consecutive datasets. This abstract retrospectively considers the enhancement of axillary vessels in the breast in order to approximate the effect of rigid in-plane registration on the CA uptake curves derived from small enhancing structures.

Method

MRI Protocols: Routine clinical DCE breast examinations were performed at 1.5T (Philips Intera) using a dedicated breast coil and 3D fat-suppressed spoiled gradient echo sequences [TR/TE = 4.7/2.3 ms; FA = 14°; In-plane reconstructed resolution = 0.68 x 0.68 mm^2; Slice thickness = 1.25 mm, 125 slices]. Patients were positioned at the coil centre by experienced radiographers. A single dose of DOTAREM (Guerbet, France) was administered at 3 ml/s (MedRad, USA) in a standardized procedure, and each dynamic series consisted of one pre-contrast and eight post-contrast axial images. Between May 2011 and June 2012, 10 patients were selected at random and anonymised. Retrospective analysis of patient examinations was approved by the Clinical Audit Committee.

Registration and CA Uptake Curve Analysis: In each examination, the central axial slice was selected and the most inferior axillary vessel located within the right breast. Rigid in-plane registration, based on a cross-correlation algorithm, was applied separately to (i) a region of interest (ROI) encompassing the right breast (180x180 pixel^2) and (ii) a smaller ROI containing the vessel itself (18x18 pixel^2) to provide a global and local registration, respectively. A 3x3 pixel^2 ROI was applied to the vessel in the most enhanced dynamic frame, and used to construct an average CA uptake curve for the unregistered, globally and locally registered image sets. The area under the curve (AUC) was calculated for each CA uptake curve. In addition, the signal enhancement ratio (SER = $(SI_{last} - SI_0)/(SI_{first} - SI_0)$) was determined to provide a quantitative measure of post-contrast behaviour: <0.9 = wash-out, 0.9-1.1 = plateau, >1.1 = continuous enhancement [2]. The maximum in-plane vessel displacement, recorded with sub-pixel resolution by the registration algorithm, was defined and calculated as the vector sum of the maximum excursions in x and y.

Data Analysis: Values of maximum displacement (d) were compared between the globally and locally registered image sets using a paired Student's t-test ($p<0.05$ indicating significance). AUC and SER values between globally and locally registered data versus unregistered data, respectively were compared using Student's t-tests ($p<0.05$ indicating significance), applying the Bonferroni correction for multiple comparisons. In addition, the effect of registration on curve shape was further investigated by measuring the correlation between maximum displacement and the difference in AUC for globally and locally registered data against unregistered image sets.

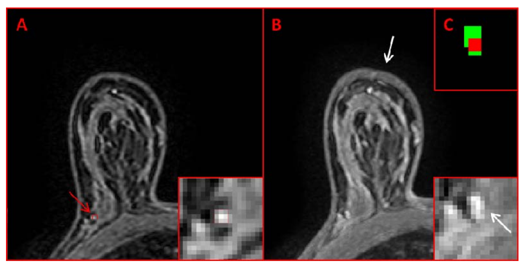

Figure 1: A representative case exhibiting pronounced motion. **A:** Global (180x180 pixel^2) and local (18x18 pixel^2) registration of inferior axillary vessel (3x3 pixel^2 ROI indicated by red arrow); **B:** Maximum intensity projection across dynamic series, white arrows indicate areas most affected by patient movement; **C:** Excursion path of ROI under local registration.

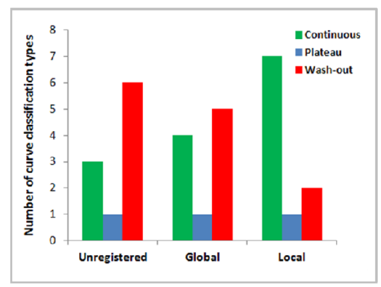

Figure 3: Number of CA uptake curves classified as continuous, plateau and wash-out by SER calculations, in unregistered, globally registered and locally registered groups, respectively.

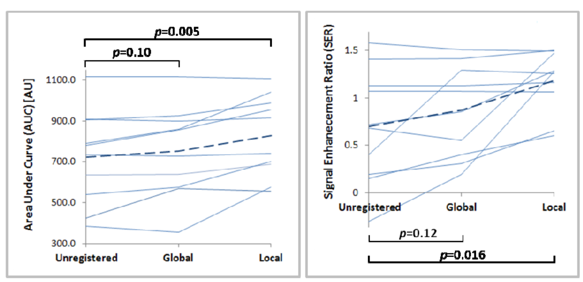

Figure 2: Ladder plots comparing the difference between unregistered, globally registered and locally registered data sets for AUC and SER parameters, respectively. Group means shown with hashed line. p values from paired Student's t-tests are indicated between relevant data sets.

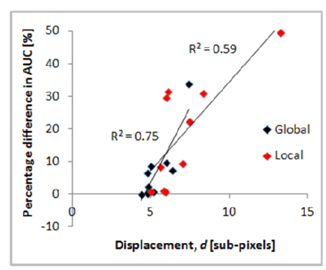

Figure 4: Plot of the absolute percentage difference in AUC from unregistered values versus vessel displacement (3x3 pixel^2 ROI) for global and local registration, respectively.

Results & Discussion

Figure 1 displays the central slice on a dataset affected by patient motion. Over the examinations analysed, patient movement was most pronounced between the pre-contrast and the first post-contrast images, and towards the end of the dynamic series. The maximum in-plane vessel displacement, d, was significantly greater under local (d_{local}) rather than global (d_{global}) registration (7.1±2.4 and 5.4±0.9 pixels respectively, $p=0.02$). Ladder plots for AUC and SER values are shown in Figure 2. Differences in AUC and SER values between globally registered and unregistered data were not statistically significant (753±221 *vs*. 723±229, $p=0.10$ and 0.87±0.48 *vs*. 0.70±0.60, $p=0.11$, respectively). In contrast, the equivalent difference between locally registered and unregistered image sets was found to be significant (827±197 *vs*. 723±229, $p=0.005$ and 1.18±0.32 *vs*. 0.70±0.60, $p=0.016$, respectively). Although global registration changed the classification of CA uptake curves in 10% of cases, this increased to 40% under local registration (see Figure 3). d_{global} and d_{local} were both found to correlate with the absolute percentage difference in AUC for globally and locally registered images sets against unregistered data (R^2 = 0.75 and 0.59, respectively) (see Figure 4).

Conclusion

Global rigid registration was unable to fully compensate for structure motion across the dynamic series, impacting on the shape of the CA uptake curves derived from the examinations. Greater motion across the dynamic series equated to a greater change in the CA uptake curves. This work examines the effect of motion on CA uptake curves derived from a 2 mm^2 ROI, centred on an axillary vessel to approximate a small enhancing structure. Even though sub-pixel resolution is recommended, this study indicates that CA uptake curves drawn on a 2 mm^2 ROI are likely to be unreliable, despite use of global registration. This work suggests high in-plane resolution in itself may not necessarily improve the ability to detect small cancers by analysis of DCE uptake curves. Further work is required to explore registration strategies (3D, non-rigid) on a larger number of patients.

References: [1] ACR Practice Guideline: Breast MRI, Revised 2008 (Resolution 25); [2] Jansen *et al*., AJR Am J Roentgenol, 2009, 193(3): 832-839.

Acknowledgements: We acknowledge the support received for the CRUK and EPSRC Cancer Imaging Centre in association with the MRC and Department of Health (England) (grants C1060/A10334 and C16412/A6269), NHS funding to the NIHR Biomedical Research Centre, and the Technology Strategy Board (grant M1550J).