Fuzzy Clustering of Heart Tissues from Combined Function and Delayed-Enhancement MRI Images

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INTRODUCTION

The ability to distinguish viable and non-viable dysfunctional tissues is important for guiding clinical therapy and predicting long term outcomes in patients after myocardial infarction [1]. However, using MRI, seldom are functional and viability images acquired at the same point in systole to allow registration and automated clustering to determine tissue viability and functional status. The modification of Strain Encoding (SENC) MRI to acquire both delayed enhancement and regional function images simultaneously in a single short breath hold provides an imaging method to enable automated classification techniques. Using these SENC viability/function images, a multidimensional space for the heart can be determined, wherein blood, contracting, non-contracting, and dead tissues are clustered using fuzzy c-means method.

METHODS

SENC MRI is usually used to determine myocardial contractility by acquiring two images with different z-phase encoding. These two images are referred to as Low Tuning (LT) and High Tuning (HT) images and can be used to create a functional map of the heart [2]. To obtain a T1-weighted delay-enhancement image, a third SENC image with no phase encoding (No Tuning, NT) is acquired after contrast injection. A combined method to obtain LT, HT, and NT images in a single breath-hold has recently been developed [3].

A dog with a reperfused myocardial infarction was scanned on a 1.5T scanner (Philips Gyroscan Intera) using spiral pulse sequence. Figure 1 shows the pulse sequence. The experiment parameters are: 0.2 mmol/kg gadolinium dimeglumine, 6 sec breath hold, 200 ms trigger delay , 23 ms TR, 4.9 ms TE, 350 mm FOV, 66.68 kHz bandwidth, 128×128 matrix, 12 spirals, and 10 mm slice thickness. Figure 2 shows the images acquired with this method (the Anatomy image is calculated from the HT and LT images [2]). Each image emphasizes some aspect of the tissues under consideration: bright parts in the NT, HT, and LT images represent infarct, kinetic, and akinetic regions, respectively. The NT-HT-Anatomy subspace is found suitable for identifying different contents of the image: blood, infarct, myocardium (contracting and non-contracting tissues), and background.

RESULTS

Figure 3(a) shows the NT-HT-Anatomic intensity distribution of different tissues, in a region of interest around the heart, and the coloring of pixels after being clustered using fuzzy c-means method. Red, blue, and black represent blood, infarct, and background, respectively, while other tissues are represented by colors ranging from yellow, for non-contraction, to green, for maximum contraction. The segmented image is shown in Figure 3(b).

DISCUSSION and CONCLUSIONS

The combined functional/delayed-enhancement images acquired with SENC MRI provide information about different tissues of interest that are intrinsically registered. Fuzzy c-means provides a powerful tool for clustering the NT-HT-Anatomy space into identifiable tissue types. Moreover, the resulting clustered image can be used to reveal more information about the heart, for example, identifying regions of the myocardium that may not appear in the delayed-enhancement image as infarct, but are dysfunctional. Thereby, improved therapeutic decisions can be made and monitoring by serial MRI exams can be performed non-subjectively.

REFERENCES

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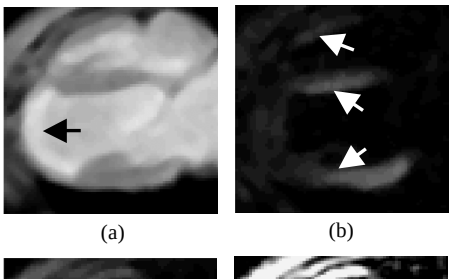
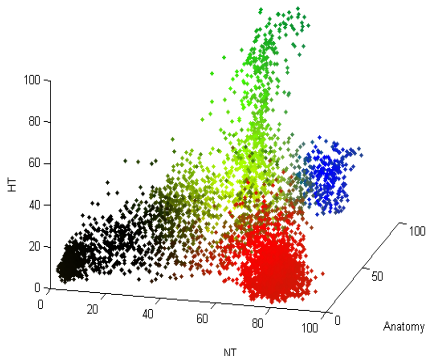
Figure 1: The steps, during one cardiac cycle, of the pulse sequence used.

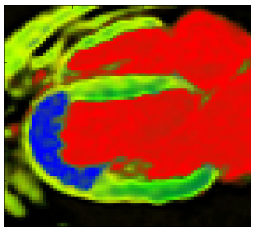


(a) (b) (c) (d)

Figure 2: The acquired images. (a) NT image (arrow points to infarct), (b) HT image (arrows point to contracting tissues), (c) LT image shows non-contracting tissues, (d) Anatomy image shows tissue (contracting and non-contracting)



(a)



(b)

Figure 3: Fuzzy clustering. Infarct, blood, background, contracting tissue, and non-contracting tissue are represented in blue, red, black, green, and yellow, respectively. (a) The NT-HT-Anatomy distribution of different clusters, (b) The segmented image.