Undersampling Artifacts and Apparent Wall Thickening of Cystic Renal Lesions on MRI

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Introduction

The Bosniak classification system has been employed since 1986 for CT evaluation of cystic renal masses (1). With widespread use of body MRI, there has been interest in the Bosniak system for MRI classification of these cystic masses as well (2,3). One of the Bosniak criteria for a simple renal cyst is that of a thin, imperceptible wall, and wall thickening has been associated with malignancy in the literature. We have observed that renal lesions that would otherwise meet criteria for a simple cyst on CT demonstrate increased wall thickness on MR imaging, thereby raising the suspicion for a complicated cyst. The problem is illustrated in Figure 1, where by CT criteria a large right renal simple cyst (Fig 1a, unenhanced 512 x 512 helical acquisition, 7 mm slice thickness, 50 cm FOV) shows apparent wall thickening in the AP direction on an axial T1-weighted 2D SPGR image (Fig 1b, 40x30 cm FOV, 512x160, 6 mm slice thickness, TR/TE 190/1.7 ms, FA 70°), and in the lateral direction on a coronal T1-weighted 3D SPGR sequence (Fig 1c, cropped from a 36 cm FOV, 256x160x40, 3 mm effective "slice" thickness, TR/TE 4.9/2.3 ms, FA 12°). This observation is confirmed also by a recent study in which increased observed wall thickness was a reason for "upgrading" cystic renal lesions when using the Bosniak criteria with MRI (3). We propose that this apparent wall thickening seen in clinical images can sometimes be produced due to undersampling, which in turn results in the characteristic Gibbs ringing, most intense at the borders of the object, i.e., the cyst wall.

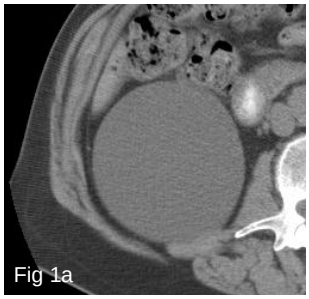


Fig 1a

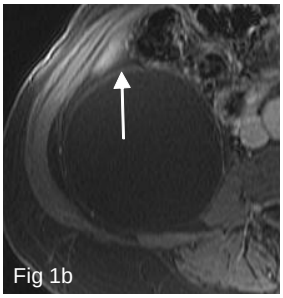


Fig 1b

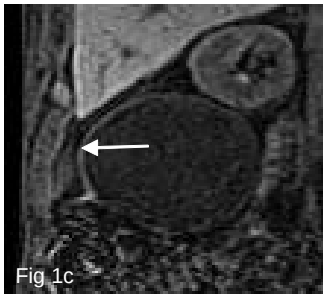


Fig 1c

Materials and Methods

A 4 cm round object was created in a simulated image of 34 cm FOV in Matlab, with a resolution of 1024x1024. A 2D FFT of these data yielded the simulated k-space data for the image. Two new k-space data sets were created using the central 512x512, 512x128, and 128x128 data points, respectively. Noise was simulated at 5% of the ideal signal intensity and added to the k-space data. The inverse 2D FFT then yielded the simulated "cyst" images. Cyst phantoms were created using balloons filled with water and "doped" with 0.08 M gd (Magnevist, Berlex, Wayne NJ) and then immersed in mineral oil to simulate the perinephric fat. 2D SPGR images were obtained on a 3.0 T Signa (GE Medical Systems, Milwaukee, WI), with FOV of 34 cm, 512x160 and 512x320 matrix, TR/TE 190/1.7 ms, FA 70°. All images were retrospectively reconstructed and displayed in Matlab.

Results and Discussion

The simulated phantom cysts for the 512x512, 512x128, and 512x128 matrices, respectively, are displayed in Fig 2a-c. As expected, there is apparent thickening of the border of the structure in the undersampled direction(s) in the lower resolution data sets. Phantom results are similarly displayed for a ~3.0x2.4 cm balloon/"cyst" cropped from the 512x512 (Fig 3a) and 512x128 (Fig 3b) images. Again, there is apparent thickening of the wall of the simulated cysts in the undersampled (phase encoding) direction. Both the simulated and phantom results closely reproduce the imaging findings observed clinically, and as illustrated in Figure 1. Undersampling artifacts, of course, are well known and well understood phenomena (4). However, in the evaluation of cystic lesions, our clinical experience and these results show that these Gibbs artifacts lead to an apparent increase in the lesion wall thickness in the phase encoding direction (because it is usually the lower resolution direction) of an otherwise simple cyst and may also hinder assessment of enhancement of the cyst wall (another feature of malignancy). This is of particular concern when SNR is low and the Gibbs ringing within the structure may produce signal oscillations that are too small to observe over the noise. This finding has important clinical implications in the management of cystic renal masses as unnecessary imaging follow-up may be performed on simple renal cysts. Wall thickness as a criterion for determining the complexity of a cystic lesion on MRI must be interpreted with caution in the context of the number of phase encoding steps of the scan so as to avoid upgrading a simple renal cyst with an imperceptible or hairline thin wall on US and CT (Bosniak I or II) to a complicated cyst (Bosniak IIF, likely benign, but in need of follow-up imaging). If a lesion depicting wall thickness on MRI is encountered, image interpretation should take into account the direction of wall thickening, and ideally images at higher resolution should be obtained as this will lead to narrowing of the Gibbs bands and thus allow differentiation of truly thick walls from artifactual complexity.

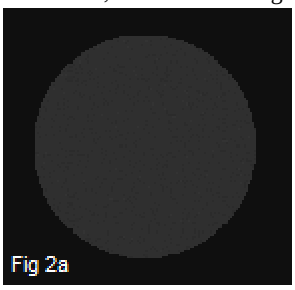


Fig 2a

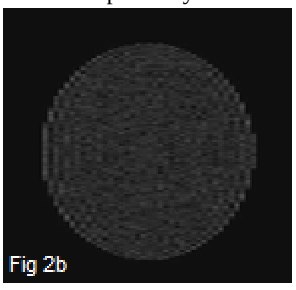
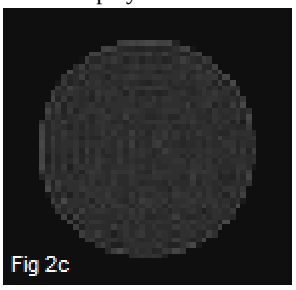


Fig 2b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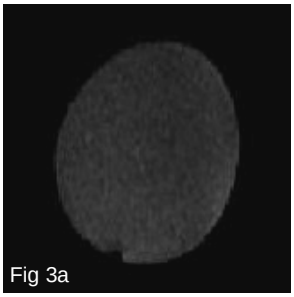
Fig 3a

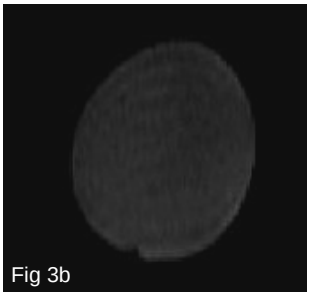
Fig 3b

References:

1. Bosniak MA, *Radiol* 1986;158:1-10. 2. Balci C et al. *Am J Roentgenol* 1999; 172:1495-1500. 3. Israel GM, et al. *Radiol* 2004; 231: 365-371.
4. Haacke EM, *Magnetic Resonance Imaging*, Wiley, New York:1999.