MR validation and quantification of TACE treatment through direct visualization of Ethiodol with Chemical Shift Based Water-Fat Imaging

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Introduction Transcatheter arterial chemoembolization (TACE) has significant utility in the treatment of malignant neoplasms of the liver, particularly hepatocellular carcinoma (HCC), that are not amenable to surgical resection or cure with transplantation[1]. Traditionally, TACE delivers a bolus of chemotherapeutic agents suspended in ethiodized oil through a hepatic arterial catheter placed under fluoroscopic guidance. A follow-up CT scan is then used to verify correspondence between the tumor (from pre-TACE imaging) and treatment sites. Fluoroscopy typically provides limited visualization of the tumor, and therefore, interventionalists often treat large, extended volumes of the liver which can deleteriously affect liver function. Real-time MR guidance of TACE, which can visualize both tumor and its supplying hepatic arterial vasculature, may thus be useful for targeting treatment and sparing normal liver[2]. Because ethiodol is principally composed of iodinated ethyl esters of the fatty acids of poppy seed oil, and has NMR behavior similar to that of common oils, it can be visualized with chemical shift based water-fat separation methods such as IDEAL[3]. Here we present the feasibility of using IDEAL for visualization of ethiodol distribution within the liver. This method demonstrates the ability of MRI to identify the treatment location for a TACE procedure and to generate a quantitative post-procedure ethiodol distribution, while providing the possibility of contrast enhanced imaging in evaluations for tumor recurrence via suppression of ethiodol signal.

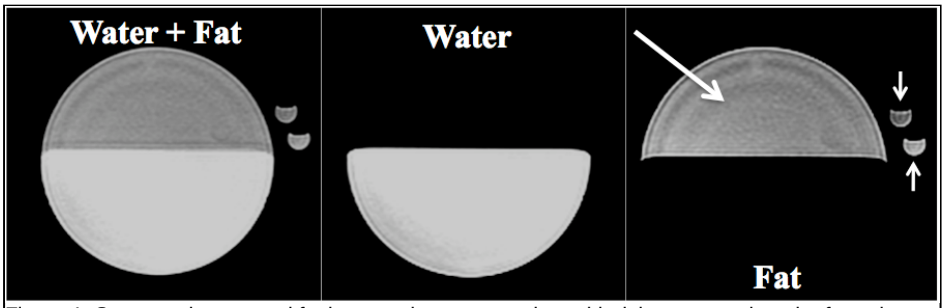

Figure 1: Separated water and fat images demonstrate that ethiodol separates into the fat-only image (small arrows) with the same signal characteristics as the peanut oil (large arrow).

Methods When injected into the hepatic artery, ethiodol embolizes within tumors such as HCC[4]. It contains a high concentration of iodine (475 mg/mL) for visualization during injection under fluoroscopic guidance, and for follow-up with CT. The oil component of ethiodol, however, can also serve as a contrast agent when imaged with an MRI chemical shift based water-fat separation method.

In this work, we utilize Iterative Decomposition of Water and Fat with Echo Asymmetry and Least-squares estimation (IDEAL) to exploit the chemical shift differences between water and fat while being insensitive to B_0 field inhomogeneities, of particular importance in the abdomen. Specifically, we use a multi-echo 3D spoiled gradient echo (SPGR) implementation of IDEAL (3D-IDEAL-SPGR)[3] with correction for T2* decay[5]. After obtaining IRB approval and informed consent, imaging was performed on a 1.5T scanner (Signa HDx TwinSpeed, GE Healthcare, Waukesha, WI) with an 8-channel phased array cardiac coil. Image parameters included: 6 echoes/TR with flyback readout gradients, TR=13.5ms, TEmin=1.3, ΔTE=2.0ms 256x160 matrix, 22 slices, 10mm slice thickness, BW=±142kHz, 35x27cm FOV, 5° flip angle to minimize T1 related bias[6], and parallel imaging acceleration with 2D-ARC[7] (R=2.2), for a total scan time of 21s. Separate water, fat and fat-fraction images were calculated with an on-line reconstruction algorithm that uses a region growing algorithm to prevent water-fat swapping[8]. To test the feasibility of this imaging modality, a spherical phantom with peanut oil floating on 0.9% normal saline doped with 5 mM $NiCl_2$ was placed in the scanner, with two 5ml vials of ethiodol placed directly adjacent to the peanut oil-water phantom. Patients with known HCC treated with ethiodol were also imaged using the same imaging protocol.

Results and Discussion Phantom images are shown in Figure 1, and demonstrate separation of all ethiodol signal into the fat-only image. The signal characteristics are very similar to those of the peanut oil. Figure 2A shows a post-TACE CT scan in a 71-year-old male patient with known HCC who underwent TACE, and clearly demonstrates the treatment area where contrast is provided by the ethiodol. An MR study of the same patient one month after TACE clearly demonstrates a matching treatment region in the fat-only IDEAL image (Fig. 2C) and in the quantitative fat-fraction map in Fig. 2D, where the average fat fraction is 17.5%. Notice that the fat signal provided by ethiodol remains localized within the tumor long after the procedure.

Unless the liver is severely steatotic, which is uncommon in end-stage cirrhotic livers, any lesions containing ethiodol should be visible with high conspicuity under IDEAL (most HCC's occur in cirrhotic livers that contain little to no fat). Additionally, it should be noted that by increasing the flip angle in the SPGR sequence, it becomes possible to increase T_1 weighting and therefore to increase the sensitivity of ethiodol detection in the fat-only image, at the cost of introducing T_1 related bias that limits our ability to quantify ethiodol in the fat fraction image[6].

Conclusions In this work we have explored the feasibility of assessing the ethiodol distribution in post-TACE livers with IDEAL, demonstrating the possibility of replacing CT with MRI for follow-up of TACE procedures to verify treatment location. Future work will explore integrating this means of treatment visualization into a real-time MR catheter tracking system to perform MR-guided TACE. If generated in real time, the fat fraction image could potentially be used to quantify the amount of ethiodol (and suspended drug within the ethiodol) that reaches the tumor as it is administered.

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References 1. Lopez, *et al.* Am Surg 1997;63:923-926. 2. Vogl, *et al.* Eur. Rad. 2002;12:1394-1400. 3. Reeder, *et al.* JMRI 2007;25(3):644-52. 4. Ramsey, *et al.* J Vasc Intv Rad 2002;13:S211–S221. 5. Yu, *et al.* JMRI 2007; 26(4):1153-61. 6. Liu, *et al.* MRM 2007;58(2):354-64. 7. Beatty, *et al* ISMRM, 2007 pg 1749. 8. Yu et al MRM 2005 54(4):1032-9.

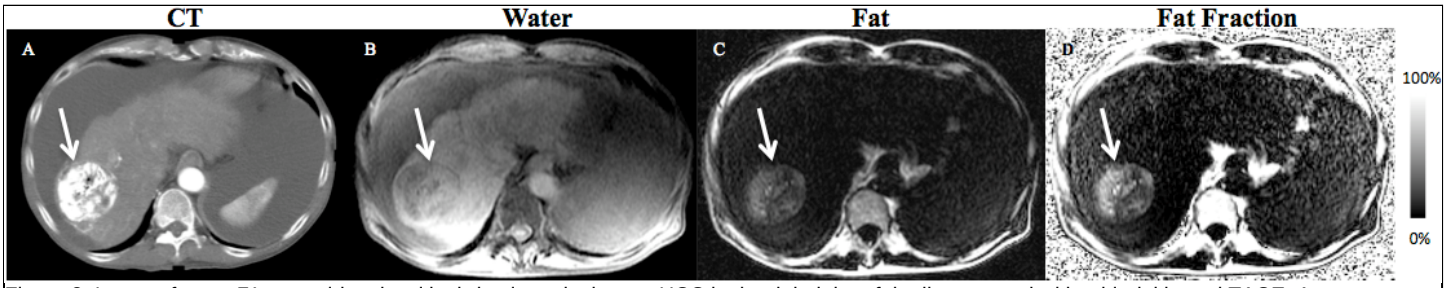

Figure 2: Images from a 71-year-old male with cirrhosis and a known HCC in the right lobe of the liver treated with ethiodol based TACE. An arrow shows the tumor location in each image. A) CT demonstrates a hyperdense region corresponding to the ethiodol distribution. Separated b) water, c) fat and d) calculated fat-fraction images are also shown.