Assessing the corticospinal tract with multimodal quantitative MRI

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Introduction

White matter pathways are visible on T1 or T2-Weighted images, especially at higher field strengths [1, 2]. Notably, at the level of the internal capsule (IC), the corticospinal tract (CST) is hypointense in T1-W but hyperintense in T2-W images [3]. Quantitative imaging techniques (T1 and T2 relaxometry, magnetization transfer ratio, MTR) at 7.0T may become precise enough to locally characterize individual fibre tracts during development, aging or illness. Here we present preliminary results from a multi-parametric study of the corticospinal tract, compared with the neighbouring normally appearing WM of the posterior limb of the internal capsule, on a total sample of 25 healthy participants (aged between 18 and 30 years).

Methods

The imaging protocol (1 hour total time) was performed on a 7.0 T Philips MRI scanner: (1) T1-W whole brain image (0.5x0.5x0.5 mm) used for precise manual positioning of all further acquisitions over the internal capsule, starting from the inter-commissural plane (figure: *A*), (2) VISTA-FSE T2W sequence (0.69 x0.69x1.6 mm, 12 slices), with a good contrast in white matter, used for offline ROI delineation (see figure: *B*), (3) MP-RAGE sequence (0.86x0.86x1.5 mm, 20 slices) with variable inversion times (160, 190, 285, 441, 680, 1050, 1619 and 2100 ms) for T1 mapping [4], (4) three images were acquired for computation of the MTR, two with different saturation pulses and one without saturation pulse (0.86x0.86x1.50 mm, figure: *C,* [5]), (5) high-resolution phase contrast image (0.48x0.48x1.95 mm, 10 slices), and (6) GESSE sequence for T2 mapping with 31 or 25 gradient echoes (0.93x0.93x3.88 mm, 8 slices, figure: *B,* [6]). After co-registration, the individual parameter data (T1 and T2 in ms, and MTR) were extracted for the CST and IC (each ROI being split in three parts, lower third, middle third and top third), and the corresponding three ANOVAs computed, with hemisphere, region and height-level as within-subject factors to assess the presence of a significant difference between the two regions (T1: n=19, T2: n=20, MTR: n=13). The image-contrast effect-sizes were computed with CST / IC ratios in each modality.

Results

Contrast ratios are shown on *D* in the figure; T1 and T2 values were longer and MTR was lower in the CST than in the IC. The T1 constant was the least different between the two regions. Accordingly, the three ANOVAs showed a significant effect of region in each modality (T2, MTR: $p < 0.001$, T1: $p = 0.005$, figure: *D*). No significant effect of hemisphere was found. A significant effect of height-level was found for T2 ($p = 0.02$, figure: *E*), and a two-way interaction between region and height was also significant for T2 ($p < 0.001$, see figure: *E*). A significant three-way interaction between height-level, hemisphere and region was observed with MTR ($p = 0.03$, figure: *E*). T1 values were differently affected by hemisphere and height in the two different regions (hemisphere by region: $p = 0.01$, height-level by region: $p = 0.02$, figure: *E*).

Discussion

The WM structural differences associated with the CST were reflected in elongation of T2 more than T1, suggesting that they would rather be related with T2 rather than T1 processes. Accordingly, the position of the CST in the posterior third of the IC was identifiable on T2 maps (figure: *B*) or MTR images (figure: *C*), but this was difficult on T1 maps. Several factors are known to affect T1 and T2, including the water and iron contents of the tissue and myelination in the WM [7]. Less myelin is associated with a decrease in MTR and longer T1/T2s [7]. Therefore, the results appear compatible with a reduced myelin density in the CST, even though many fibres in the CST are heavily myelinated [3]. Histological studies have reported larger, heavily myelinated, but less densely packed fibres in T2W-hypointense tracts such as the CST and inferior longitudinal fascicle (ILF) [3, 8]. The ILF is more densely stained by the Weigert stain for myelinated fibres than the optic radiation ([9], figure: *B*). From visual inspection, the phase contrast (figure: *C*) seems to enhance dense fibre tracts such as the optic radiation [8], running under the ILF, the anterior parts of the corona radiata, or the short "U"-shaped association fibres running under the cortex [9]. The ILF may be seen with phase contrast as well, but it is still difficult to tell whether phase contrast is sensitive to changes such as those associated with the CST or ILF.

References

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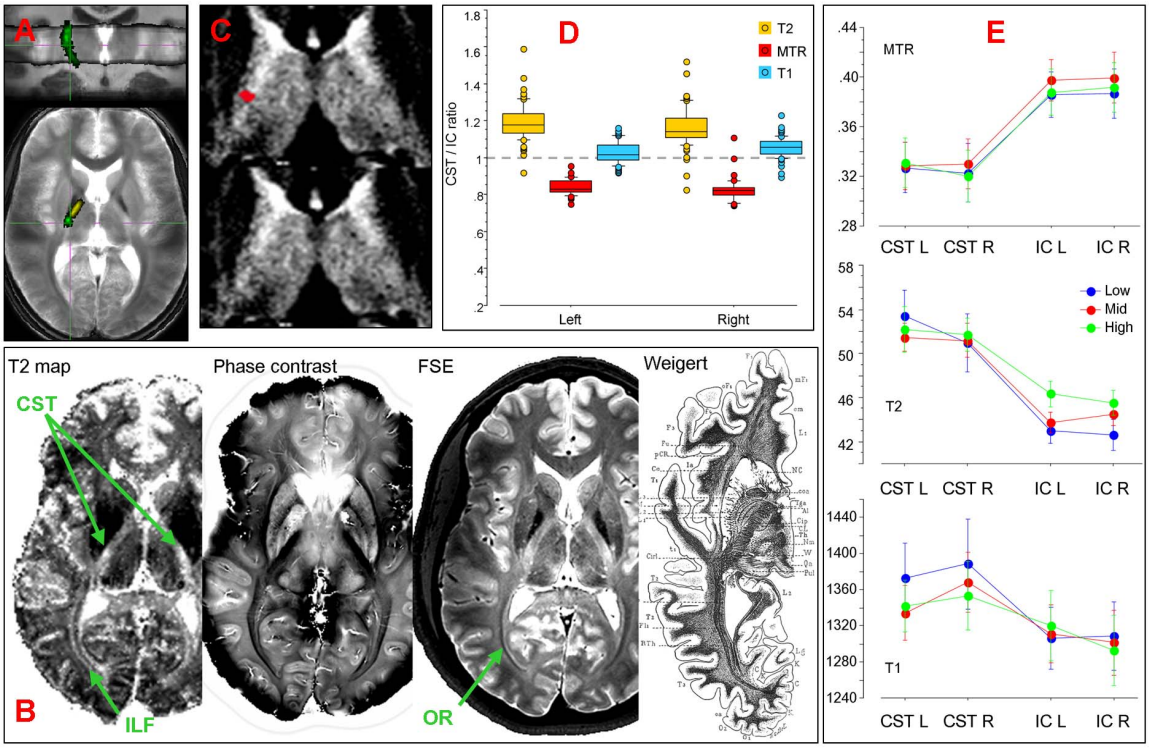

A. Stereotactic averages of T1 and T2W images, with average ROIs for the right CST (green) and IC (yellow) overlaid.
B. Example of T2 mapping, phase contrast and VISTA-FSE images (corresponding slices), along with a Weigert myelin-stain illustration [2]. The CST can be seen on the VISTA-FSE and T2 map.
C. MTR images, showing the CST (ROI in red).
D. CST / IC ratios for T2, MTR and T1.
E. Average (95%CI) MTR, T2 and T1 constants in ms in each ROI (left and right), at three different height levels at the level of the internal capsule