3D MRSI of the Premature Brain: Defining Normal and Abnormal Maturational Changes

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Introduction

Neonatal MR spectroscopy studies have demonstrated significant metabolic changes due to maturation [1] and to brain injury [2]. Although single voxel MRS has been widely used to monitor metabolite levels in the newborn brain, 3D MRSI can quantify significant variations in metabolite levels across anatomic locations in premature and term infants [3]. In this study, lactate-edited 3D MRSI was applied in a large cohort of premature infants to define the anatomic and maturational changes of brain metabolite levels in infants with normal 1-year neurodevelopmental outcome and to investigate metabolic abnormalities in those with poor outcome.

Methods

Patients: A total of 97 exams were acquired from 58 prematurely born neonates at post-conceptional ages ranging from 27.7 weeks to 42.4 weeks. The studies were performed in an MR compatible incubator to provide a temperature-controlled, well-monitored environment to safely image the neonates, with a specialized, high sensitivity neonatal head coil [4]. Neurologic outcome was assessed at 1 year of age using a validated neuromotor score (NMS) of 0-5 and the mental development index (MDI) of the Bayley Scales of Infant Development II. To assess normal brain maturation, the anatomic and spatial variations of metabolite ratios were analyzed in 61 exams of 35 newborns with normal neurodevelopmental outcome (NMS=0; MDI≥85). A total of 32 exams were acquired from 20 newborns with mild to moderate abnormal outcome (NMS 1 -2 or MDI 70-85), and 3 exams from 3 preterm newborns with severely abnormal outcome (NMS = 3,4 and MDI<70), were compared with the normative, age-corrected values defined in this study.

MRI/MRSI: The neonatal MR studies, performed on a 1.5 T Signa Echospeed scanner (GE Healthcare, Milwaukee, WI), included: 1) T1 weighted sagittal and axial images and 2) T2 weighted axial dual echo, spin-echo with TR of 3sec, TE of 60 and 120ms. Multivoxel 3D MR spectroscopy was performed to obtain metabolite levels covering most of the brain using a custom lactate-editing PRESS-MRSI sequence [5]. The uniformity of the selected region was obtained by slightly overexciting the prescribed region and shaped with very selective saturation (VSS) pulses. The acquisition parameters were 144ms/1s (TE/TR), 1cc resolution, 8x8x8 array, and an acquisition time of 17 minutes.

Analysis Methods: MRSI Analysis was performed using an automatic algorithm [6] to yield metabolite values in specific regions, which were compared using ratios. ROIs were drawn bilaterally on T2 images in the regions of Basal Ganglia (BG), Thalamus (THAL), Optic Radiations (OR), Calcarine Gray Matter (CGM), Corticospinal Tract (CST), Parietal White Matter (PWM), and Frontal White Matter (FWM). The normative data was plotted as age versus metabolite ratios for each of the anatomic regions. Those with abnormal outcome were analyzed as standard deviations from the normative mean corrected for age.

Results and Discussion

For the premature newborns with normal neurological outcome, NAA/CHO levels were found to increase linearly with age in all 7 ROIs. The rate of increase was highest in the optic radiations and corticospinal tracts, which are known to mature most rapidly over this period. The later maturing posterior white matter demonstrated lowest maturational increase. LAC/CHO and LAC/NAA levels were found to decrease with age within this group. The infants with severely abnormal outcome had LAC/NAA and LAC/CHO ratios ranging from 2.5 to 12.0 standard deviations above the mean normative values. Thus this 3D MRSI study demonstrated variations in brain metabolite levels in premature infants due to maturational and anatomic effects, as well as those associated with differences in neurodevelopmental outcome.

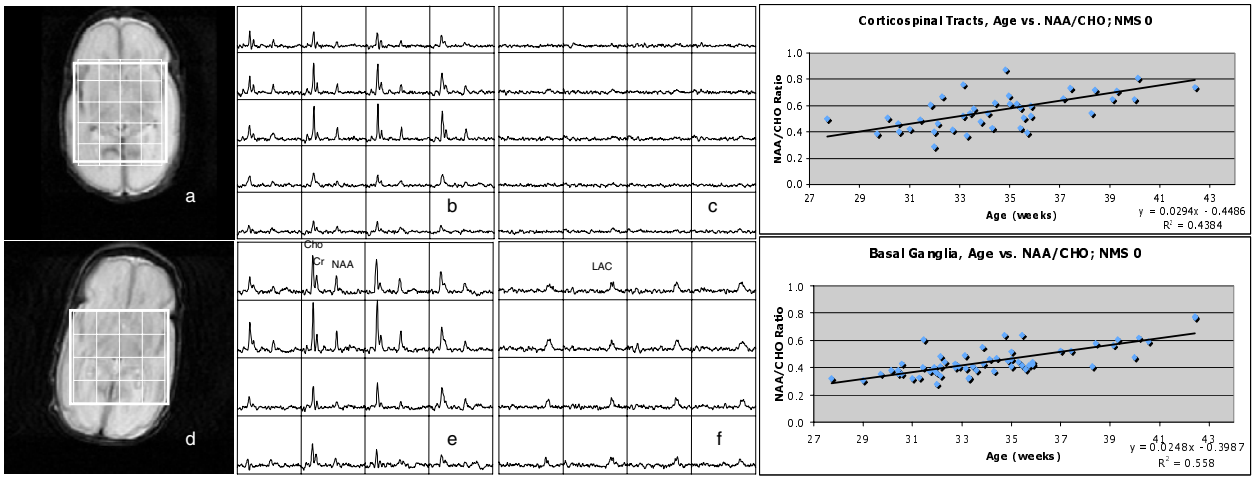

Figure 1. Normative 29 wk MRSI (a, b, c) demonstrate minimal observable lactate (c, f are lactate-edited spectra) compared to a 29 wk neonate with abnormal outcome (d, e, f).

Graphs of the normative MRSI data on the right demonstrate increasing NAA/CHO with age in the CST and BG.

References

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