MR Studies of the Brains of Human Newborn Infants at 4.7T: Initial Experiences

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Introduction Due to their unique diagnostic and prognostic powers for more than two decades magnetic resonance (MR) techniques have been used to assess cerebral development and pathology in the first few weeks following birth [1,2]. During these 20 years, the quality of MR images and spectra and the abundance of disparate MR measurables has increased steadily due to hardware and sequence development. Whilst high field systems should theoretically provide superior image quality and spectral resolution, their neonatological use is restricted by increased safety concerns (mainly increased radio-frequency power deposition and gradient related acoustic noise). Additionally, changed relaxation (lengthening of T1s and shortening of T2s) challenge the achievement of good structural contrast. We have developed a 4.7T compatible patient handling system, including physiological monitoring and artificial ventilation, dedicated to studies of newborn human infants that additionally provides substantial acoustic noise attenuation. We have ethical approval, for the study at 4.7T of term infants with severe neonatal encephalopathy (NE) requiring artificial ventilation (Sarnat grade II and III). Here we report on the first experiences of neonatal brain imaging and spectroscopy at 4.7T.

Methods MR data were acquired on a whole body 4.7 Tesla system (SMIS MR5000; provided by Philips, Best, Netherlands). Six babies (mean corrected post-conceptional age at scan 41 weeks and 4 days) were scanned with informed parental consent. The infants were protected by a custom made MR compatible perspex pod (o.d. 256mm) lined with sound absorbing material (Sonex 1, Illbruck, USA). The infants were ventilated with a neonatal MR compatible ventilator (B100, BabyPac) and they were fitted with both trimmed sound-absorbing ear plugs (Earsoft, Aearo, UK) and minimuffs (Natus, USA). Continuous physiological monitoring included skin temperature, ECG and pulse oximetry (Nonin, USA). The standard birdcage adult head rf coil (i.d. 28cm) was employed with a loading ring filled with saline solution to achieve good tuning/matching for the neonatal head. All MR sequences were tested for specific absorption rate (SAR) and maximum peak sound pressure level: SAR were well below 2W/kg, acoustic noise levels below 84dbA taking into account the average sound attenuation of earplugs and minimuffs. For T1-weighted (T1-w) imaging a single-echo spin echo (SE) sequence was used with TR/TE 800/13ms, in-plane resolution 0.45x0.9mm^2, slice thickness 4-5mm and 2.5mm interslice separation; 10-12 slices were usually acquired. On 2 babies, SE images were acquired with various TR/TE combinations to evaluate T1 and T2 contrast. For T2-weighted (T2-w) imaging, an 8-echo fast spin echo (FSE) sequence optimised at 4.7T [3] was used, with TR/TEeff=3500/88ms and 22ms echo spacing. Eight slices (thickness 2mm, separation 0.7mm) were acquired with an in-plane resolution of 0.47x0.47mm^2; the total acquisition time was 5m 40s (data-matrix: 512x768). The voxel volume was thus 0.44mm^3, 1/3 to 1/6 that typically employed at lower field [4]. ^{1}H spectra were acquired from a cubic 8ml thalamic voxel using Foci-PRESS [5] with TE=144/288ms and TR=7s and quantified using the jMRUI package [6].

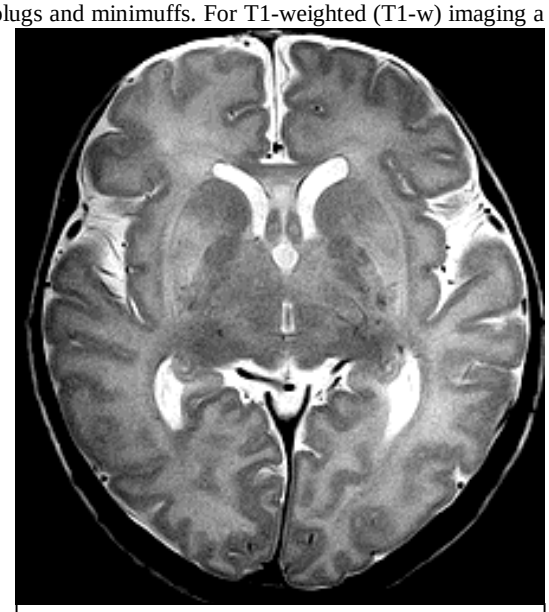

Fig. 1. 4.7 T axial Fast Spin Echo image (TE_{eff}=88ms) of an infant with suspected hypoxic ischaemic encephalopathy (GA: 39+4, age at scan: 13 days).

Results All physiological measurements were stable during the scans. At 4.7T T1/T2 values for white and grey matter in babies with NE ranged between 2200-2600ms/90-130ms and 1700-2100ms/70-90ms respectively. Grey to white matter contrast in the SE T1-w images does not appear greater than at lower fields. However, the high-resolution T2-w FSE images had excellent signal to noise and grey to white matter contrast and allowed differentiation of structures and nuclei not so easily discernible at low field (Fig. 1). These include layers within the hippocampi, different nuclei within the thalami, the medullary laminae separating medial and lateral globi pallidi, lines of alternating signal intensity at the edges of the putamina, external and extreme capsules and claustri. Vessels crossing the slice are also easily visible. The lactate signal at 1.33ppm was observed in all spectra, inverted at TE=144ms and upright at TE=288ms. Peak areas corresponding to N-acetylaspartate, lactate, total creatine and choline were corrected for T2 relaxation so that concentration ratios of these metabolites could be compared with normative values acquired previously at 2.4T [7].

Discussion and Conclusions These are the first MR data to be collected at 4.7T from newborn brain. On T1-w images similar patterns of signal abnormalities associated with neonatal hypoxic ischaemic injury were seen as at lower field. Due to the lengthened and convergent brain T1s in the newborn brain at 4.7T, conventional SE does not appear to be the T1-w method of choice to achieve image quality improvements vs low fields. Having recently optimised MDEFT [8], for the adult brain at 4.7T [9], we are now adapting it to obtain 3D T1-w data from newborn brain. Good quality single-voxel spectra were obtained from all infants. We are now implementing LCModel for absolute quantitation of metabolite concentrations as well as a spectroscopic imaging sequence. Our FSE images demonstrate dramatic improvement in resolution and structure delineation vs lower field T2-w images. This increased detail is likely to prove extremely useful in advancing our knowledge of the relation between structural NE abnormalities and neurodevelopmental outcome. However, detailed interpretation of 4.7 T images will require knowledge of the appearance of healthy brains at a comparable age. All infants will undergo a detailed neurodevelopmental follow-up and we will then be able to construct a retrospective set of normative data from infants with normal outcomes that will improve the prognostic capabilities of both 4.7T images and spectra. Though much further work is required to exploit the full potential of the higher field strength, including development of dedicated, multinuclear, neonatal head coils, our initial experience demonstrates that neonatal MR can be performed safely at 4.7T; with appropriate choice of methodology and in combination with detailed follow-up studies, it can provide new insights into both normal brain development and perinatal brain injury.

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