Dual echo balanced SSFP for positive contrast of passive nitinol devices in MRI-guided cardiovascular interventions

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TARGET AUDIENCE
This abstract is intended for researchers and clinicians in interventional MRI interested in utilizing commercially available passive nitinol devices.

PURPOSE
MR-guidance of cardiovascular interventions potentially offers an ionizing radiation-free alternative to traditional X-Ray guidance. In order to perform interventions under MR-guidance, imaging sequences must be fast, interactive and low SAR. Guidewires and needles are manufactured commercially using MR-safe paramagnetic materials, such as nitinol. However, visualization *in vivo* using only the signal void caused by T2* properties is difficult in practice. We aimed to develop a real-time imaging method to improve visualization of commercially available passive nitinol devices *in vivo*.

Bright positive contrast of paramagnetic materials can be generated by exploiting local field gradients induced by the material to compensate for gradients in the pulse sequence which otherwise cause background signal dephasing [1,2]. In this abstract, we demonstrate a dual echo balanced SSFP sequence which generates both a positive contrast image of the device and an anatomical image in a single acquisition, allowing for real-time visualization of passive nitinol interventional devices, with variable flip angle for reduced SAR.

METHODS
Pulse Sequence: The dual echo bSSFP sequence uses incomplete slice-selective gradient refocusing, relying on local field gradients to complete refocusing and conserve signal around the wire, while in the background, spins remain dephased through-plane. A gradient blip between echoes serves to complete slice refocusing for the second echo (Figure 1). A variable flip angle scheme was implemented, with high flip angles only for center k-space lines [3]. Partial echoes of 75% were used to reduce TR. The dual echo sequence was incorporated into the interactive real time protocol used for imaging during interventions, such that the dephased echo can be switched on/off, the magnitude of dephasing gradient moment can be modified and the flip angle range can be varied interactively while scanning.

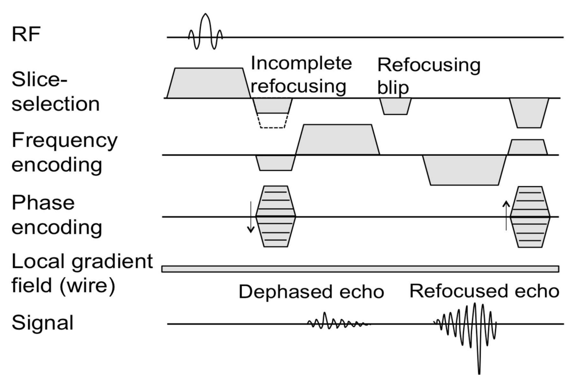

***Figure 1:** Dual echo bSSFP pulse sequence diagram*

Post Processing: To remove high signal intensity in the dephased echo image caused by the coil sensitivity at the chest wall, the inverse of the refocused echo image (maximum signal – image signal) is squared and multiplied by the dephased echo image to highlight the wire (Figure 2). Thresholded high signal intensity pixels are overlaid in color on the anatomical image to guide interventional procedures. This post-processing is performed in the Siemen's Image calculation environment (ICE) and images are displayed for the operator in real-time on the Interactive Front End (IFE) interface.

In vivo proof-of-concept: Imaging was performed on a 1.5 T Siemens Aera scanner (Erlangen, Germany). Animal experiments were conducted according to local ethical guidelines. As a proof-of-concept for this method, a 0.035" Nitrex nitinol guidewire (Covidien, Dublin, Ireland) was inserted transfemorally to the thoracic aortic arch of a pig and imaged. Scan parameters were: $TE_1/TE_2/TR$= 1.15/2.83/3.89 ms, flip = 20-40°, matrix = 128^2, FOV = 300 mm, 32 center lines acquired with high flip, 48 lines ramp flip up/down, slice thickness = 8 mm, slice refocusing gradient moment reduced by 90%.

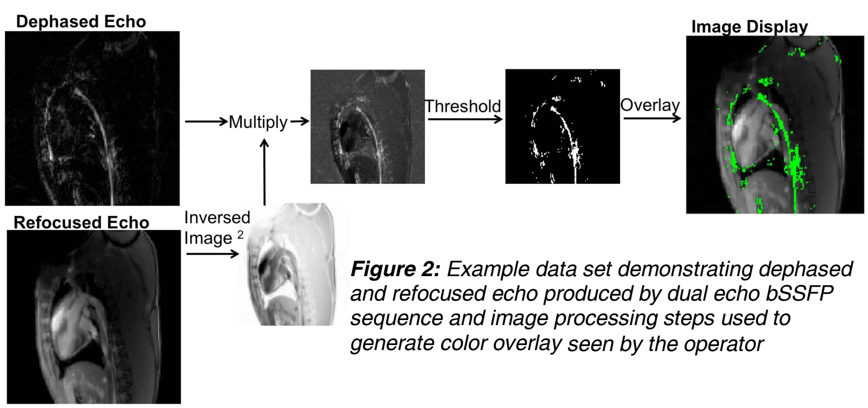

***Figure 2:** Example data set demonstrating dephased and refocused echo produced by dual echo bSSFP sequence and image processing steps used to generate color overlay seen by the operator*

RESULTS
This sequence generates 3 frames/second using an acceleration factor of 2. The dephased echo generated a clear positive contrast visualization of the guidewire *in vivo* (Figure 2). Signal scaling with the inverse of the anatomical image successfully removes confounding signal from the chest wall, however spurious signal remains at tissue interfaces. The variable flip angle scheme maintained good blood-myocardium contrast, while reducing the total RF energy to 68%, compared to a constant flip angle of 40°.

DISCUSSION AND CONCLUSION
The use of a dual echo sequence improves temporal resolution and reduces the RF power required to generate two images with difference contrasts. Further image processing will be utilized in the future to reduce the presence of spurious signal from tissue interfaces. Additional commercially available and modified guidewires will be tested in the future to improve conspicuity of the wire tip. This work has demonstrated a dual-echo balanced SSFP sequence to improve visualization of commercially available nitinol devices, without modification, during real-time MRI, and will be useful for cardiovascular interventions.

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