21 Tesla Rat Heart Magnetic Resonance Microimaging By Paramagnetic Anti-Troponin Bound Polyethylene Based Iron-Oxide Nanoparticles And Image Processing

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Abstract:

A nanoparticle (SPIOT) containing antitroponin coated and polyethylene encapsulated biotin-avidin-iron-oxide core in center was used in microimaging of rat heart at 21 Tesla MR by rapid 3D fast low angle shot, 3D gradient echo flow compensated and mutislice multiecho MR imaging techniques. The rat heart images were processed for the measurement of cardiac wall, ventricle volume, aorta, possible orientation details of cardiac myofibrils tissue and cardiac atlas with cardiac shape, texture and motion analysis.

Introduction:

The rat heart 3D MR images have both diagnostic and therapeutic implications. SPIOT particles serve to visualize heart muscle orientation using antibody-troponin binding (functionality) within muscle and generate dephasing heart maps due to iron-oxide paramagnetic character. The heart shape on images may predict cardiac function.

Preparation of nanoparticle composites:

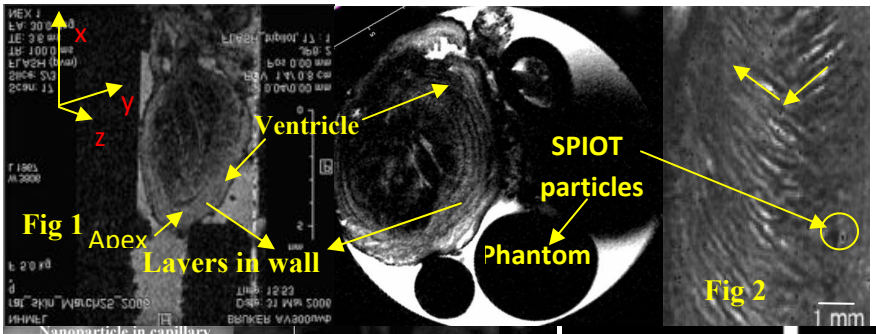
The method has three steps: 1. synthesis of iron-oxide particles; 2. Formation of polymer-iron oxide composite; 3.Protein Coupling with the Polyethylene Composite Particles.[1].The structure of SPIOT is: Fe_3O_4-Avidin-Polyethylene-Biotin-Anti-Troponin. It binds with troponin.

Materials and Methods:

The nanoparticle-based microimaging was done on 21T MR vertical bore imager using standard animal protocols[1]. The imaging techniques were used: i. GE Flow compensated; ii. 3D FLASH pulse sequence; iii. Multislice multiecho spin echo sequence; iv.The diffusion-sensitizing bipolar gradients in six non-colinear directions using TE = 18 ms; TR = 10000 ms; time interval between gradient pulses = 5 ms; gradient pulse duration = 0.5 ms, gradient factor = 950 s/mm^2, b value 950 s/mm^2, in-plane resolution a 35x35 µm, slice thickness = 1 mm, slice gap = 0.5 mm, number of slices covering heart = 7[1]. Image processing was done by MRI analysis package and ImagePro software.

Results:

At 21 Tesla, 3D reconstruction using ImagePro 3D reconstructor program, 3D set of FLASH images displayed heart images in three planes [Fig 1]. The diffusion tensor imaging weighted (DTI) images with diffusion-sensitizing bipolar gradients showed six non-colinear directions displayed as tensor maps. Quantitative characterization showed contraction related fiber orientation at apex, midventricle, apex from primary eigenvector and sheet *orientation* by secondary and tertiary eigenvector offers an evaluation of radial myofiber shortening [Fig 2]. Segmentation: It was iterative method to estimate maximum likelihood (correct classification) [Fig 3]. Delineation and measurement of feature mass showed vascular area and shape analysis showed cardiac features[Fig 4].



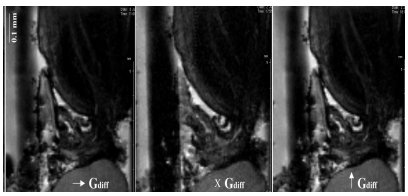


Fig 2 DW images(on top)

Fig 1:21T MRI Heart image at TE/TR 8/100

Fig 2:The diffusion-wt images as tensor maps (on top). On left, fiber orientation is shown with SPIOT particles trapped inside (shown in circle).

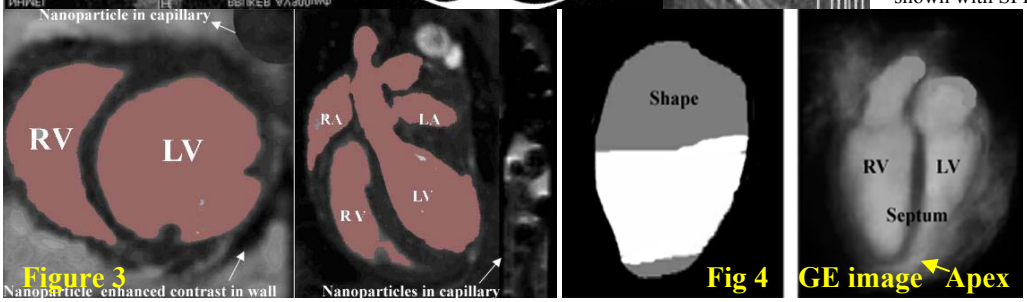


Fig 3:Segmentation to measure colored area of different features.

Fig 4:Shape analysis showed comparable shape with MSME and GE image on right panel

Discussion:

At 21T ultrahigh resolution, cardiovascular layers were well defined. The route and location of nanoparticles were visible on images. The cardiac flow parameters were measurable. The cardiac muscle fiber orientation was visible by diffusion-wt images. Other analysis for: Construction of probabilistic atlas of heart; Probabilistic maps; Intensity template: Semiautomated segmentation approach effective diffusion tensor (D_{eff}), diffusion characteristics, myocardial fiber orientation, and Laminar fiber sheet orientation showed the technique as robust[1].

Conclusion:

The heart imaging was able to visualize fibers well with trapped nanoparticles to do segmentation and analysis of muscle fiber orientation. The microimaging technique by 21T MRI is technical advancement suitable to labs to design functional imaging contrast agents.

References

1. US patent. http://www.freepatentsonline.com/y2009/0220434.html