Three dimensional acute radiofrequency ablation lesion visualisation and correlation with electro-anatomical mapping system ablation points.

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Figure 1: *Flow diagram of image fusion technique showing all transformations used.*

Figure 2a-b: *Delayed enhancement images pre- and post–intervention, respectively. Red arrows show areas of enhancement present post intervention.*

Figure 3a-b: *3D visualisation of the left atrium (a-posterior, b-anterior) with the delayed enhancement signal intensities mapped*
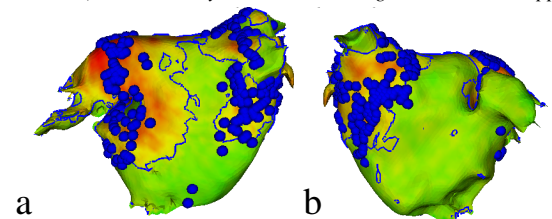
Figure 4a-b: *Intensity mapped surfaces with a defined contour and overlaid by the ablations points acquired with NavX.*

Introduction Radio-frequency ablation (RFA) has become an increasingly common treatment for cardiac arrhythmias, such as atrial flutter (AFL) and atrial fibrillation (AF). The procedures are carried out using X-ray fluoroscopic guidance and are usually assisted by using electroanatomical mapping systems (EAMS) such as EnSite/NavX (St. Jude Medical) and CARTO (Biosense Webster). EAMS provide the ability to visualise where lesions were delivered but they cannot reveal the extent of the myocardial tissue damage caused. The ability to visually assess the location and extent of the actual RFA lesions at the time of the procedure would be of great importance in correlating the extent of ablation lesions with clinical outcome and identifying those factors that predict arrhythmia recurrence. Magnetic resonance imaging (MRI) has been shown to be an effective technique for the detection of the presence of ablation lesions [1] using delayed contrast enhanced MRI. However, the interpretation of the ablation pattern from a series of 2D slices is difficult. We present an automated method for the 3D visualisation of ablation lesions that allows for an intuitive assessment of lesion patterns. In this investigation, we demonstrate how our novel technique can be used to verify lesions locations shown by EAMS.

Methods *MRI protocol:* Eleven patients underwent RFA treatment for either AF (n=8) or AFL (n=3) by catheter intervention with RF ablation. Pre- and post-intervention, the patient underwent an MR examination. If the intervention was performed in the XMR setting, the intervention and the pre- and post-procedure MR scans were performed whilst the patient remained on the MR table. Otherwise the pre- and post- MR scans occurred the day before and after the intervention, respectively. Ablation points were acquired either using the XMR [2] (n=3, AFL patients) or using NavX (n=8, AF patients) EAMS. In the MR examination a number of scans have been applied: a 3D, T_2-prepared, free-breathing balanced turbo field echo (b-TFE) scan for registration purposes; a MR angiography (MRA) scan of the left or right atrium following administration of a 0.4ml/kg dose of 0.5mmol/ml Gd-DTPA; and a delayed enhancement scan approximately 20 minutes after contrast administration. The latter scan was a 3D, ECG-triggered, inversion recovery (IR) TFE scan with respiratory navigation, TR/TE/α were 6.3ms/3.0ms/30°, resolution of $1.3\times1.3\times2mm^3$, and an acquisition window of approximately 120ms. The IR delay time was determined from a look-locker sequence for the partial suppression of both myocardium and blood. The number of slices was set for complete coverage of the left or right atrium. *Image Fusion:* A 3D surface of the left or right atrium was automatically segmented from the MRA by thresholding. This surface was then fused with the post delayed enhancement MR images as shown in Figure 1. Once fused, a maximum intensity projection (MIP) was performed into the delayed enhancement images at normal vectors to the surface at a length of ±3mm. The MIP values were displayed as a colour value at the surface vertices. Enhancement was defined by a contour for the purpose of correlation with EAMS ablation points. This contour was defined as any area of signal intensity greater than the mean plus three standard deviations of an area of healthy myocardium. All NavX geometries and ablation points were exported and reconstructed. The NavX surface and an MR-derived cardiac volume were registered using a landmark-based registration, where landmarks were defined as the PV ostia of each surface. This allows the transformation of ablation points to the cardiac surface. XMR mapping system ablation points were located onto a cardiac surface during the intervention and so no additional processing was required. Each ablation point was then positioned onto the cardiac surface at the nearest vertex.

Results On inspection of the delayed enhancement MRI, as shown in Figure 2, it can be seen that in the region of the PVs an area of enhancement has appeared in the post intervention image (Figure 1b) that was not present pre intervention (Figure 1a). The 3D representation, as shown in Figure 3 allows visualisation of the pattern of ablation. From this, areas void of enhancement (blue arrow, Figure 3a) are easily visible. Ablation points were also overlaid (Figure 4) to assess correlation of delayed enhancement with ablation points. From all the patients with ablation points acquired with NavX, on average 61% of the points were found within the predefined contour. Using the XMR-EAMS, this number was 100%, however, these were patients undergoing RA ablation for AFL, and so there are fewer lesions, and the patterns are simpler.

Discussion and Conclusions Observation of the MR images was sufficient for the detection of RF ablation lesions and scarring. However, determination of the completeness of the intended ablation patterns is difficult to determine by observation of 2D MR images. Automatically transferring the MIP signal intensities from the MR images onto an anatomically derived cardiac surface offers greater intuition for the determination of the ablation patterns. Due to the number of transformation steps involved in this type of image fusion, there is the potential to introduce errors. The two largest sources of error will arise from (1) patient motion during an MR protocol, as DICOM geometries are used for image fusion, and (2) from segmentation errors. Cardiac phase may also play a role if the heart rate changes significantly between pre- and post-intervention imaging. Segmentation errors may become significant if the quality of the MRA is poor. Further investigation into the effect of errors will be conducted. In summary, we have presented a novel technique to visualise RFA lesions that are detected using MRI. We illustrate one of the uses of our technique for assessing the correlation of ablation points as indicated by EAMS and actual lesion delivery as measured by MRI. We envisage that our approach will make the interpretation of MRI-based RFA lesion imaging more intuitive and allow it to become a useful tool for electrophysiology procedures.

References

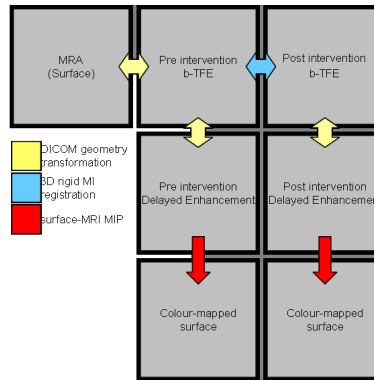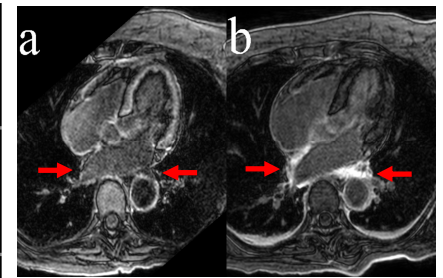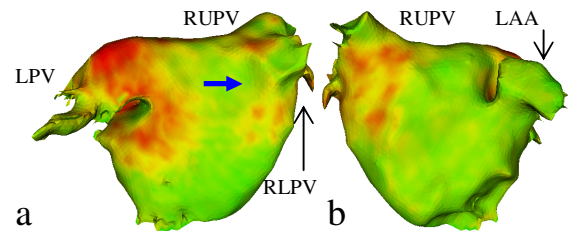[1] Peters DC *et al.* Radiology 2007;243:690-695.. [2] Rhode KS. *et al.* IEEE TMI 2005;24:1428-1440.