Abstract
Renal vein thrombosis is an important but difficult clinical diagnosis. Current MR methods rely on time of flight or black blood techniques which are subject to flow artifacts. Contrast enhanced techniques using 2D or 3D gradient echo are time dependent so that scans must be obtained during peak venous enhancement. Post-contrast 3D steady state free precession imaging is well suited for renal vein imaging because it yields high venous SNR even 10-20 minutes after contrast administration. This means that excellent depiction of the IVC and renal vein can be obtained without careful timing of the sequence relative to the administration of contrast media.

Introduction
Renal vein thrombosis (RVT) is a complication of diseases such as renal cancer, lupus nephritis and acute pyelonephritis. A variety of MRI techniques - time of flight (TOF), black blood, and delayed Gadolinium-enhanced MRA - have been used to evaluate renal vein patency. However there are still several limitations to these methods. TOF relies on blood in-flow for bright venous signal and disturbances in flow (e.g. in-plane flow or turbulent flow) can result in erroneously dark or heterogeneous renal venous signal. Spin echo and other black blood techniques rely on venous washout to generate dark venous flow void. Insufficient washout as seen with slow flow may falsely generate bright signal that mimics thrombus. The technique of delayed imaging following contrast administration typically requires the prolongation of the bolus (i.e. slow or dual phase injection rate) and/or the use of higher doses (e.g. double dose or 40 mL) of Gadolinium contrast media in order to achieve sufficiently high venous concentrations of Gadolinium during the delayed phase. Furthermore, with contrast enhanced 3D gradient echo pulse sequences, maximal venous signal is significantly less than the maximal arterial enhancement. Venous signal in the body after a conventional antecubital intravenous administration of contrast is often less than 30% of the peak arterial signal and falls off precipitously with increasing time after the initial contrast bolus. Steady state free precession pulse sequences (a.k.a. FIESTA, true-FISP, balanced FFE) depend on the ratio T2/T1 and can provide exceptionally high vascular SNR following Gadolinium contrast media because of shortening of T1. Foo et al. has shown that this effect is prolonged and can be seen even at 20 minutes following the administration of Gadolinium contrast media. The aim of this study is to evaluate whether the gadolinium-enhanced MRI using 3D FIESTA sequences, can provide accurate MR venographic images for the diagnosis of renal vein thrombosis.

Methods
Nine patients (8 with renal cell carcinoma, one with kidney transplant) with clinical risk for renal vein thrombosis underwent MR evaluation. All studies were conducted on a 1.5 T MR scanner (C/M, GE Medical Systems, Waukesha, WI) equipped with high performance gradients. The imaging protocol included the following: a 2D or 3D fast spoiled gradient echo sequence acquired immediately after contrast administration during the arterial phase and delayed phase of the contrast bolus. Cononal imaging was performed during a 10-15 sec breath-hold period. This was followed by a late delayed phase 3D FIESTA sequence acquired 8-10 minutes after gadolinium administration using the following parameters: TR=4.7 msec/TE=1.8 msec/Flip angle=40°/Matrix=266x256/0.5 NEX/1-2mm slice thickness/40-50 sections acquired in a coronal view in a 15-25 second breath-hold period. All patients received intravenous injections of Gadolinium (0.1 mmol/kg) at 0.3-2 cc/sec. Qualitative evaluation included ratings by two observers for the presence, and extension of the thrombus, vein conspicuity, signal-to-noise ratios, and analysis of cause of RVT (e.g. renal cell carcinoma) if possible. Source images of 3D FIESTA sequences were reformatted using MIP.

Results and Discussions
Four of 9 patients demonstrated bland thrombosis (n=1) and tumoral invasion (n=3). The image quality was superior to conventional enhanced 2D or 3D SPGR because of the high SNR of FIESTA. The 3D high resolution FIESTA sequence acquired during 15-25 second breath-hold produced excellent images of the renal vein and IVC (Figure 1). They could be reformatted in any plane due to the high thru plane resolution. Numerous projections were reconstructed from a single three-dimensional volume of data acquired to obtain perpendicular and optimized views for visualization of the extension of the thrombus. The signal intensity of the enhanced renal veins and inferior vena cava was appropriate for visualizing the presence of any thrombus in all patients with RVT. Image quality of 3D FIESTA technique as rated by the two observers was also superior to 2D or 3D SPGR based on the depiction of the thrombus. All patients with positive RVT results underwent surgery. MR findings were compared with surgical data.

Conclusion
The 3D FIESTA sequence is a promising technique for evaluating for renal vein thrombosis. It can be obtained quickly but with high spatial resolution and SNR. The venous signal is not highly time dependent and remains enhanced many minutes after injection. Thrombus appears as sharply defined low signal filling defect. The 3-D data set can be reformatted in any plane to allow optimal evaluation of the oblique renal veins and vertical inferior vena cava.

References