How to Write an Abstract

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Comparison of non-contrast in-flow inversion recovery (Inhance) steady state free precession renal MRA at 1.5T and 3T

D. W. Stanley[1], J. F. Glockner[2], N. Takahashi[2], S. L. Williams[2], M. R. Wood[2], N. Takei[3], and S. Wei[4]
[1]GE Healthcare, Proctor, MN, United States, [2]Mayo Clinic, Rochester, MN, United States, [3]Applied Science Laboratory Japan, GE Yokogawa Medical Systems, Hino, Tokyo, Japan, [4]MR Engineering, GE Healthcare, Waukesha, WI, United States

Purpose: Contrast-enhanced MR Angiography (CE-MRA) is a widely accepted technique for evaluation of the renal arteries; however, recent concerns regarding the development of nephrogenic systemic fibrosis (NSF) after gadolinium contrast agent administration in patients with reduced renal function have emphasized the need for robust non-contrast MRA methods. One such technique is steady state free precession with in-flow inversion recovery (Inhance). In early evaluation, Inhance has produced accurate and reliable images of the renal arteries in a variety of patients at 1.5T. Inhance at 3T offers both potential advantages (improved SNR) and limitations (increased image artifact). We compared image quality and diagnostic accuracy of Inhance at 1.5T and 3T in a series of volunteers and patients.

Methods: Inhance is an angiographic method to utilize inflow effect during the inversion time of a slab inversion pulse (IR). The IR pulse was respiratory-triggered and applied to the image volume region. The pulse was designed to suppress signal from veins such as the inferior vena cava and from static tissues of kidneys and to avoid saturating upstream arterial blood from the heart and thoracic aorta. Data were acquired in an axial 3D volume that includes the renal arteries using a steady state free precession sequence (FIESTA). It provides high blood signal and T2-like contrast.
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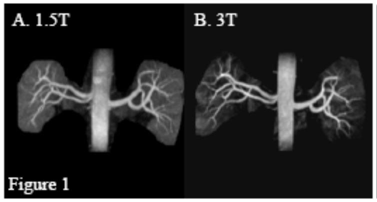

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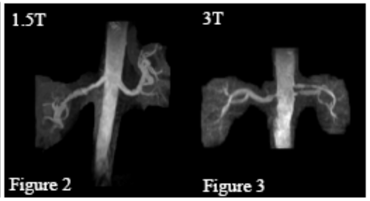

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David W. Stanley
MR Collaboration Leader
GE Healthcare

Contributors

- James Glockner, MD, PhD
- Steve Williams
- JoAnn Bromley
- Dan Rettmann
- Manoj Saranathan, PhD

Why write an abstract?

- Learn something new
- You find something fascinating
- Want to talk about an application that is unique at your site
- Teaching
- Networking

Outline

- What is an abstract
- Components of an abstract
- Types and examples
- Important tips
- Why write an abstract

What is an abstract?

- An abstract is a short summary of your completed research work. If done well, it makes the reader want to learn more about your work or project

Types of abstracts

- Research-Technical development
- Research/Clinical-A non commercially available clinical evaluation
- Clinical-commercially available clinical evaluation
- "How to" or "this is what we do"-describing an application

Components of an Abstract

- Motivation/problem statement
- Methods/procedure/approach
- Results/findings
- Conclusion/implications

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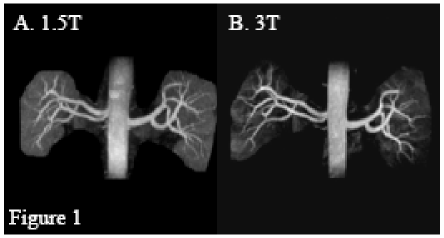

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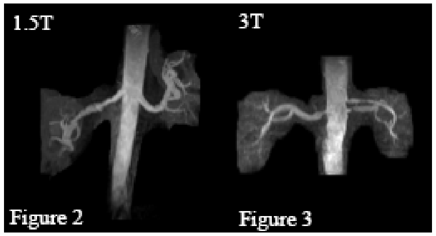

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Title and Authors

- Concise title
- List all authors who actually help you with the abstract
- List where the co-authors work and where

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Motivation/problem statement

- Why do we care about the problem?
- What practical, scientific, theoretical or artistic gap is your research filling?

Purpose: Contrast-enhanced MR Angiography (CE-MRA) is a widely accepted technique for evaluation of the renal arteries; however, recent concerns regarding the development of nephrogenic systemic fibrosis (NSF) after gadolinium contrast agent administration in patients with reduced renal function have emphasized the need for robust non-contrast MRA methods. One such technique is steady state free precession with in-flow inversion recovery (Inhance). In early evaluation, Inhance has produced accurate and reliable images of the renal arteries in a variety of patients at 1.5T. Inhance at 3T offers both potential advantages (improved SNR) and limitations (increased image artifact). We compared image quality and diagnostic accuracy of Inhance at 1.5T and 3T in a series of volunteers and patients.

Methods/procedure/approach

- What did you actually do to obtain your results?

Methods: Inhance is an angiographic method to utilize inflow effect during the inversion time of a slab inversion pulse (IR). The IR pulse was respiratory-triggered and applied to the image volume region. The pulse was designed to suppress signal from veins such as the inferior vena cava and from static tissues of kidneys and to avoid saturating upstream arterial blood from the heart and thoracic aorta. Data were acquired in an axial 3D volume that includes the renal arteries using a steady state free precession sequence (FIESTA). It provides high blood signal and T2-like contrast.

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Results/findings/product

- As a result of completing your project, what did you learn, invent or create?

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Conclusion/implications

- What are the larger implications of your findings, especially regarding the problem mentioned in the Introduction/Purpose?

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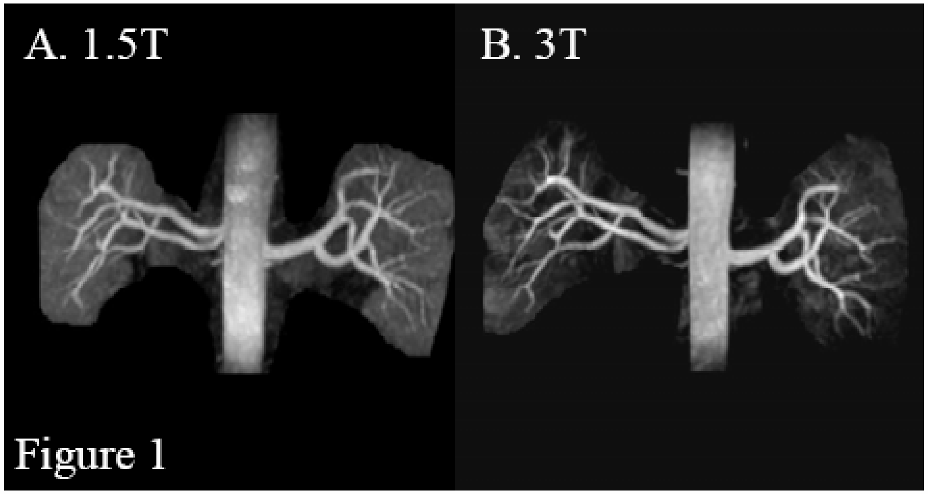
Include a visual aide

- Images
- Graphs
- Tables



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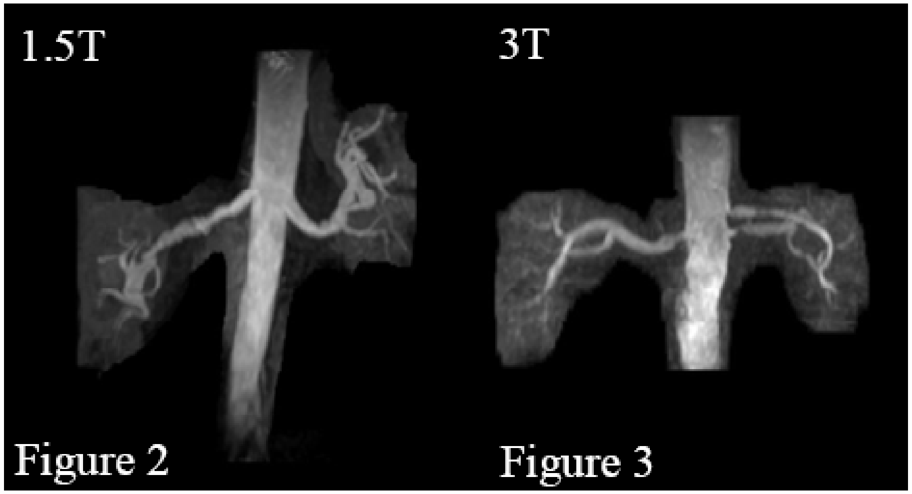

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Examples

1. Comparison of non contrast in-flow inversion recovery (Inhance) steady state free precession renal MRA at 1.5T and 3T
   - Research/Clinical evaluation
2. MRI Guided Focused Ultrasound Treatment of Uterine Fibroids
   - "How to"
3. Diagnostic Chronic Exertional Compartment Syndrome with MRI
   - "How to" or "this is what we do"
4. 3T MRI in the staging of Rectal Cancer
   - "How to" or "this is what we do"
5. MR Renal Angiography: CE MRA Versus Non-Contrast Inhance
   - Research/Clinical evaluation

Examples

6. High Spatial volume selective 3D FSE imaging
   - Research-technical
7. Clinical evaluation of a novel, near isotropic resolution volume selective 3D FSE pulse sequence for prostate MRI
   - Research/Clinical evaluation
8. MRI Enteroclysis
   - "How to" or "this is what we do"
9. Evaluation of vessel wall enhancement in vasculitis with myocardial delayed enhancement sequence: feasibility and preliminary results
10. Pericardial enhancement in pericarditis and pericardial constriction: evaluation with myocardial delayed enhancement sequences

9 and 10 are a combination of research pulse sequences, clinical evaluation and feasibility testing.

Important tips

- Find a GOOD Mentor (Doctor,Scientist,Technologist)
- Pick a topic that you are interested in
- Do a literature search--PubMed www.ncbi.nlm.nih.gov/sites/entrez
- Proof read your abstract 1000 times
- Have several people proof read it (one at a time)
- Study the abstract submission process carefully
- Have Fun!

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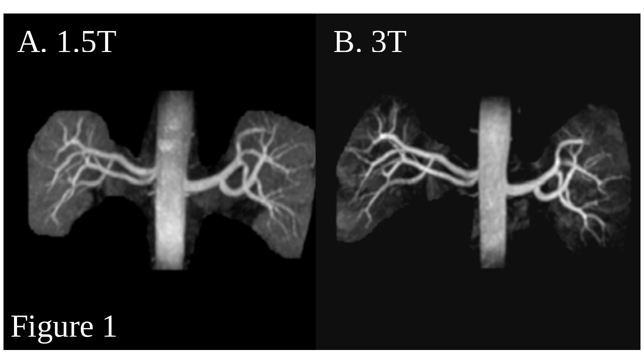

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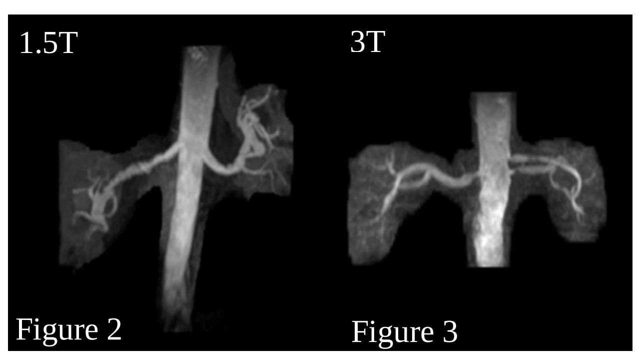

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MRI Guided Focused Ultrasound Treatment of Uterine Fibroids

JoAnn Bromley, Gina Hesley, Krzysztof Gorny, Kelly Dunagan, Joel Felmlee
Department of Radiology, Mayo Clinic, Rochester, Minnesota, USA

Purpose

Women with symptomatic uterine fibroids have traditionally been offered medical therapy or invasive surgical procedures such as myomectomy, hysterectomy, and more recently uterine artery embolization. Today, MR Guided Focused Ultrasound (MRgFUS) is a non-invasive option for fibroid therapy. This technique uses high intensity ultrasound focused through the abdominal wall to thermally ablate uterine fibroid tissue. MRI is central to this process and is used to provide high quality images for treatment planning, to measure the temperature achieved at the focus during treatment, and to acquire final images used to assess the treatment effectiveness. MRgFUS therapy has recently received FDA approval after extensive testing at several clinical sites. Our experience has shown the MR technologist to be an important team member in all stages of MRgFUS treatment: planning, workflow, patient care, and final assessment of therapy. The purpose of this presentation is to inform and educate technologists about MRgFUS therapy.

Method

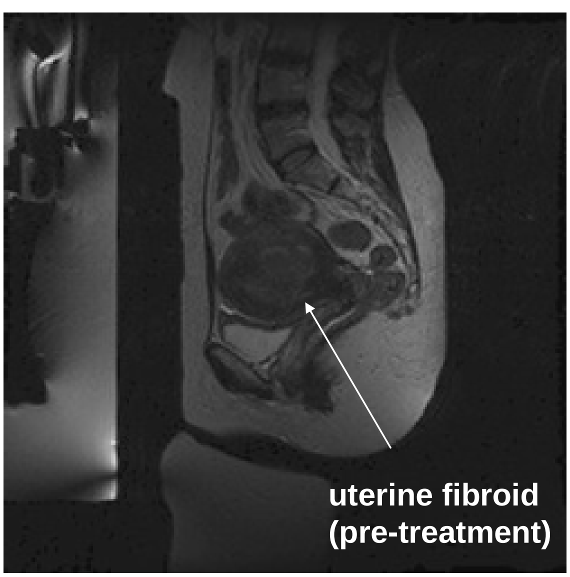
The treatments at our site were performed using an ExAblate® 2000 MRgFUS system (InSightec, Dallas, TX) integrated with a 1.5 Tesla MR imager (Signa GE Medical Systems, Milwaukee, WI). During treatment planning, the technologist and physician review the pre-screening MR images and determine the initial patient positioning. Three plane localization images of the abdomen and pelvis are then acquired to assess positioning of the target fibroid with respect to the ultrasound transducer located inside the MR table. The patient is repositioned as needed to assure that vital organs such as bowel, bladder, and nerves do not lie within the MRgFUS beam path. Initial patient positioning is critical and without proper attention to this an extended treatment time, patient discomfort, treatment limitation, or serious injury may result. Treatment planning images are subsequently acquired using a high resolution T2 weighted fast spin echo sequence in each of the axial, coronal, and sagittal planes (see Figure 1a). The physician to define the treatment volume uses these images. During treatment the ultrasound energy is selectively focused on points within fibroid tissue in order to heat and ablate it. The ultrasound energy is delivered in ~20 second pulses (sonications). During the course of a treatment, the technologist interacts with the patient by helping her to assess her pain level and location. The physician to determine and modify the sonication parameters such as MRgFUS power level and frequency, focus size, sonication duration, and angle of the MRgFUS beam constantly uses this crucial information. Upon completion of the treatment, high resolution T1 weighted fast spoiled gradient echo images (fspgr), (with and without Gd contrast) are acquired for assessment (see Figure 1b).

Results

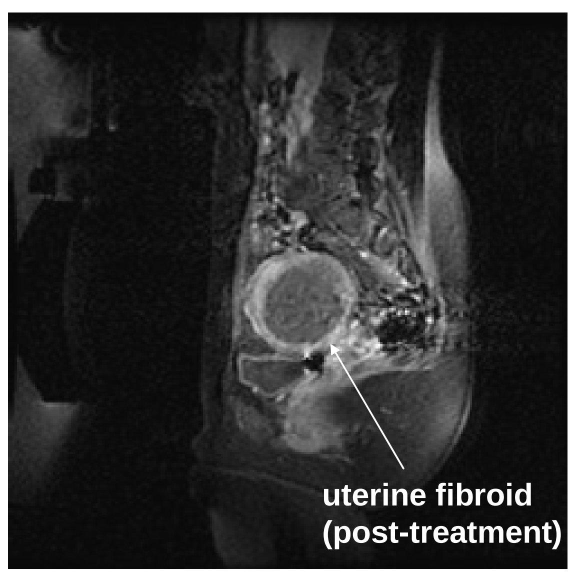
Using the above model our site has treated a total of 47 patients over a period of 3 years. Nine of the patients had two treatments to treat symptomatic fibroids. In our experience the successful treatments usually consisted of approximately 60 individual sonications over approximately 3 hours. Follow up MR images were performed at 6 months, 12 months, 24 months, and 36 months under prior FDA protocol to evaluate the effectiveness of therapy.

Conclusion

MRgFUS therapy is an emerging, non-invasive treatment technique, which poses a new set of challenges to diagnostic MR technologists. We demonstrate and discuss individual steps associated with MRgFUS treatments employed at our site. The involvement of an MR technologist in each of these steps is essential for the success of the MRgFUS treatment and therefore an MR technologist is a key part of the treatment team.



1a.



1b.

Figure 1: Pre- and post-treatment MR images of the fibroid tumor (sagittal plane). **a.** The untreated fibroid is indicated with an arrow. **b.** The treated (ablated) fibroid tissue appears darker on post-treatment images.

Diagnosing Chronic Exertional Compartment Syndrome with MRI: A Simplified Protocol Using the Body Coil

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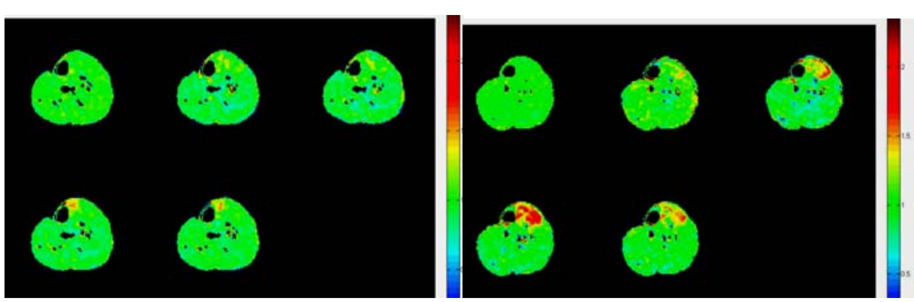
Purpose: The purpose of this study was to compare the proven dual birdcage protocol to a protocol substituting the body coil for the custom coils in patients with suspected chronic exertional compartment syndrome (CECS). CECS is a syndrome where activities such as running cause lower extremity pain. As the disease process progresses even routine activity such as walking may be limited. Young female athletes are classically affected but it has recently been shown that people of all ages and activity levels may suffer from CECS. The anterior compartment of the lower leg is most commonly affected. Normal muscle activity involves increased water within a muscle compartment, which diffuses quickly after the activity ceases. This can be measured as a ratio of relative signal intensity changes on T2 weighted imaging. In cases of CECS, there is a delay or barrier to the egress of this fluid within the muscle compartment, which is believed to be the source of pain, and compression symptoms causing an increase in the ratio of T2 signal compared with rest images. Currently, intracompartmental pressure measurements remain the standard for diagnosis of CECS. This involves the placement of a hollow needle within the affected compartment, with a pressure transducer being placed through the closed system. Because of the costs and risks associated with pressure testing we developed an effective screening protocol for CECS to avoid the need for intracompartmental pressures in patients either strongly negative or positive for CECS using our established criteria [1]. Our published protocol depends on custom-built paired coils, which limits the use of this protocol to our institution and to 1.5T. We hypothesized that the body coil would provide adequate SNR and improved uniformity and would generate similar results for the ratios of T2 signal intensity.

Methods: For the in-scanner exercise protocol a Plexiglas platform was placed on the table, which has a footboard, fused on the bottom with attached Velcro straps to create appropriate conditions for resisted isometric dorsi and plantar flexions during the exercise portion of the exam. The current standard protocol uses a dual birdcage coil placed on top of the plexiglas platform toward the lower portion, enabling the subject to slide both lower extremities through the coil, placing their feet firmly against the footboard. All imaging was performed at 1.5T (GEHC, Twin Speed 11.0). Initial axial T2 weighted images are acquired at rest and then compared to images obtained during exercise and recovery. The imaging protocol consisted of T1-weighted images (TR/TE 400/20 ms, 40 cm FOV, ½ phase FOV, 10mm slices with a matrix of 256 x256 pixels and 2 NEX after the 3-plane localizer to center over the proximal third of the calf) followed by the T2-weighted sequences above. 3 slices were selected at the bulkiest portion of the anterior compartment of the calf for T2 weighted images. Two initial rest series were obtained followed by two series of resisted isometric dorsi flexion, two series of rest images, two series of resisted isometric plantar flexion and two series of rest images for a total of 11 series in addition to the scout. For this study two subjects (one normal volunteer and one patient with CECS) were imaged in both the body coil and the paired coils. The protocol and foot holder were identical for both exams for each patient. The volunteer was imaged twice on the same day and the patient was imaged with a week intervening between the two exams.

Results: The peak ratio of T2 signal intensity for the normal subject was 1.28 on the right and 1.16 on the left in the custom paired birdcage coil and 1.18 on the right and 1.06 on the left in the body coil. The patient with CECS had peak ratios of 1.74 on the right and 2.0 on the left in the paired birdcage coils and 1.58 for both right and left with the body coil. The result for the normal subject was 8% lower on the right and 9% lower on the left with the body coil. The result for the patient with CECS was 3% lower on the right and 21% lower on the left with the body coil. The peak ratios of signal intensity were reached in the first rest period after resisted isometric dorsiflexion for both subjects and both methods.

Conclusion: CECS is a distinctive condition of exercise-induced pain felt to be due to increased tissue pressure within a confined muscle compartment. Results were similar for the body coil and paired birdcage coil in a normal subject and patient with CECS with the body coil results being lower in each case. We believe that the lower value with the body coil for the patient's most symptomatic side may have been due to fatigue. Excluding that result the difference in the body coil and custom paired birdcage coil results are within the standard deviation reported in our prior study. The results for both subjects remain diagnostic using our validated threshold value of 1.54. These early results suggest that it will be possible to use the body coil alone for this test. This has several implications including ease of use for the technologists and the general availability of this protocol at any institution. Further testing is required to confirm this result but it appears that the use of the body coil alone with our in-scanner exercise protocol will be adequate for screening patients with lower extremity pain for CECS.



Normal Subject — Patient with CECS

1. Litwiller DV et al. *Skeletal Radiology*. 36(11): 1067-75, 2007.

3T MRI in the Staging of Rectal Cancer

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Purpose: Preoperative staging of rectal cancer is currently performed with endorectal ultrasound at our institution. Limitations of endorectal ultrasound include limited FOV and difficulty traversing the tumor with large masses. The purpose of this study is to assess the image quality, accuracy and added benefit of 3 Tesla MR in the preoperative imaging algorithm for rectal cancer

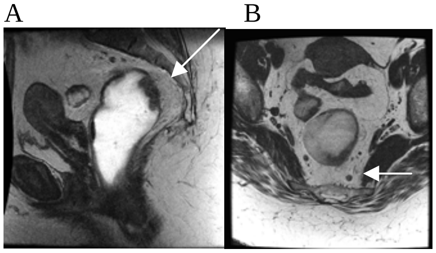
Methods: 3 male patients were imaged on a 3 Tesla system (GE Signa Excite, Twin-speed) with the use of an eight element phased- array surface coil for clinical indication of rectal Ca staging. Prior to imaging the patients are instructed to have a fleet enema, one hour prior to exam to empty the rectum of any fecal matter. Imaging was performed using the following series parameters:

1) Axial FSE T-1and T-2 sequences of the entire pelvis to screen for adenopathy or metastases
2) Axial FSE T-2, high resolution images though the tumor and rectum: TE: 120ms, TR: 4000+/-ms, matrix: 384x256/ 3 NEX, FOV: 160-200mm, slice thickness 3-4mm, spacing.
3) 5mm; oblique axials perpendicular to the rectal tumor using the same parameter as straight axials; before and after insertion of 60-90 cc of ultrasound gel.
4) Sagittal and/or coronal depending on tumor location using the same sequence;
5) Oblique axial 3D Inner volume Xeta: 3D Frfse-XL with inner volume, TE-minimum, TR-2300ms, Echotrain-60, BW-62khr, matrix-256x192/ 1 NEX, 2mm slice, FOV-200mm;
6) Axial 3D LAVA-pre contrast, and 30, 70, and 180 seconds post injection, TE-Min Full, TR-125-200 ms, Flip angle-70, spacial spectral saturation, matrix 256x160-224/ 1 NEX, 3 mm slice thickness;
7) Axial 2D Fast spoiled Grass: TE-Min full, TR-125-200 ms, Flip angle -70, matrix 320x224/ 2 NEX, fat saturation, 3-4mm thickness, .5mm spacing.

Results: 3T MR exquisitely demonstrated the tumor in all 3 cases. The tumor was better seen following the inserting of the rectal gel. In 2/3 cases the MR and ultrasound agreed on staging. In the third case MR detected positive perirectal lymph nodes that were missed at ultrasound. Both underestimated the minimal extension of tumor into the perirectal fat in one case at surgery. MR also provided an excellent demonstration of the location of the tumor to the anal sphincter which is not routinely displayed with ultrasound**.**

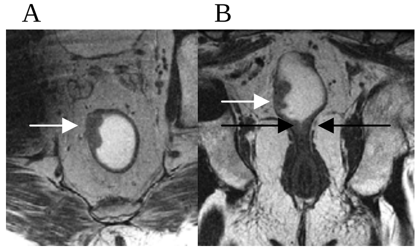
Discussion: At our institution endorectal ultrasound has historically been used for preoperative staging of rectal cancer. For malignancies confined to the rectum, surgical resection is performed. However, if there is evidence of extension into the perirectal fat or surrounding lymph nodes then preoperative chemoradiation is usually performed. Endorectal ultrasound has limitations. At our institution there is a significant backlog. For large tumors the probe may not be able to be passed beyond the tumor thus limiting the overall visualization of the tumor and its local extent. In addition the FOV of ultrasound is limited and some surrounding nodes may not be visualized. 3T offers many advantages over ultrasound. High resolution images can be obtained without the need for insertion of a rectal coil. MR provides an overview of the entire pelvis and can detect adenopathy in the pelvis. MR also can show the distance of the tumor to the mesorectal fascia (MRF). The MRF is a fascial plane that surrounds the perirectal fat. The distance of tumor extension to the fascia is predictive of recurrence. The multiplanar capability of MR allows exquisite display of the relationship of the tumor to the anal sphincter which may impact the surgical procedure performed. Limitations of MR include the difficulty in differentiating perirectal fibrosis from viable tumor and the difficulty in differentiating benign from malignant lymph nodes.

A B

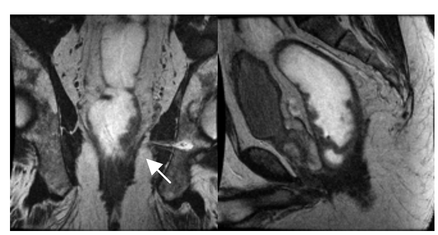


Sagittal T2-weighted image (a) shows a rectal carcinoma along the posterior wall (arrow) and mildly enlarged perirectal lymph node (arrow) on the axial image (b) that contained metastatic disease at surgery. The lymph node was not seen at endorectal ultrasound.

A B



Axial (a) and sagittal images show the rectal carcinoma along the right rectal wall (arrow). Note the excellent demonstration of the tumor in relation to the anal sphincters (black arrows)



A low rectal carcinoma is only a short distance above the sphincter (arrow)

MR Renal Angiography

Contrast-Enhanced MR Angiography Verses Non-Contrast Inhance

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Purpose: The possibility of developing nephrogenic systemic fibrosis (NSF) after administration of a gadolinium contrast agent in patients with reduced renal function has accentuated the need for a reliable non-contrast MRA method. Until now, Contrast-enhanced MR Angiography (CE-MRA) has been the gold standard for the evaluation of renal arteries with MRA. We present a comparison between a newly developed technique that uses a steady state free precession with in-flow inversion recovery (Inhance) and the standard 3D CE-MRA. We hypothesize that Inhance will produce accurate and reliable images of the renal arteries in most patients.

Methods: Inhance is a 3D steady state free precession sequence with an inversion recovery pulse. The IR pulse is respiratory-triggered and applied to the imaging volume. The pulse is designed to suppress signal from veins such as the inferior vena cava and from static tissues such as kidneys and retroperitoneal fat and to avoid saturating upstream arterial blood from the heart and thoracic aorta. Inhance images provide high arterial signal and T2-like contrast.

An investigational version of the Inhance Inflow IR pulse sequence used was acquired in the axial plane with the following parameters: TE/TR 2.0/4.0msec, TI 200msec, flip angle 70 degrees, receiver bandwidth 125kHz, FOV 30-42 cm, slice thickness 2mm, number of views 56, imaging matrix 256x256, parallel imaging acceleration factor of 2, spectral spatial saturation pulse, and respiratory triggering on a 1.5T GE Signa Excite system. The 3D Contrast Enhanced-MRA was performed in a coronal oblique plane with the following parameters: TR/TE 3.4/1.6ms, flip angle 30, receiver bandwidth 83 kHz, FOV 26-30cm, section thickness 1.6mm, 42 views, matrix 256x224. 0.1 mM/kg gadolinium contrast was injected at 3 ml/s, with the scan delay determined by a test bolus.

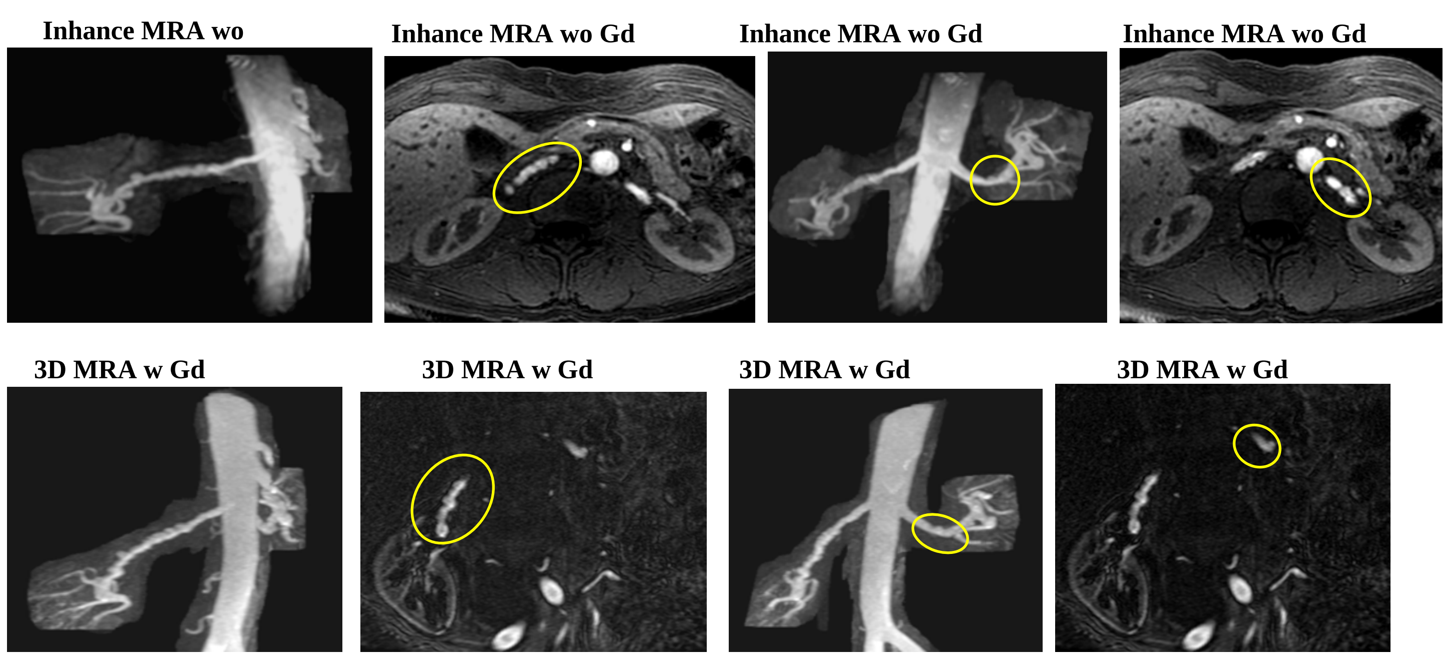
50+ Patients with suspected renal artery disease were studied on both CE-MRA and Inhance protocol. Two radiologists compared and rated the images for renal artery visualization and overall image quality using a five-point scale (1=uninterpretable; 5= perfect image).

Results: Results of the clinical patients are summarized in Table 1.

Table 1	Inhance	CE-MRA
Proximal Renal Artery visualization	4.1	4.7
Distal Renal Artery visualization	3.8	4.0
Intrarenal Renal Artery visualization	3.5	2.5
Overall Image Quality	4.0	4.2

Discussion: Our preliminary results suggest that non-contrast renal MRA imaging using Inhance can be performed effectively for the evaluation of patient with contraindications for gadolinium-based agents.

52 year old female with a history of fibromuscular dysplasia of carotid arteries underwent Inhance MRA and CE-MRA. A beaded appearance of both renal arteries is well depicted on Inhance MRA. CE-MRA confirmed the findings seen on Inhance MRA.



High spatial resolution, volume selective 3D FSE imaging

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Introduction: Although conventional multi slice 2D FSE is routinely used for tissue characterization of both malignant and benign processes, diagnostic limitations become apparent in small (e.g. prostate) and complex, tortuous (e.g. perianal fistulae) structures. It would be advantageous to use a high spatial resolution 3D acquisition scheme with thin sections that would permit multiplanar reformatting. Until recently, the appeal of a near-isotropic 3D FSE acquisition has been beset by blurring caused by long echo-train lengths needed to maintain reasonable scan times. Modulation of the refocusing flip angles in FSE to minimize signal modulation from T_2 relaxation has enabled the use of long echo trains [1-3]. In this study, we developed a novel technique that combines inner-volume (IV) selection [4] and highly selective spatial saturation bands [5] with an eXtended Echo Train Acquisition (XETA) 3D FSE-Cube sequence. This pulse sequence, called IV-XETA, was evaluated for imaging of the prostate and perianal fistulae.

Methods: <u>Pulse sequence design</u>- A 3D-XETA-Cube pulse sequence was modified to incorporate inner volume selection. XETA employs modulated refocusing flip angles [1,2] for long echo-train lengths, an auto-calibrating hybrid space parallel imaging scheme with acceleration along phase and section encoding dimensions [3] and an optimized view ordering scheme for a non-separable k_y-k_z grid [6]. Inner volume selection was achieved by applying the slice selective gradient for the excitation pulse along the phase encoding direction. To improve the selectivity profile further and eliminate any residual aliasing, highly selective saturation RF pulses with narrow transition bands [5] were applied at the edges of the excitation and refocusing slabs. Scan time and TR were unaffected by these additions, as they were played during the otherwise quiescent period between echo trains of the non-SAR limited sequence.

<u>Experiments</u>- All images of the pelvis were acquired on a Signa EXCITE HDx 3T system (General Electric Healthcare, Waukesha, WI) and an eight-channel torso coil (GE Coils, Cleveland, OH). Typical scan parameters for IV-XETA were as follows- 320x224 matrix, 80-100 slices 1.2-1.6 mm thick, 20-24 cm FOV, TE/TR 100ms/2s, ETL 70-80, BW $\pm$83 kHz, acceleration factors 1.8-3X, scan time 3.5-4.5 min. Conventional 2D FSE images were acquired on all 3 orthogonal imaging planes for comparison (320x224 matrix, 24-32 slices 3 mm thick, 2-3 NEX, 20-24 cm FOV, TE/TR 100ms/2s, ETL 12, BW $\pm$83 kHz, scan time 3-4 min.). Typically, chemical fat suppression was used when imaging fistulae for both the 2D and 3D scans for better visualization. Data were acquired on 12 subjects (5 healthy subjects, 7 patients with perianal fistulae) after prior informed consent per guidelines of the institutional review board. The 2D FSE and the 3D IV-XETA images were compared for SNR, artifacts and spatial resolution.

Results: Figure 1 shows a comparison of XETA with no volume selection or sat bands (A) with sat bands alone (B), with inner volume selection alone (C) and with inner volume ***and*** sat bands (D). Notice that the combination of the two selection schemes (D) has eliminated all aliasing artifacts along section and phase encoding dimensions despite the small FOV. Figure 2 compares coronal (A) and axial (B) slices from a 2D FSE prostate exam to corresponding sections from a 3D coronal slab (C) and an axial reformat (D), acquired using the proposed IV-XETA sequence. The 2D scans were 4 min. long compared to the 5 min. IV-XETA 3D scan. Note minimal artifacts in the reformatted section due to the high spatial resolution of the coronal volume. Figure 3 shows a coronal section (A) and a reformatted axial (B) section acquired using the IV-XETA sequence with fat suppression on a patient with perianal fistula, which was depicted very clearly in both the imaging planes. Two views of a volume rendered coronal slab are shown in Fig. 3C and 3D, demonstrating both the high resolution of the 3D dataset and the utility of the 3D acquisition, which facilitates Parks's classification of perianal fistula.

Conclusion: The use of a novel, high spatial resolution volume selective 3D FSE-Cube sequence was demonstrated for T_2 weighted imaging of small and complex structures such as the prostate and perianal fistulae. Using IV-XETA, a typical 3D slab with a 320x256x96 matrix with 1.4 mm thick sections was acquired in 5 minutes compared to three separate 2D scans with comparable matrix dimensions, 3 mm thick slices and a total scan time of ~ 12 minutes. Post processing of near-isotropic 3D acquisitions allowed optimal visualization of small, tortuous structures, obviating complex, often uncertain, scan plane prescriptions with 2D methods. True isotropic acquisition would require sub-mm section thickness and would necessitate the use of signal averaging to recover the concomitant SNR loss, at the cost of scan time increase. The addition of fat suppression to 3D IV-XETA improves outlining of simple and complex abnormal structures. IV-XETA can potentially replace conventional 2D FSE sequences in the sagittal and/or coronal planes, improving scan efficiency.

References: [1] Mugler et al. ISMRM 2000, p687. [2] Busse et al. MRM, 55:1030-7 (2006). [3] Busse et al. ISMRM 2007, p1702. [4] Feinberg et al. Radiology, 156:743-747 (1985). [5] Le Roux P. ISMRM 1997, p1538. [6] Beatty et al. ISMRM 2007, p1749.

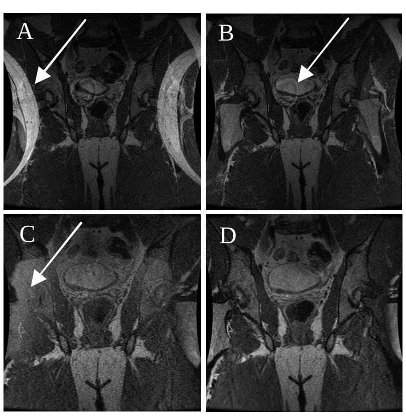


Figure 1. Comparison of a section from a 3D IV-XETA with no sat pulses or inner volume selection (A) with sat pulses alone (B), with inner volume selection (C) and with both sat pulses **and** inner volume selection (D). Note that all residual aliasing artifacts are eliminated in (D).

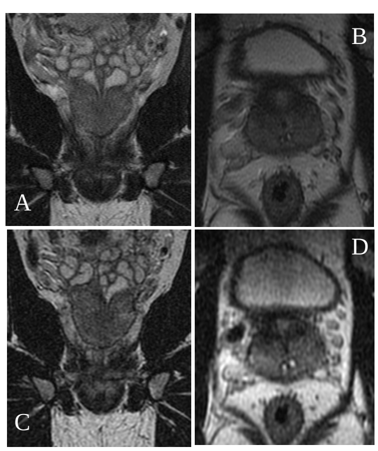
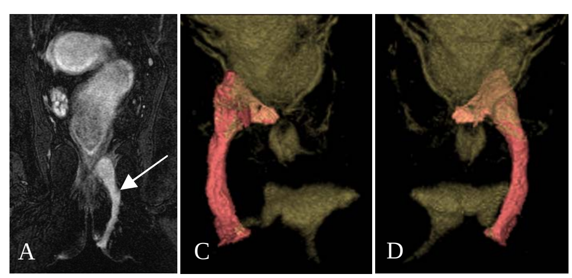


Figure 2. Coronal (A) and axial (B) 2D FSE images of the prostate compared to corresponding sections from a coronal 3D IV-XETA scan (C) and an axial reformat of the 3D slab (D).



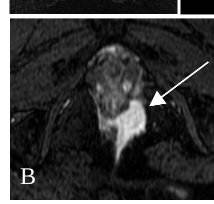


Figure 3. A coronal section (A) and an axial reformat of the coronal 3D slab (B) using the proposed IV-XETA sequence with fat suppression on a patient with perianal fistula (arrows). Two different views (C,D) of a volume rendered 3D coronal slab are shown, illustrating the benefit of using a near-isotropic 3D scan over conventional 2D scans.

Clinical evaluation of a novel, near-isotropic resolution volume selective 3D FSE pulse sequence for prostate MRI

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Introduction: MRI is the preferred investigation for tumor localization and local staging prior to prostate carcinoma treatment despite its current limitations. Typically, multi-slice 2D Fast Spin Echo (FSE) sequences in three orthogonal planes aligned to optimally visualize the prostate are used to outline the contour and zone anatomy of the prostate gland and to reveal gross tumor extension to the seminal vesicles and neurovascular bundles. It would be advantageous to use a high-resolution 3D acquisition scheme with thin sections, permitting multiplanar reformation in arbitrary planes, especially for the visualization of the prostate gland contour and peri-prostatic tissue. Also, it could potentially reduce the overall examination time by replacing one or more of the 2D acquisitions with a single 3D acquisition. In this study, we investigated a novel, volume-selective near-isotropic 3D FSE-Cube pulse sequence and its potential as an adjunct and/or replacement to conventional multiplanar 2D FSE imaging.

Methods: Pulse sequence- An inner volume eXtended Echo Train Acquisition (IV-XETA) 3D FSE pulse sequence was developed. XETA employs modulated refocusing flip angles [1,2], an auto-calibrating hybrid space parallel imaging scheme [3] and an optimized view-ordering scheme for a non-separable k_y-k_z grid [4]. Inner volume selection [5] was achieved by playing the slice selective gradient for the excitation pulse along the phase encoding direction. To improve the selectivity profile further and eliminate any residual aliasing, highly selective saturation rf pulses with narrow transition bands [6] were applied at the edges of the excitation and refocusing slabs. Scan time and TR were unaffected by the addition of saturation bands as they were played during the otherwise quiescent period between echo trains.

Experiments- All imaging was performed on a 3T Signa HDx MR scanner (GE Healthcare, Waukesha, WI) using an eight-channel phased array torso coil (GE Coils, Cleveland, OH). Eight subjects (seven with no known pathology, one with prostate cancer after external beam radiation) were imaged after prior informed consent. After the localizer scans, multi-slice 2D FSE were acquired in 3 orthogonal planes followed by a coronal 3D IV-XETA scan. The scan parameters for the 2D FSE sequence were as follows: TR/TE 4000 ms/105 ms, $\pm$50 kHz bandwidth, 3 mm slice thickness, slice gap 0.2 mm, 384x256 matrix, echo train length 16, 3 NEX, 22 cm FOV, 20-24 slices, scan time ~ 4 min. Scan parameters for IV-XETA was as follows: TR/TE 2200 ms/108 ms, $\pm$62 kHz bandwidth, 1.2 mm slice thickness, number of slices-100, 320x256 matrix, echo train length 70, 1 NEX, 22 cm FOV, scan time ~ 5 min. The 3D IV-XETA coronal volume was reformatted to match the same location, slice thickness and FOV as the 2D FSE scans. Images were retrospectively evaluated by two abdominal radiologists in consensus for depiction of prostate contour and peri-prostatic structures, perceived SNR, sharpness and degree of image artifact, grading on a 5-point scale. The sequences were also ranked in order of preference. A non-parametric signed test was used to assess statistical significance.

Results: Compared to coronal 2D FSE, both source and coronal reformatted images of 3D IV-XETA were equally useful in outlining the prostate contour and seminal vesicles. With regard to perceived SNR and overall image quality, reformatted 3D IV-XETA images were superior to corresponding 2D FSE images ($p < 0.05$) for all imaging planes. However, direct axial 2D FSE images were superior to reformatted axial 3D IV-XETA in the depiction of the neurovascular bundles and seminal vesicles due to inferior in-plane resolution of the reformats ($p < 0.05$). Coronal 3D IV-XETA was preferred to coronal 2D FSE in four of the six cases. Figure 1 compared 2D FSE images obtained in coronal, sagittal and axial plane with corresponding reformatted sections obtained using IV-XETA on a normal subject. The original coronal section (C) is also shown to illustrate the high spatial resolution of the 3D acquisition. Figure 2 showed the comparison on a patient with known prostate tumour for coronal and axial planes.

Conclusions: Our preliminary results suggest that 3D IV-XETA sequence with multiplanar 2D reformation is promising for prostate imaging and has the potential to replace direct coronal and/or sagittal 2D FSE sequences at 3.0 T. Further study in patients with prostate cancer remains necessary to determine the accuracy for local staging with 3D IV-XETA. With a 32-channel system, it might be possible to achieve an SNR that could permit true isotropic sub-mm^3 voxel 3D acquisition, which could potentially eliminate the need for conventional 2D FSE imaging.

References: [1] Mugler et al. ISMRM 2000, p687. [2] Busse et al. MRM, 55:1030-7 (2006). [3] Beatty et al. ISMRM 2007, p1749. [4] Busse et al. ISMRM 2007, p1702. [5] Feinberg et al. Radiology, 156:743-747 (1985). [6] Le Roux P. ISMRM 1997, p1538.

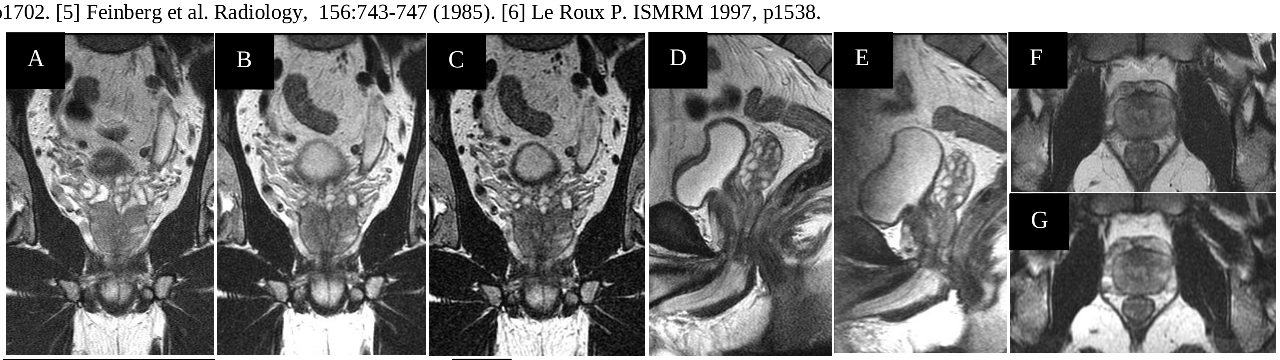

Fig 1. Coronal 2D FSE (A), source (B) and reformatted (C) 3D IV-XETA images of the prostate. Sagittal/axial 2D FSE images (D,F) with corresponding reformatted sections from 3D IVXETA (E,G)

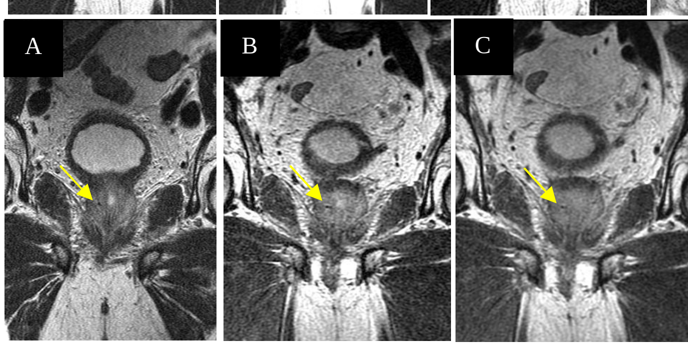

Fig. 2. Coronal 2D FSE (A), source (B) and reformatted (C) 3D IV-XETA images in a patient who after external beam radiation for prostate cancer (arrows- gold seed marker). Recurrent tumor is better defined on axial reformatted 3D IV-XETA (E) than 2D FSE (D)(white arrows).

MRI ENTEROCLYSIS

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Purpose: Currently, Computed Tomography Enteroclysis (CTE) is the main imaging modality used in our practice to diagnosis low grade small bowel obstruction. CTE combines the benefit of enteroclysis (improved small bowel distension) and cross sectional imaging (ability to see all bowel loops). However, because of the radiation exposure, only limited views of the small bowel can be obtained. MR Enteroclysis (MRE) provides the opportunity to repetitively image the small bowel without concern for radiation. The purpose of this presentation is to review our experience in the performance of MR Enteroclysis. Specifically, we will review the technical hurdles that must be overcome in order to successfully utilize this technique in your practice as well as review the benefits of the different pulse sequences. The use of MRI to perform MR Enteroclysis is evolving as an important tool in the evaluation of low grade small bowel obstruction. MRE is an imaging technique with the use of an oral contrast agent that can show small bowel obstruction, map peritoneal adhesions, and may be useful in pre-operative planning.

Methods:

1. Placement of nasal gastric tube in to the duodenum under fluoroscopy and then transfer to the MR suite
2. Set up of extension tubing (30 feet) and pump (the infusion pump is ferromagnetic so the pump needs to stay outside of the scan room, we feed the tubing though a waveguide by the operators console).
3. Infusion technique. Rate varies from 80-120 ml/minute, depending on degree of distension desired.
4. Scans preformed during filling
    a. 2D Coronal Fiesta
    b. Thick-slab coronal SSFSE for general overview
    c. 2D multiphase Fiesta to evaluate peristalsis and distensibility
5. We stop the pump once the contrast reaches the colon. We usually do not wait till it reaches the rectum.

A three lumen catheter is inserted through the nasal pharynx into the duodenum under fluoroscopy, the balloon in inflated with 30cc of air, then Volumen is infused at the dose rate of 80-120 ml/minute though an peritoneal dialysis infusion pump until approximately 2000ml have been given. The patient is imaged proximately every two minutes with the three scans mentioned above until the Volumen reaches the colon. Then the pump is turned off and the fourth scan (ax fiestas both upper and lower abdomen) is completed. Then the patient is gotten up and taken to the restroom.

The MRI Enteroclysis studies were performed on a General Electric, 1.5-T, Excite twin speed scanner with the use of an eight channel phased- array surface coil. 10 volunteers and two patients have been evaluated to assess bowel distension using different flow rates by using the following technique:

1) Coronal T2 weighted half-Fourier rapid acquisition(single-shot fast spin-echo) using the following parameters: minimum TR,440 TE, 30mm/0 Slice/skip, 352x512 matrix;
2) Coronal 2D Fiesta: min full TE, 6mm/0 slice/skip, 340x192, .75 NEX;
3) Coronal Fiesta Multiphase: min full TE, 75* flip angle, 10mm/0 slice/skip, 340x192, .75 NEX, 30 phases, and
4) Transaxial Fiesta two locations one-diaphragm to below kidneys, second bottom of kidneys to perineum.

Results: 2D Fiesta sequences can be performed rapidly and provide a good overview of the bowel and surrounding structures. We can evaluate areas that aren't well distended multiple times to see if it distends or if it is a fixed narrowing or stricture. They can also be used to look at the degree of filling and adjust flow rate. Limitations include the artifacts that occur secondary to air. It is a 2D sequence so it can not be reformatted into other planes. A rapid (acquired in 2 sec)projection image can be obtained using the thick slab SSFSE and gives a general overview of the small bowel but resolution is not good enough for diagnostic purposes Multiphase imaging allows the evaluation of small bowel peristalsis. If the infusion rate is too fast and distension is too much you may induce atony and will start to see the peristalsis decrease. 2D fiesta multiphase also allows you to look at the distensibility of an area in real-time.

Discussion: MR Enteroclysis is well suited to evaluate the small bowel for low grade obstruction. Because nasoenteric tubes are placed under fluoroscopic guidance there must be good communication between technologists in fluoroscopy and MR in order to facilitate patient through put. We have adapted our CT and fluoroscopic enteroclysis equipment so that it is MR compatible. We utilize an electric pump that is placed outside the scan room and extension tubing placed through the scan room wall to the magnet. Other options such as hand injection are possible but will not provide consistent bowel distension. We also have nursing personnel in the scan room with the patient to monitor for any discomfort or nausea. If any is encountered then the flow rate is adjusted accordingly. Several MR pulse sequences can be used and are complimentary. First sequences are performed to provide an overview of small bowel filling. These are used to determine if the bowel is adequately distended. If there is not enough distension the flow rate is then increased. If the bowel is over distended, usually greater than 3cm the rate is decreased. These sequences are also helpful to monitor the progress of the contrast through the bowel. For the monitoring of filling we utilize the thick slab SSFSE images for a general overview and the 2D FIESTA sequences. The 2D FIESTA sequences provide better spatial resolution and transition points or areas of narrowing can be better visualized. In suspicious areas the multiphase 2D FIESTA can be performed through this area during breath holding to look for changes in bowel caliber that may indicate a contraction vs. fixed narrowing.

Evaluation of vessel wall enhancement in vasculitis with myocardial delayed enhancement sequences: feasibility and preliminary results

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Purpose
Current techniques to evaluate vasculitis include computed tomography (CT), MRI, PET and conventional angiography. CT provides high resolution images of vessel wall thickening and vascular stenosis or occlusion, but also involves use of iodinated contrast media and ionizing radiation. Conventional angiography is an invasive technique also requiring iodinated contrast and radiation, with superb spatial resolution but no depiction of the vessel wall. Common MRI techniques include 3D contrast-enhanced MRA, black blood imaging of vessel walls, and post contrast T1-weighted images to demonstrate vessel wall enhancement. Myocardial delayed enhancement techniques have recently been applied to vessel wall imaging. These sequences generally include an inversion recovery preparation pulse to null the signal of normal myocardium. The inversion time (TI) can also be chosen to null the signal of the normal vessel wall, thereby emphasizing enhancement in patients with vasculitis. We evaluated the feasibility of this technique in 11 patients with known or suspected vasculitis involving the thoracic aorta, performing single shot myocardial delayed enhancement sequences following contrast administration for 3D contrast enhanced MRA.

Methods
Single shot MDE (sshmde) is a cardiac gated inversion recovery fast gradient recalled echo technique in which all data for a single slice is acquired in 3 R/R intervals (1 R/R to bring the slice to steady state and 2 R/R to acquire all of the lines in k-space). TI was selected using a multi TI cine sequence (CINE IR) performed in a sagittal oblique or axial projection through the thoracic aorta and then reviewed to determine the optimal TI (which typically ranged between 175-225 msec). Axial black blood imaging was performed using either a single shot or fast spin echo cardiac gated double inversion recovery sequence. 3D MRA was then performed and followed by delayed enhancement acquisitions 5-15 minutes following contrast injection. Post-contrast axial fat-saturated 3D SPGR images were also obtained.

Results
Mild vessel wall thickening without enhancement was seen in 4 patients, and vessel wall thickening with enhancement in the remaining 7 patients. Subjective evaluation of patients with vessel wall enhancement revealed a preference for sshmde images in 3 patients, no preference in 3 patients, and a preference for ungated 3D SPGR images in 1 patient. Single shot MDE images generally provided greater image contrast in depicting vessel wall enhancement, but at a cost in reduced SNR, longer acquisition times, and reduced spatial resolution (Fig. 1).

Discussion
Preliminary results are promising using sshmde to evaluate vasculitis. Improved conspicuity of vessel wall enhancement may allow detection of subtle vascular inflammation, and more accurate assessment of the activity of treated vasculitis.

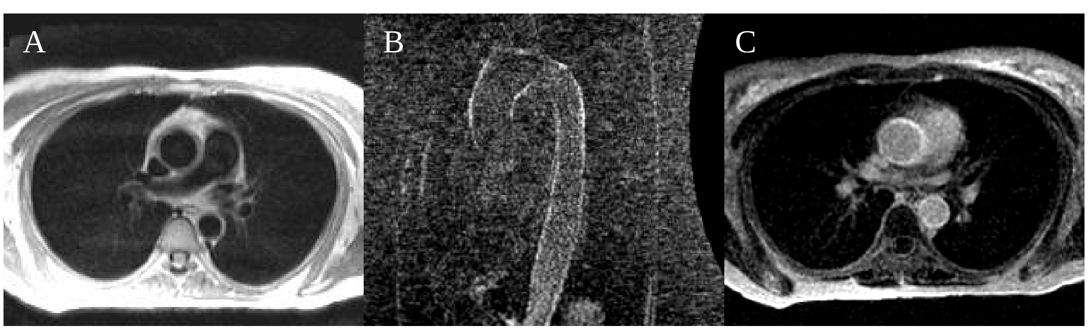

Fig. 1. 28 yo female with Takayasu's arteritis. The inter-volume black blood FSE (A) technique demonstrates vessel wall thickening while the CineIR (B) and sshmde (C) signal enhancement in the ascending and descending aorta vessel wall.

Pericardial enhancement in pericarditis and pericardial constriction: evaluation with myocardial delayed enhancement sequences

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Purpose

Current techniques to evaluate pericarditis include MRI, computed tomography (CT), and echocardiography. CT provides high spatial resolution and exquisite sensitivity to detect pericardial calcification, but also involves use of iodinated contrast media and ionizing radiation. Echocardiography is fast, inexpensive and is helpful in differentiating restrictive versus constrictive pericarditis, but is less useful in showing pericardial thickening. MRI protocols typically consist of black blood imaging and SSFP sequences to detect pericardial thickening, anatomic deformity, and functional abnormalities. Myocardial delayed enhancement sequences have recently been applied in pericardial imaging to detect pericardial enhancement/inflammation. We evaluated the use of myocardial delayed enhancement sequences in 27 patients with pericarditis or pericardial constriction.

Methods

Single shot MDE (sshmde) is a cardiac gated inversion recovery fast gradient recalled echo technique in which all data for a single slice is acquired in 3 R/R intervals (1 R/R to bring the slice to steady state and 2 R/R to acquire all of the lines in k-space). TI was selected using a multi TI cine sequence (CINE IR) performed in a short axis projection through the mid-left ventricle and then reviewed to determine the optimal TI (which typically ranged between 175-225 msec). Axial and/or short axis black blood imaging was performed using either a single shot or fast spin echo cardiac gated double inversion recovery sequence. SSFP short axis cine was then performed followed by a gadolinium contrast injection with delayed enhancement acquisitions in short axis and long axis planes acquired 5-15 minutes later.

Results

Pericardial enhancement was seen on MDE sequences in 17/27 patients with pericarditis or pericardial constriction. Two patients had constrictive pericarditis (on the basis of clinical symptoms, pericardial thickening, and abnormal septal motion in early diastole) and pericardial enhancement which improved on follow up examination after steroid therapy. Two patients had constrictive physiology with normal pericardial thickness on black blood images, but intense pericardial enhancement on delayed enhancement images. In 5 cases, the extent of pericardial enhancement was greater than the extent of pericardial thickening visualized on black blood and SSFP images.

Discussion

Myocardial delayed enhancement sequences are useful in the evaluation of pericarditis and pericardial thickening. Pericardial enhancement presumably reflects active inflammation which may respond to medical therapy, in contrast to non-enhancing thickened pericardium which likely represents fibrosis and/or calcification (Fig. 1). MDE sequences may also increase the sensitivity for detection of abnormal pericardium, particularly overlying the left ventricle where the pericardium is more closely opposed to the myocardium and difficult to visualize on non-contrast sequences.

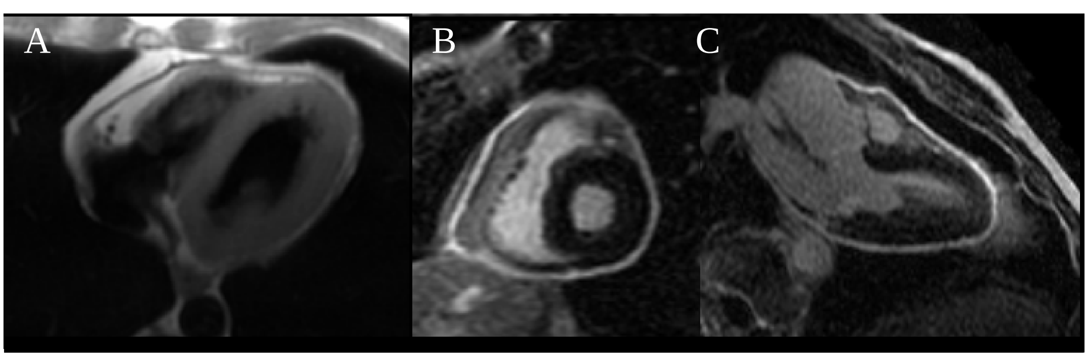

Fig. 1. Axial double IR FSE image (A) shows mild pericardial thickening overlying the right ventricular free wall. MDE short and long axis views (B and C) reveal diffuse enhancement of the pericardium.