MULTI-STAGE CLUSTERING OF DIFFERENT HEART TISSUES IN PATIENTS USING COMPOSITE STRAIN ENCODING (C-SENC) MRI IMAGES

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INTRODUCTION

The combination of myocardial functional and viability images is useful for identifying different tissue types of the heart. This is important for therapeutic decision making in patients with myocardial infarction (MI). Composite strain encoding (C-SENC) MRI imaging provides both functional and viability images at the same cardiac phase (1). This allows for applying automatic clustering techniques without suffering from misregistration problems. In this work, a multi-stage clustering technique was applied to the resulting C-SENC images of seven patients. The technique used both fuzzy c-means (FCM) and ISODATA clustering methods. Normal myocardium, infarction, and blood were successfully identified using the proposed technique. In addition, different degrees of contractility were assigned to the non-infarcted myocardium.

METHODS and EXPERIMENTS

Seven patients (6 males and 1 female; average age = 50; 6 have MI) were scanned on a 3T Philips MRI scanner. The subjects were injected with 0.2 mmol/kg of GD-DTPA. Then, 10-15 minutes post injection, C-SENC images were acquired. The imaging parameters were: TR = 18 ms; TE = 2.6 ms; scan duration = 11 s; trigger delay (TD) ≈ 300 ms (adjusted to image at end-systole); and flip-angles = 27˚, 32˚, and 40˚ for the three C-SENC images: No-Tuning (NT), Low-Tuning (LT), and High-Tuning (HT), respectively. The NT, LT, and HT images were consecutively acquired in a single acquisition. Bright regions in the NT, LT, and HT images represent infarcted, akinetic, and kinetic myocardium, respectively. Figure 1 shows representative images resulting from C-SENC imaging, as well as anatomical and strain images computed from the LT and HT images (2).

Different tissues of interest appear well clustered in the NT-HT-Anatomy subspace. Blood appears bright in the NT image and dark in the HT and Anatomy images. Infarcted myocardium appears bright in the NT and Anatomy images and dark in the HT image. Normal myocardium appears bright in the Anatomy image, has medium brightness in the NT image, and occupies a continuum of intensities in the HT image.

Figure 2 shows a schematic diagram of the proposed unsupervised clustering technique. It consisted of two stages. In the first stage, the Fuzzy-C-Means (FCM) algorithm (3) was applied to the NT-HT-Anatomy subspace and the number of clusters was set to three. The fuzzy c-means membership matrix was initialized using the minimum Euclidean distance principle. From the membership matrix, the centers of the clusters, as well as a dissimilarity measure were calculated. The fuzziness factor, m, was set to 2. This resulted in three clusters: blood, background noise, and myocardium (both contracting and non-contracting). In the second stage, the myocardium cluster was further clustered into normal myocardium and infarction, if applicable, using the fuzzy Iterative Self Organizing Data (ISODATA) technique (3). The maximum number of clusters was set to two. The clustering algorithm was iterated until the improvement in the dissimilarity measure reached a preset threshold or the pre-defined maximum number of iterations was reached. Finally, the pixels in the normal myocardium cluster were given different grades of color based on contractility.

RESULTS

Figure 3 shows the 3-D distribution of the signal intensities, and the resulting clustered images, of a ROI encompassing the heart shown in fig. 1, after applying the proposed clustering technique. The clustering algorithm took 18 iterations. Red, blue, and black represent blood, infarction, and background noise, respectively. Normal myocardium is represented by grades of green depending on contractility. An interesting point is that there is a white rim adjacent to the infarction in the clustered image. This region is not contracting, however it is not dead. More results from other patients are also shown in figure 4.

DISCUSSION and CONCLUSIONS

C-SENC imaging provides simultaneous functional and viability imaging that allows for automatic clustering. The proposed clustering technique showed successful in identifying different heart tissues in patients. The technique resulted in three or four clusters based on myocardium condition. If proved clinically, the clustered images can be useful for revealing more information about the myocardium, for example identifying hibernating or stunned tissues (outer arrows in figure 3), which has big impact in therapeutic decision making.

REFERENCES
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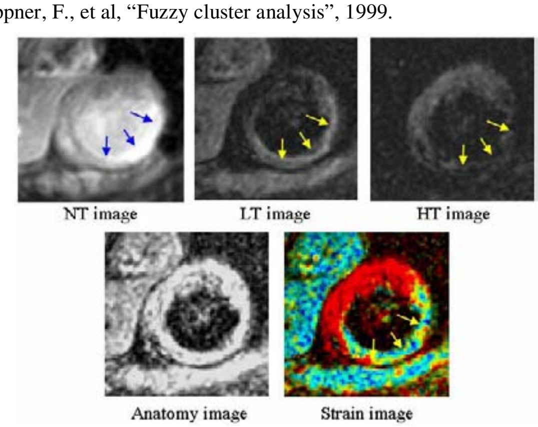

Fig. 1: Representative C-SENC images. Infarction is marked by arrows.

ACKNOWLEDGEMENTS
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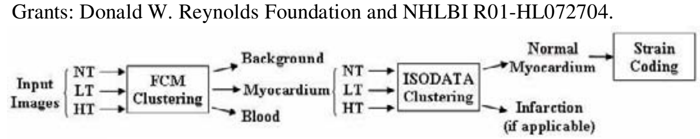

Fig. 2: Schematic diagram of the clustering method.

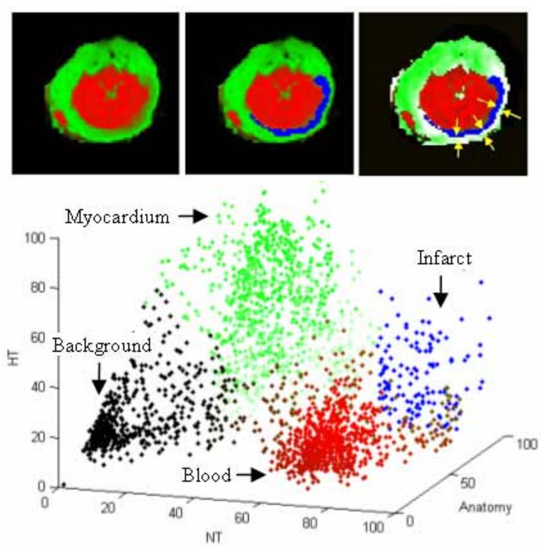

Fig. 3: The resulting images after applying each stage of the clustering method: FCM (left), ISODATA (middle), and strain coding (right). The figure also shows the NT-HT-Anatomy density distribution of the final image.

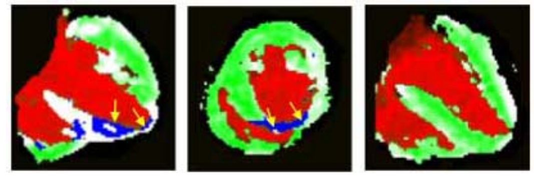

Fig. 4: The resulting clustered images from other patients (the third image is for a volunteer who did not have infarction).