In vivo visualization of cerebellar cortical layers using structural high field MRI

J. P. Marques[1], W. van der Zwaag[1], C. Granziera[2], G. Krueger[3], and R. Gruetter[1]

[1]Centre d'Imagerie BioMédicale, CIBM, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Vaud, Switzerland, [2]Department of Neurology and Radiology, Centre Hospitalier Universitaire Vaudois, CHUV, Lausanne, Vaud, Switzerland, [3]Advanced Clinical Imaging Technology, Siemens Medical Solutions-CIBM, Lausanne, Vaud, Switzerland

Introduction The cerebellum is a complex brain structure, which plays a major role in movement control and cognitive-emotional processing[1]. The integration of multiple cerebellar functions takes places in the cortical layer, a convoluted structure organized in folia and divided into 3 layers (inside-out: granular, Purkinjie, molecular). The cerebellar cortex is affected by a number of neurologic and psychiatric diseases, such as stroke, tumors, autism and schizophrenia. Therefore, non invasive methods delivering precise anatomical images of the cerebellar cortical architecture could potentially provide new markers for diagnosis and follow up. Our hypothesis is that, at high B_0, susceptibility related contrast in both magnitude and phase GRE images could reveal microstructural features of the cerebral human cortex. This is supported by previous work enhancing the contrast between WM and cortical GM and its layers[2] and the large heterogeneities seen in WM in T2* weighted images. In addition, the increased contrast and signal obtainable at high field allows the exploration of spatial resolutions until recently forbidden. In this study, with the use of a surface coil at 7T, we explore the feasibility of imaging the human cerebellum with an in-plane spatial resolution of 120µm, and observe the granule and molecular layer of the cerebellar cortex.

Methods Three healthy subjects were scanned on a 7T (Magnetom 7T, Siemens, Germany), equipped with a home-built quadrature surface TxRx rf-coil, providing excellent coverage of the cerebellum and occipital cortex. B_0 homogeneity in the cerebellum region was optimized using the vendors shim protocol. Gradient-echo images of the human cerebellum were acquired with a nominal in-plane resolution of ~120µm, slice thickness 1mm (a seven-lobe sinc-pulse was used), FOV 115x115 mm. Slices were positioned obliquely between coronal and sagittal directions in order to minimise through-slice changes in anatomy. TR/TE=1000/25ms with t_{acq} 30ms per readout. 2 repetitions were acquired for each subject, total acquisition time 20 mins. The nominal flip angle was set to 65^0 in the ROI, based on results from a B1-mapping protocol. TE=25 ms was ~T_2^* of GM to optimize phase (1) and T_2^* contrast between different cortical layers of GM.

For comparison, and to evaluate the expected contrast in the cerebellum, an adult rat (Sprague-Dawley, 253g) was scanned in a 14.1T/26cm scanner (Varian/Magnex Scientific). The rat was anesthesised and stereo-taxically fixed with ear bars. Gradient-echo images of the rat cerebellum were acquired with a nominal in-plane resolution of ~30µm. Other scan parameters: matrix 512x512, slice thickness 0.5mm, FOV 17x17mm, TR/TE=1010/16ms, t_{acq} = 10ms. 10 repetitions, total scan time ~60 mins.

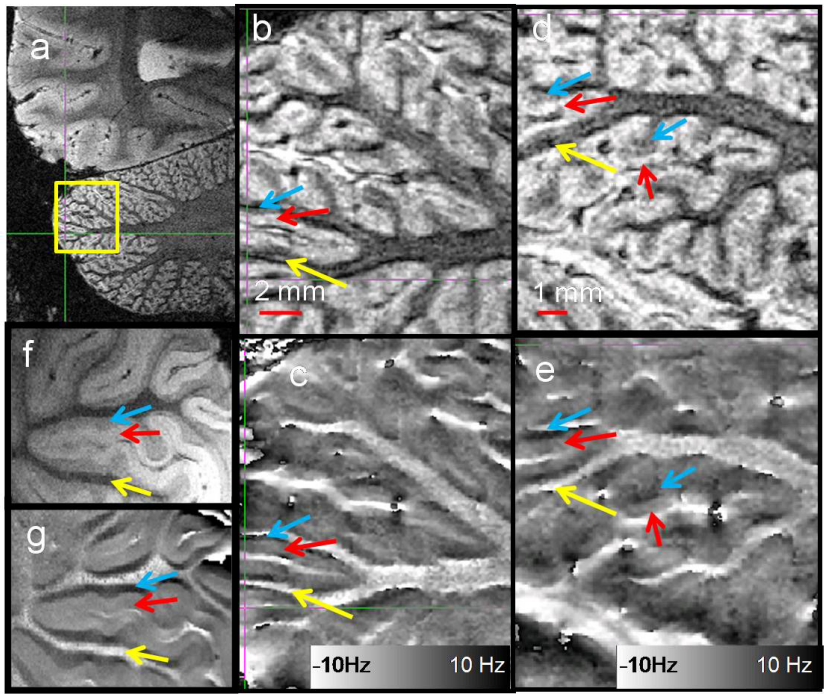

Figure 1 (a) Magnitude GRE cerebellum image of one of the volunteers. The yellow square in (a) represents the region zoomed in the (b) magnitude and (c) phase images in the centre. Magnitude (d) and phase (e) images of similar region obtained from a second subject are also shown. For comparison, rat cerebellum (f) magnitude and (g) phase images acquired at 14T are also shown. Blue, red and yellow arrows point the granule layer, molecular layer and white matter respectively.

Results Because of the complex cerebellar geometry it was not possible to orient slices perpendicular to the cerebellar cortex throughout (Fig. 1a). In magnitude (Fig. 1b and 1d) and phase (Fig. 1c and 1e) images of a region where the cerebellar cortex was found to be perpendicular to the slice direction as judged from the adjacent slices are shown. The white matter bundles conveying into one cerebellar folium appear dark in the magnitude images (MI, yellow arrow) and light in the phase image (PI). The two layers of the cerebellar cortex, on the contrary, appear lighter in the MI and darker in the PI, if compared to the white matter. Two layers within the cerebellar cortex can be distinguished (red and blue arrows) mainly due to the phase contrast.

Discussion The presented high-resolution images exhibit structural details *in-vivo* that – in our opinion - correspond to cerebellar structures (assigned to be the granular and molecular layer). These same structures are more clearly visible in the rat (Fig. 1f-g) thanks to the longer acquisition time, higher resolution and higher B_0.

The use of a TxRx surface coil in the human experiments allowed a reduced field of view and, by reducing the signal from distant regions with increased flow or movement, noise was reduced in the region of interest. While the same resolution may be obtained via parallel imaging, the SNR is still the limiting factor. The rat images (Fig 1f and g) shown are oriented along B_0; the same direction as in the human images (top-down) because the phase contrast of the cerebellum shows an orientation dependence of the granular layer with B_0. This suggests that the contrast of the granule layer has a susceptibility origin and given its amplitude in the phase images suggests that it is highly paramagnetic when compared to most brain tissues.

Conclusion Using ultra-high magnetic fields in combination with a dedicated coil, it was possible to acquire human in-vivo images of the cerebellum with a spatial resolution of ~120 µm and visualise layers within the cerebellar folia that have a thickness of ~240 µm.

References : (1) Schmahmann et al., Brain, 2006, 129, 306-320 (2) J. Duyn et al., PNAS, 2007, 104, 11796-11801; (3) T-Q Li et al., Neuroimage, 2006, 32:1032–1040;