Atlas-based reference tracts improve automatic white matter segmentation with neighbourhood tractography

S. Muñoz Maniega[1], M. E. Bastin[2], A. M. McIntosh[3], S. M. Lawrie[3], and J. D. Clayden[4]

[1]Division of Clinical Neurosciences, University of Edinburgh, Edinburgh, United Kingdom, [2]Medical Physics, University of Edinburgh, Edinburgh, United Kingdom, [3]Division of Psychiatry, University of Edinburgh, Edinburgh, United Kingdom, [4]Institute of Child Health, UCL, London, United Kingdom

Introduction: Segmentation of white matter using tractography from diffusion MRI (dMRI) data provides a means for studying brain connectivity *in-vivo*. Neighbourhood tractography (NT) is a novel technique that aims to automatically segment the same fasciculus in different subjects, thereby facilitating comparison of white matter integrity between groups in clinical studies[1]. The method works by scoring the similarity between a predefined "reference tract" and a group of candidate tracts generated with different initial seed points, with the tract that best matches the reference chosen to represent the fasciculus of interest for each subject. In the original implementation, the reference tract was manually selected from the data set. However, a reference tract selected from a single subject might not be representative of the topological distribution of that particular fasciculus across all subjects under investigation. Also, a new reference tract would be needed to apply NT in new studies. A preferable strategy might be to derive a reference tract from a standard brain representing the common anatomy of the tract of interest. In the current work we have created reference tracts derived from a white matter atlas, which is independent of all subject data, and tested how NT results compare when using this and a reference tract selected from a single subject from the study.

Methods: Fifty normal volunteers (age 35±11) underwent dMRI on a GE Signa LX 1.5T clinical scanner which consisted of 3 T_2-weighted and 51 non-collinear diffusion-weighted (b=1000 s/mm^2) volumes with an acquired voxel dimension of $2.3 \times 2.3 \times 2.8$ mm^3. Seed points were selected in the MNI brain[2] in the left cingulum, left arcuate fasciculus, left uncinate fasciculus and left anterior thalamic radiation (ATR) in areas were no crossings of fibres were expected. These fasciculi were chosen as they are harder to segment than larger fibres such as corpus callosum. The seeds were registered into native space for all subjects and tractography was performed using BEDPOST/ProbTrack[3]. From the resulting tracts, a reference tract, which was considered to best represent the tract of interest, was manually selected from the data set for each fasciculus. Separately, we created references tracts for the same fasciculi referring to a white matter atlas[4], by segmenting manually in the MNI brain the whole region corresponding to the complete tract of interest and resampling to the resolution of the native space. An example showing a sagittal maximum intensity projection of the left uncinate fasciculus is shown in Fig.1a. To obtain a unique maximum intensity pathway running through the tract, adequate for the use of NT, the tract was first binarised (Fig.1b); smoothed with a Gaussian kernel of 2mm SD, therefore encoding at each voxel the distance to edge of the region (Fig.1c); then skeletonised using the same principle as the TBSS technique[3] (Fig.1d). The final reference tract (Fig.1e) was obtained by calculating the reduce tract as shown previously[1].

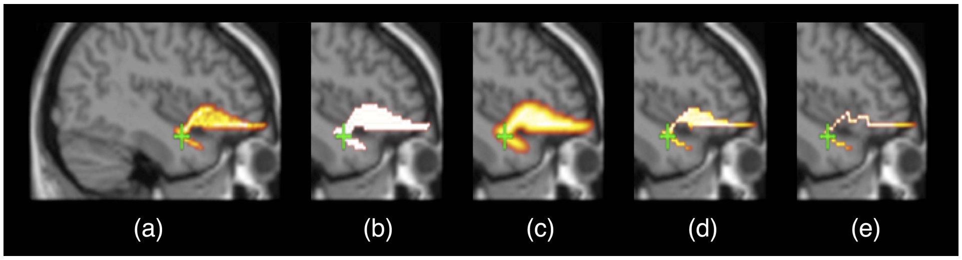

Fig.1 Steps for atlas-based reference tract generation in left uncinate. The green cross indicates the seed point.

Both reference tracts were used in NT to segment each fasciculus of interest in all subjects by selecting the best match. This resulted in two segmentations for each fasciculus, one calculated from the single subject reference tract and one calculated from the atlas based reference tract. To compare both segmentations, the proportions of visually plausible tracts were recorded and the coefficients of variation (CV) of the mean FA values extracted from the resulting tracts calculated. Tracts were not considered plausible if any portion of the tract ran in a direction different from that expected from anatomy or if they were truncated.

Results: Table 1 shows the % of visually plausible tracts and CV of the tract-averaged FA over the entire group. For all fasciculi, atlas-generated reference tracts increased the number of tracts that were anatomically plausible, particularly in the left cingulum. This improvement also translated into a decrease of the variability of FA measured in the entire group as shown by the CV.

Discussion: The reference tract represents the target for NT segmentation and it is therefore crucial that it epitomises correctly the topological characteristics of the fasciculus of interest. We have demonstrated that the results from NT can be significantly improved if the reference tract is generated from an anatomical atlas, rather than from a subject chosen from the study group, as this should be more representative of the standard geometry of the tract. This also has the advantage that once the reference tract has been defined it can be used in a number of studies. However, although the improvement is significant, it is still not sufficient to make the manual checking of the segmented tracts unnecessary, suggesting that further work is required to make this method completely automatic.

Reference Tract		Left cingulum	Left arcuate	Left uncinate	Left ATR
Manually selected	% Plausible	24	50	52	60
	FA CV(%)	19.6	15.7	16.6	15.8
Atlas generated	% Plausible	82	68	66	68
	FA CV(%)	17.7	14.1	16.2	14.6

Table 1 Proportion of plausible tracts and CV using NT and manually selected and atlas-based reference tracts

References:

1. Clayden *et al.* Neuroimage 2006; 33:482-92.

2. Holmes *et al.* J Comput Assist Tomogr 1998; 22:324-33.

3. www.fmrib.ox.ac.uk/fsl/.

4. Mori *et al.* 2005, Elsevier.

Acknowledgements: Scanning was performed in the SFC Brain Imaging Centre (www.dcn.ed.ac.uk/bic)