

Anatomical assessment of the optic radiation in children with probabilistic tractography

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Introduction

Seizure freedom in intractable temporal lobe epilepsy in children can be achieved with surgery. However, temporal lobectomy poses the risk of post-operative visual field defects caused by possible damage to the anterior part of the optic radiation (OR) which has a distinctive curved trajectory, referred to as Meyer's loop (ML). Tractography based reconstructions of the OR are challenging not only due to this pronounced curvature but also due to the presence of neighbouring fibres leading to partial volume effects. Given the lack of anatomical data in children, either through dissection studies or using tractography, we used the latter technique to document anatomical distances associated with the OR in a series of children and adolescents aged 7 to 18 years for the purposes of neurosurgical planning.

Methods

Subjects: 15 children participated in the study without any known medical condition (healthy controls) for which informed consent was obtained. The subjects were composed of 8 boys and 7 girls aged 11.8 ± 3.7 years (range 7 to 18).

DTI data acquisition: The DTI data were acquired on a 1.5 T Siemens Avanto system with a double refocused spin echo EPI sequence, 45 contiguous 2.5 mm slices (averaged for two acquisitions with TE = 89 m), 20 non-collinear directions, b values of 0 and 1000 s.mm⁻². This protocol was repeated 3 times and lasted less than 15 minutes. The reconstructed voxel size was 2.5 mm isotropic.

DTI processing: Correction for eddy currents and small movements was carried out by registering all volumes to the first b=0 volume with a 12-parameter affine transformation (with FSL [1]). Diffusion tensor (DT) fitting was implemented with linear least-squares (with Camino [2]).

Tractography: Tractography was carried out using 10000 iterations of the DT PICo algorithm [3] without any angular threshold to account for the high curvature of ML. A 16-voxel seed region was placed in each hemisphere anterolaterally to the lateral geniculate nucleus in a coronal plane intersecting ML. Tractography was constrained by placing a waypoint ROI to include the stratum sagittale and exclusion ROIs medially (to prevent tracking of the anterior commissure and forceps major), laterally (acoustic radiation) and anteriorly (inferior occipito-frontal and uncinate fasciculi). As the exclusion ROIs trimmed most of the artifactual tracts, the PICo threshold was set to 0.01%.

Anatomical assessment: The tractography results were assessed by measuring distances related to anatomical landmarks and comparing them to an exhaustive list of reference dissection studies in adults (for example [4]) as well as to findings from OR tractography conducted in adults. The distances measured were from the tip of ML to the temporal pole (ML-TP), and to the occipital pole (ML-OP). They were subjected to a multiple regression analysis using cerebral hemisphere (right/left), age and gender as explanatory variables.

Results and Discussion

Tractography: The PICo algorithm enabled the reconstruction of the optic radiation in all subjects with the distinctive shape of the ML being clearly visible. However the use of strictly planar exclusion masks may have prevented the reconstruction of all the fibers of ML. The probability map shown in Figure 1 has a linear scale from red (probability closer to 0) to yellow (probability closer to 1).

Anatomical assessment: For both ML-OP and ML-TP measurements, a one sample T-test on the distance differences between hemispheres showed side dependence (p-value of 0.01 and 0.02 for ML-OP and ML-TP respectively). Distances were thus analysed separately for each hemisphere. The multiple regression analysis model did not demonstrate any age effect, justifying the comparison with adult dissection studies. It did show a significant dependence on gender in the right hemisphere for ML-OP (p = 0.01) and some evidence for a gender dependence in ML-TP (p = 0.07). Weak evidence was found for a gender dependence in the left ML-OP (p = 0.11) but not for the left ML-TP (p = 0.2) Gender specific mean distance estimates (and SEs) are listed in Table 1. Compared to previous tractography studies in adults (e.g. [5]) the ML-OP distance found in this study is systematically larger and ML-TP smaller, with the exception of [6] in which smaller values of ML-TP, 28 ± 3.0 [24,34] mm, is reported. The ML-OP distances computed compared well with dissection studies in adults but the values found for ML-TP were larger. For example [4] reported 98 ± 6.2 [85,108] mm for ML-OP and 27 ± 3.5 [22,37] mm for ML-TP. These findings suggest a reconstruction of most of the OR except for the most infero-anterior part corresponding to the high curvature of ML.

Conclusions

This study provided two main contributions. First it showed a statistically significant dependence on gender with respect to the dimensions of the OR, which has not previously been reported in tractography or dissection studies. Secondly, it provides data on the anatomical distances associated with the OR in a paediatric series. The results suggest that in this cohort aged 7 to 18 the dimensions of the OR is equivalent to that in adults but also that in this group hemisphere and gender must be taken into account when evaluating the extent of the OR. It is envisaged that these findings are relevant when considering neurosurgical planning for temporal lobectomy in children.

References

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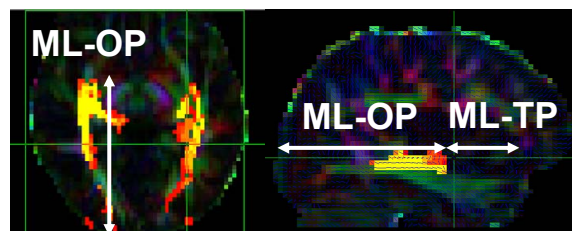


Figure 1: probability map from the PICo algorithm.

| Gender | Distance (in mm) for left OR | | Distance (in mm) for right OR | |
|--------|------------------------------|----------------------------|-------------------------------|----------------------------|
| | ML tip - Occ. pole | ML tip - Temp. pole | ML tip - Occ. pole | ML tip - Temp. pole |
| F | 93.9 ± 1.5 [90.0, 100] | 34.3 ± 1.7 [32.5, 40.0] | 93.9 ± 1.5 [90.0, 100] | 31.4 ± 0.9 [27.5, 35.0] |
| M | 98.1 ± 1.9 [90.0, 105] | 36.6 ± 1.2 [32.5, 40.0] | 100.6 ± 1.5 [95.0, 107.5] | 35.0 ± 1.5 [30.0, 42.5] |

Table 1: anatomical distances computed from tractography.

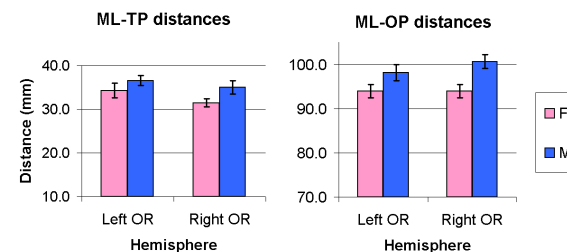


Figure 2: ML-TP and ML-OP distances according to gender and hemisphere.