LIMITATIONS OF T2-CONTRAST 3D-FAST SPIN ECHO SEQUENCES IN THE DIFFERENTIATION OF RADIATION FIBROSIS VERSUS TUMOR RECURRENCE

Andrea Vargas[1], Laurent Milot[2], Simon Graham[1], and Philip Beatty[1]
[1]*Medical Biophysics, University of Toronto, Toronto, Ontario, Canada,* [2]*Sunnybrook Research Institute, Toronto, Canada*

TARGET AUDIENCE MR Physicists and clinicians interested in obtaining T2 contrast using 3D-Fast Spin Echo in body applications.

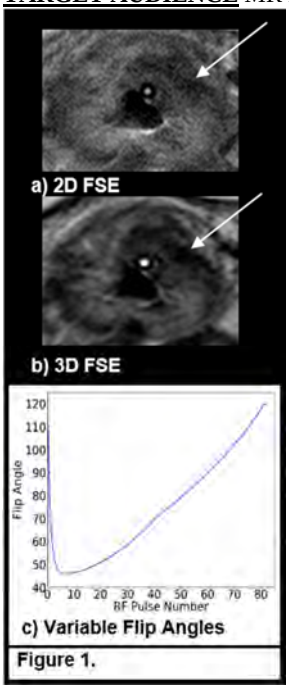

Figure 1.

BACKGROUND The development of extended radiofrequency (RF) refocusing pulse trains with variable flip angles (VFA) instead of conventional 180° refocusing pulses, enabled the acquisition of 3D Fast Spin Echo (3D-FSE) for T2-weighted contrast [1]. The use of VFAs does, however, store magnetization in the longitudinal direction and consequently alters signal intensities relative to 2D-FSE. Figure 1 a) and b) show a sample of contrast alterations between a 2D and a 3D –FSE sequence. Signal alterations are problematic in treatment monitoring, because the differentiation of radiation fibrosis from recurrent tumors can be obscured. The classification of fibrosis versus tumor recurrence has previously been based on estimated ratios of the tissue-to-muscle signal, radiation fibrosis is expected to have a relatively low signal (similar to muscle, with a tissue-to-muscle ratio close to 1.0) while recurrent or untreated tumors are expected to have a ratio close to 3.0 in T2 weighted images [2].

In a 3D-FSE experiment, the equivalent T2 contrast (to the 2D-FSE scan) is targeted by calculating the effective echo time for a given VFA train using an Echo Phase Graph (EPG) [3] algorithm and representative relaxation values (T1rep/T2rep). Current methods choose brain tissues for these representative values, with the correction scheme validated by comparing 2D and 3D-FSE brain images [4]. To date, detailed assessments have not been performed for body applications. It is of particular interest to investigate signal and contrast changes with tissues that exhibit T2 relaxation values that are different from those in the brain using different T1rep/T2rep values.

Table 1.

Tissue	Min/Max T1/T2 (ms)	
Muscle/Fibrosis[5]	1006/35	1008/44
Normal[6,7]	1000/49	1135/58
Cancerous[6]	1000/74	1000/84

PURPOSE **1)** We evaluate the performance of methods to correct the T2-contrast in 3D-FSE sequences in the treatment monitoring of a body application (cervix) which encompasses a relatively wide range of clinically important T2 values (35 ms <T2 < 84 ms) at 1.5T. **2)** Furthermore, we explore the effects of using two different representative tissues to produce equivalent 2D T2 contrast in 3D-FSE.

METHODS An EPG-based simulation framework was developed in Python to model the signal evolution of ranges of key tissues in cervical imaging, as is shown in Table 1. The VFA shown in Figure 1c [1] (which is implemented in current 3D FSE) was used with an echo spacing of 4.0 ms. Two different representative tissues, brain and muscle with T1rep/T2rep of 1000/100 ms and 1000/40 ms, respectively were used compare resulting tissue-to-muscle ratios from 3D-FSE with ratios those of a 2D-FSE at various echo times (TEeffective). . The tissue-to-muscle ratios were calculated using the following equation: $Ratio_{Tissue-Muscle}\,(TEeffective) = \frac{Signal_{Tissue}\,(TEeffective)}{Signal_{Muscle}(TEeffective)}$ for classification (i.e. fibrosis, cancerous) using the ratio ranges provided in reference [2].

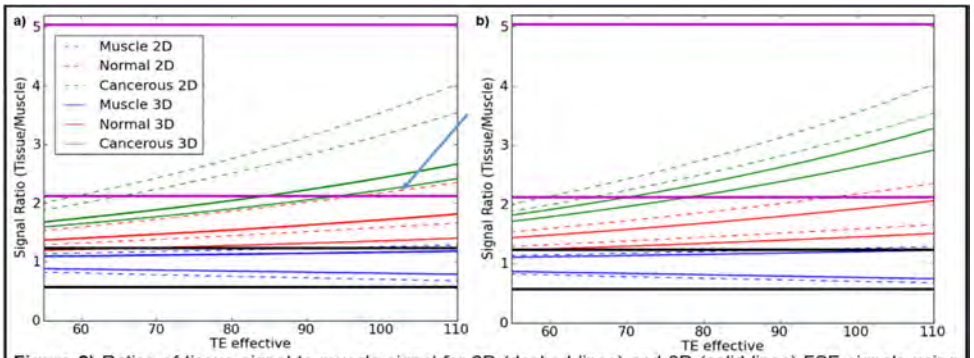

Figure 2) Ratios of tissue signal to muscle signal for 2D (dashed lines) and 3D (solid lines) FSE signals using correction values (T1rep/T2rep) of **a)** brain (T1rep/T2rep=1000/100ms) and **b)** muscle (T1/T2=1000/40ms). Range of ratios indicating recurrent/untreated tumors and radiation fibrosis are enclosed by magenta and black lines, respectively. Upper and lower limits of magenta and black lines have been derived from mean values and standard deviations, which are 3.78 +/- 1.26 and 0.9 +/- 0.33, respectively.[2]

RESULTS In Figure 2a, where contrast had only been corrected with brain T1rep/T2rep=1000/100ms, a near overlap can be seen in the curves (as indicated by arrow). This is problematic because the cancerous tissue now falls below the region considered to be tumor (between magenta lines). However, corrections using muscle (rather than brain) T1rep/T2rep values, as shown in Figure 2b, result in closer tissue ratios between 2D and 3D-FSE (where there are smaller differences between the dashed and solid lines, for each tissue). Although the contrast is more similar after correcting with muscle T1rep/T2rep, there are still discrepancies (between the dashed and solid lines) depending on TE effective. This suggests that clinical T2 contrast may not be simultaneously achieved over all tissues. These differences, even if subtle, can have great effects in treatment monitoring. Simulations were focused on cervical tumors, but the results are relevant to any other body application that have similar range of T2 values.

CONCLUSION This study is relevant to clinical applications involving tissues with T1/T2 values that differ substantially from those of brain. The simulations suggest that it may not be possible to achieve the optimal T2 contrast with 3D-FSE and existing VFA schemes over all ranges of T1/T2. It was found that the changes in signal intensities and contrast between 3D and 2D FSE depend on the reference tissue. Therefore, depending on the clinical application, the implementation of VFAs (no matter what specific VFA schedule) must be undertaken with caution. Even subtle alterations in contrast may obscure the differentiation between recurrent cancerous tissue, fibrosis, and normal tissue. This simulation framework is useful for the validating and optimizing 3D-FSE sequence parameters towards achieving the desired T2-contrast in body applications.

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