Hyperintense Signal from Craniofacial Bones in SWIFT Images of Fetal Mouse

Jinjin Zhang[1], Djaudat Idiyatullin[1], Vladimir Leon Salazar[2], Curtis Corum[1], and Michael Garwood[1]
[1]*Center of Magnetic Resonance Research, University of Minnesota, Minneapolis, Minnesota, United States,* [2]*Div. of TMD and Orofacial Pain, University of Minnesota, Minneapolis, Minnesota, United States*

INTRODUCTION

The detection of skeletal anomalies and accurate prenatal diagnosis of skeletal dysplasia remain problematic with ultrasonography (1,2,3). Although MRI can be used to diagnose some fetal musculoskeletal abnormalities, studies using MRI to visualize fetal bones are limited (4,5,6,7). This is due mainly to the very short transverse relaxation time (T_2) of bone, which makes detection by conventional MRI very difficult. Thus, x-ray computed tomography (CT) must sometimes be used, despite its potential risk to the fetus even with low dose protocols (8). Here, we utilized the MRI method known as SWIFT (Sweep Imaging with Fourier Transform), which is sensitive to short T_2 spins, to image craniofacial bones of a fetal mouse head (9). Due to the near absence of T_2-weighting, SWIFT yields nearly pure T_1-weighted contrast. The aims of this study were to evaluate the performance of SWIFT for fetal imaging and to estimate the longitudinal relaxation times (T_1) of fetal mouse head tissues.

MATERIALS AND METHODS

MRI was performed on a fresh specimen of fetal mouse head (18.5 days old), having an approximate size of 1.0 cm x 0.5 cm x 0.5 cm. Proton MRI measurements were performed on a 31 cm bore 9.4 T scanner (Oxford Magnet/Agilent DirectDrive Console) using a home-made single loop surface coil (2 cm diameter). The specimen was placed at the center of the coil and wrapped with Teflon film. SWIFT images were acquired with bandwidth=125 kHz, TR=3.3 ms, matrix=256^3, number of spokes=128000, and FOV=2 cm x 2cm x 2cm. T_1 relaxation time of the sample was measured by varying the nominal flip angle, θ = 2,3,5,11,15,22 and 33°. A B_1 map was measured with the double-angle method (10) using a 2D gradient echo sequence with TR=3000 ms, TE=4 ms, bandwidth=50 kHz, matrix size=64^2, and slice thickness=2 mm. The T_1 relaxation time was calculated in MATLAB using non-linear two parameter fitting to the Ernst equation. Furthermore, 3D gradient-echo images were acquired with bandwidth=100 kHz, flip angle=40°, TR=6.6 ms, TE=3.3 ms, and the same matrix size and FOV as in the SWIFT experiment. The acquisition time was 6 minutes for each SWIFT image and 7 minutes for GRE. For reference, the specimen was also imaged using μCT scanner (Nikon Metrology NV, Belgium) with tube voltage= 90 kV, current=91 μA, number of projections=2000, exposure time=708 ms.

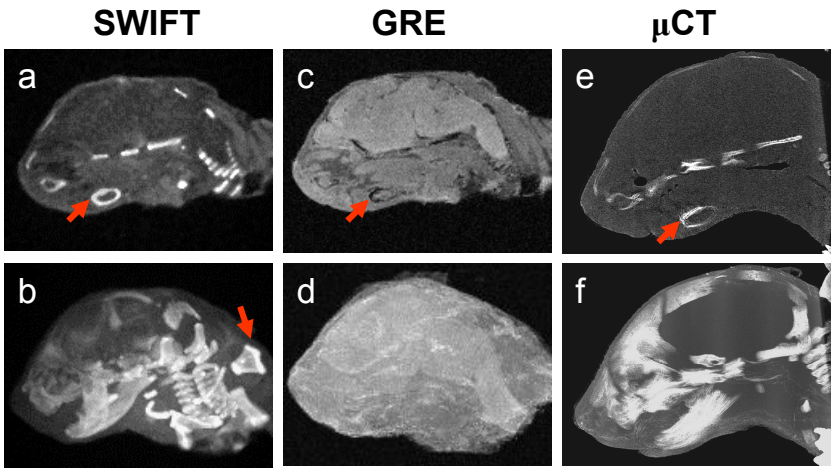

Figure 1 Selected slice of 3D SWIFT image with FA=33° **(a)**, of 3D GRE image with FA=40° **(c)** and of the micro-CT image **(e)**. MIP of SWIFT image **(b),** MIP of GRE image **(d)** and MIP of μCT image **(f)**.

RESULTS AND DISCUSSION

Figure 1 shows selected slice from the SWIFT (a), GRE (c) and μCT (e) image of the fetal mouse head. Maximum intensity projections (MIPs) from SWIFT (b), GRE (d) and μCT (f) are also shown. The craniofacial region and some sections of the spine appear hyperintense in SWIFT images (Fig. a,b), while being nearly invisible in GRE images (Fig. c,d) due to loss of signal from short T_2 spins. The delineation of bony structures in SWIFT images was superior to GRE and with comparable quality to the μCT images (arrows in Fig. a,c,e). In the SWIFT MIP (Fig. b), it is easy to delineate the profiles and dimensions of the nose, jaw, skull, and some parts of the spine. Signal variation on the edge of some bones was observed (arrows in Fig. b), which is indicative of differences in components in the bone. This observation suggests that SWIFT may be useful to visualize compositional development of bone. The average T_1 value for the fetal brain tissue in the specimen was ~1380 ms, which is slightly longer than that of mature brain tissue possibly due to undeveloped myelination and higher mobile water content. The average T_1 values for skeletal tissues were measured to be ~410ms. The nearly simultaneous excitation and acquisition in SWIFT allowed the detection of very short T_2 spins and made the skeletal tissues highly visible in the fetal mouse head. In this experiment, soft tissues were saturated due to the short TR and high flip angle. This enhanced contrast between skeleton and soft tissue. The TR or flip angle in SWIFT can be changed to optimize contrast between differing tissues in a given experiment.

In summary, MR imaging can play a complementary role to ultrasonography for fetal imaging. The feasibility of SWIFT to delineate the anatomy of the fetal skeleton in early gestation stage and to quantify the T_1 relaxation time of the skeleton makes it a promising technique to detect skeletal anomalies and to perform prenatal diagnosis of skeletal dysplasia.

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