Large matrix acquisition of a chemically fixed human embryo for construction of a 3D anatomical database

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INTRODUCTION

Kyoto University has a large collection of chemically fixed human embryos (~50,000) collected since 1961 [1]. To construct their 3D anatomical database, 3D MR microscopic images of about 1,200 chemically fixed human embryos from Carnegie Stage (CS) 13 (28-32days) to 23 (56-60 days) were acquired with a 128×128×256 image matrix in a 2.35 T magnetic field [2]. In 2005, 3D MR images of human embryos from CS16 to 23 were acquired with a 256×256×512 image matrix in a 9.4 T magnetic field using saddle shaped RF coils [3]. For a feasibility study of the forthcoming project, we acquired 3D MR microscopic images of a CS22 (54-58 days) human embryo using a 512×512×1024 image matrix (30 μm^3 isotropic resolution) in a 4.7 T magnetic field using a solenoid coil.

MATERIALS AND METHODS

A CS22 chemically fixed human embryo was inserted into an NMR sample tube (12 mm OD, 10.5 mm ID) filled with preservation fluid to avoid sample motion and susceptibility artifacts (Fig.1). The specimen was inserted into a 4 turn solenoid coil (12.5 mm ID, 25 mm in length) fixed in a gradient coil probe with a planar gradient coil set designed by the target field method and the genetic algorithm. The gradient coil probe was inserted into a 4.74 T vertical bore superconducting magnet (88.3 mm ID). MR images were acquired with a PC (Corei7, 16 GB memory) -based digital MRI system running under the 64-bit Windows 7 operating system utilizing a PC pulse programmer [4]. The pulse sequences were 3D gradient-echo and spin-echo sequences (FOV: (15.36mm)^2×30.72mm, image matrix: 32~512×512×1024, TR=200ms, TE=6~20ms).

RESULTS

Figure 2 shows central cross-sections acquired with the 3D gradient-echo and spin-echo pulse sequences using a 32×512×1024 image matrix (each acquisition time ~ 55 minutes). Table 1 shows signal to noise ratio in the central nerve system and the liver. This table shows that T_2 of the water mobile protons contained in the fixed specimen was ~ 10 ms. Figure 3 shows mid-sagittal and axial cross-sections acquired with the 512×512×1024 matrix using the 3D gradient echo sequence (TR/TE=200ms/6ms, NEX=1, image acquisition time ~ 14.6 hours). The size of the raw data was 2 GB and the image reconstruction time was less than 30 seconds using the PC. Although some artifacts are seen around the right-hand side of the FOV, the anatomical structures of the embryo are clearly acquired. Figure 4 shows average power of the MRI signal plotted against the wavenumber in the k-space for the 3D image data. This graph suggests that although the noise floor was around -70 dBr, high spatial frequency components of the MRI signal were properly acquired up to ~(30 μm)$^{-1}$ ~ 30000m^{-1} [5].

DISCUSSION

For construction of the 3D anatomical database of the human embryos, the matrix size, the spatial resolution, and the measurement time are essential. Our experimental results demonstrate that the 512×512×1024 image acquisition, the 30 μm isotropic resolution, and the image acquisition time less than 24 hours were feasible in our 4.7 T digital MRI system. If we use a higher magnetic field (e.g. 9.4 T) together with a solenoid coil, much higher spatial resolution (~20 μm^3) will be achieved using the same matrix size. In conclusion, the 512×512×1024 image acquisition for chemically fixed human embryos of various developmental stages is feasible with spatial resolutions between 20 and 30 μm^3 at high magnetic fields.

REFERENCES

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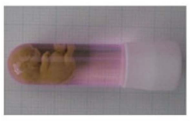

Fig.1

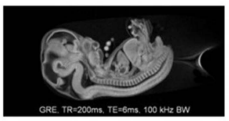

Fig.2(a) GRE, TE=6ms

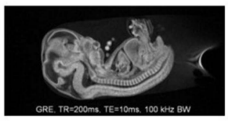

Fig.2(b) GRE, TE=10ms

Fig.2(c) SE, TE=10ms

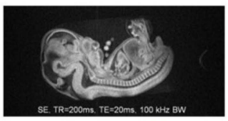

Fig.2(d) SE, TE=20ms

	GRE	GRE	SE	SE
TE (ms)	6	10	10	20
SC	38.1	26.7	16.7	13.5
Liver	34.1	17.9	17.0	7.3

Table 1

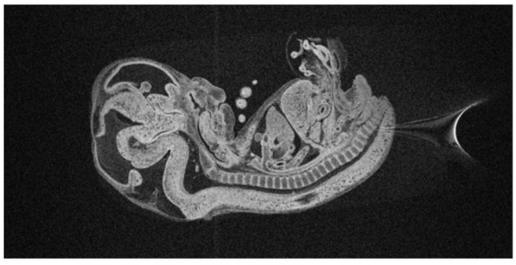

Fig.3(a) Central sagittal section

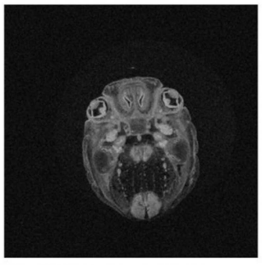

Fig.3(b) Head section

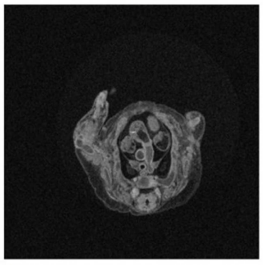

Fig.3(c) Chest section

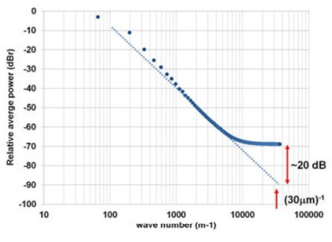

Fig.4 Average power vs wavenumber