A NEW ROBUST TECHNIQUE FOR SEGMENTING DIFFERENT HEART TISSUES USING COMBINED FUNCTIONAL AND VIABILITY C-SENC MR IMAGES

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INTRODUCTION

Assessment of myocardial viability is important for therapeutic decision making in patients with suspected myocardial infarction (MI). In addition, functional MRI provides important complementary information about the contractile status of the heart muscle. Composite Strain-Encoding (C-SENC) MRI enables acquiring both viability and functional images at approximately the same cardiac phase (1). In this work, a new unsupervised fuzzy clustering algorithm is applied to C-SENC images in order to identify different heart tissues: normal myocardium (with preserved contractility), infarcted myocardium, and blood. The technique was compared to the more common fuzzy c-means (FCM) clustering technique (2) for robustness.

METHODS and EXPERIMENTS

Using C-SENC MRI, three images result: low-tuning (LT), high-tuning (HT), and no-tuning (NT). Bright regions in the NT, LT, and HT images represent infarcted, akinetic, and contracting tissues, respectively. A black-blood, anatomical image of the heart can be obtained by addition of the LT and HT images. The NT, HT, and Anatomy images were used to build a 3-D space model of the heart, where different tissue types can be identified.

The fuzzy c-means (FCM) clustering technique (2) is widely used in many applications. FCM assumes hyperspherical clusters. Thus, it can only detect clusters with the same shape. However, multiple clusters in a dataset can have different shapes and orientations as a result of noise or other factors in the imaging process. Gustafson and Kessel (GK) extended the standard FCM algorithm by employing an adaptive distance, in order to detect clusters of different geometrical shapes in the data set (2).The GK algorithm allows each cluster to adapt to the local topology of the data.

The proposed GK clustering technique was adjusted to allow for automatic determination of MI, if present. An upper bound for the number of clusters was estimated, and the clustering algorithm was run for the different cases. For each partition, the Xei and Beni (XB) validity index (2) was computed. The XB index quantifies the ratio of the total variation within clusters and the separation of clusters. The optimal number of clusters minimizes the index. Blood, background noise, non-infarcted myocardium, and infarct (if present) were colored in red, black, green, and blue, respectively. Non-infarcted tissue was assigned different shades of green based on contractility. The clustering algorithm took about 15 iterations.

A numerical model of the NT, HT, and Anatomy cardiac images was created. Different degrees of Gaussian noise were added to the different images in order to test the proposed technique for identifying clusters with different shapes. The technique was also applied to the images from four dogs with reperfused MI. The results of the GK algorithm were compared to those of the FCM algorithm and the resulting tissue identified as infarcted was compared, on a pixel-by-pixel basis, to those from the standard delayed-enhancement (DE) images using the full-width at half-maximum (FWHM) technique. The dogs were scanned on a 1.5T Philips scanner with the following imaging parameters: TR/TE = 23/4.9 ms; FOV = 350×350 mm^2; slice thickness=10 mm; scan matrix=128×128; and 0.2 mmol/kg gadolinium-DTPA injected 10-15 minutes before image acquisition.

RESULTS

Figure 1 shows the simulation images of an infarcted heart after the addition of different degrees of noise. The figure shows the intensity distribution in the NT-Anatomy plane and the resulting clustered images after applying FCM and GK methods. Figure 2 shows the results from a representative dog study. The results show that the FCM method failed to identify the infarct cluster because its shape deviated from the spherical assumption; it rather split the infarct into two clusters. This resulted in discontinuities in the identification of the infarct in the clustered image (arrows). The GK algorithm successfully identified the infarcts as evidenced by the DE image. The proposed GK technique showed sensitivity and specificity of 88% and 87% with respect to the DE images in identifying infarcts.

DISCUSSION and CONCLUSIONS

Precise identification of the infarcted myocardium is important for proper therapeutic decision making. The proposed technique was capable of classifying heart tissue viability despite the existence of different degrees of noise. The technique resulted in high concordance with the DE images. The GK-clustered images could help reveal more information about dysfunctional, viable myocardium, e.g. identifying hibernating or stunned tissues.

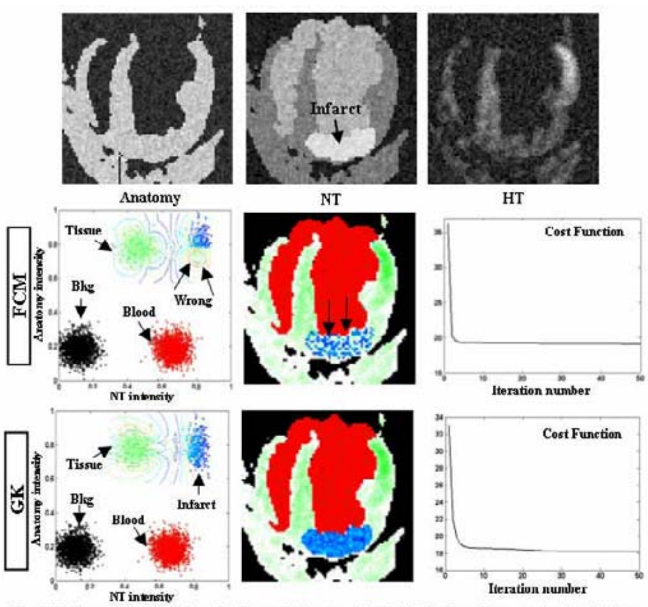

Fig. 1. Numerical model of infarcted heart. The FCM algorithm split the infarct cluster into two clusters (arrows). The GK algorithm successfully identified the infarct cluster despite its elongation in the Anatomy axis (blue cluster).

REFERENCES

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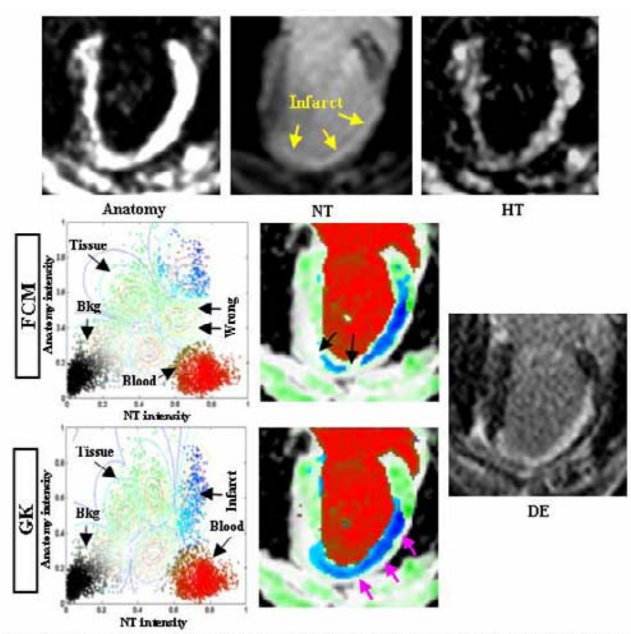

Fig. 2. Results of an infarcted dog. The GK algorithm successfully identified the infarct cluster despite its elongation in the Anatomy axis. The clustered infarct has good agreement with the DE image. The GK-clustered image could even show hibernating or stunned myocardium (arrows).