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Diffusion tensor imaging tractography of Meyer's loop in planning resective surgery for drug-resistant temporal lobe epilepsy

Jija S. James[b], Ashalatha Radhakrishnan[a,*], Bejoy Thomas[b], Mini Madhusoodanan[a], Chandrashekharan Kesavadas[b], Mathew Abraham[a], Ramshekhar Menon[a], Chaturbhuj Rathore[a], George Vilanilam[a]

[a] *R Madhavan Nayar Centre for Comprehensive Epilepsy Care, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum 695011, India*
[b] *Department of Imaging and Interventional Radiology, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum 695011, India*

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Summary
Purpose: Whether Meyer's loop (ML) tracking using diffusion tensor imaging tractography (DTIT) can be utilized to avoid post-operative visual field deficits (VFD) after anterior temporal lobectomy (ATL) for drug-resistant temporal lobe epilepsy (TLE) using a large cohort of controls and patients. Also, we wanted to create a normative atlas of ML in normal population.
Methods: DTIT was used to study ML in 75 healthy subjects and 25 patients with and without VFD following ATL. 1.5 T MRI echo-planar DTI sequences with DTI data were processed in Nordic ICE using a probabilistic method; a multiple region of interest technique was used for reconstruction of optic radiation trajectory. Visual fields were assessed in patients pre- and post-operatively.
Results: Results of ANOVA showed that the left ML-TP distance was less than right across all groups ($p = 0.01$). The average distance of ML from left temporal pole was 37.44 ± 4.7 mm (range: 32.2—46.6 mm) and from right temporal pole 39.08 ± 4.9 mm (range: 34.3—49.7 mm). Average distance of left and right temporal pole to tip of temporal horn was 28.32 ± 2.03 mm (range: 26.4—32.8 mm) and was 28.92 ± 2.09 mm, respectively (range: 25.9—33.3 mm). If the anterior limit of the Meyer's loop was $\leq$38 mm on the right and $\leq$35 mm on the left from the temporal pole, they are at a greater risk of developing VFDs.

* Corresponding author. Tel.: +91 471 2524282; fax: +91 471 2446433.
E-mail address: drashalatha@sctimst.ac.in (A. Radhakrishnan).

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Conclusions: DTIT is a novel technique to delineate ML and plays an important role in planning surgical resection in TLE to predict post-operative visual performance and disability.

Introduction

Anterior temporal lobectomy (ATL) is a widely accepted surgery for temporal lobe epilepsy (TLE). However, a standard ATL can sometimes cause optic radiation (Meyer's loop, ML) injury in the temporal lobe, which may lead to an incongruous superior quadrantanopia of varying severity. Although the degree of visual field defect (VFD) greatly depends on the anatomic range of the resection, it is well known that the same extent of resection can result in different degrees of VFD in different individuals. The reported rates of VFDs after ATL range from 60 to 100% in various studies (Jensen and Seedorff, 1976; Barton et al., 2005). This is especially important in the context of pre-surgical counseling of patients who undergo ATL for drug-resistant TLE, both lesional and non-lesional, where the field defect that can happen after surgery needs to be detailed to the patient and the family.

The optic radiation (OR) shows high degree of intersubject variability and cannot be delineated on conventional magnetic resonance imaging (MRI) since the variability of white matter signals are minimal. The anterior limit of ML has been estimated to be anywhere from 20 to 60 mm posterior of the temporal pole, with much lower estimates in more recent studies (Salmon et al., 2000; Nilsson et al., 2004; Yogarajah et al., 2009). Although cadaveric study still remains the gold standard to delineate the optic radiations and ML, diffusion tensor imaging tractography (DTIT) with an individual 3D brain model provides a complementary method to study the OR and ML in vivo. DTIT is a non-invasive advanced neuroimaging technique that allows the delineation of microstructural architecture of white matter fiber pathways in vivo which has been standardized in our center (Radhakrishnan et al., 2011). This technique can probe the magnitude of diffusion of water molecules in different directions in each voxel (Basser, 1995; Mori and Van, 2002). The location of the ML is variable with its anterior position varying as much as 1—2 cm between individuals (Ebeling and Reulen, 1988). So it is important to identify the varying patterns of OR in different individuals and in different populations to study their inter individual variability.

To minimize the occurrence of VFD after ATL, a surgeon may have to limit his resection to standard measurements especially in individuals where their occupation or driving is likely to be jeopardized. But this method of limiting the resection to avoid VFD may not help all patients, since the anatomy is variable in each individual and in different populations, thus causing this over simplification irrational and patient can sometimes become a ''triple loser'' by not becoming seizure-free despite financial losses he/she incurs paying for surgery, at the same time ending up with a VFD. Hence, a procedure like DTIT of ML if standardized and utilized routinely may play an important role in the presurgical evaluation of anterior temporal lobe resections in TLE to avoid postsurgical VFD.

The aim of the present study was to create a normative atlas of Meyer's loop for clinical and research purposes on a large age-matched population of male and female participants which has not hitherto been established. The objectives while doing so were to

(1) Map the extent of optic radiation and especially the ML in a sizeable cohort of healthy normal adults.
(2) To assess the interindividual variability in the extent of the ML in normal healthy volunteers at various anatomic locations.
(3) To measure the fractional anisotropy (FA) indices, mean diffusivity (MD) values and fiber tract volume of ML using diffusion tensor imaging and fiber tractographic techniques.
(4) Application of these measurements to decide on the safe limit of anterior temporal lobe resection in refractory TLE on either side (right and left) not causing VFD in patients.

Materials and methods

Subjects

The study was undertaken at the R. Madhavan Nayar Center for Comprehensive Epilepsy Care and Department of Imaging and Interventional Radiology, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum, Kerala, South India, a tertiary referral center with ample expertise in tackling difficult-to-treat epilepsies. Data were obtained from 75 healthy age matched subjects (age range: 22—37 years, 45 males and 30 females; all right handed) with no head injury, history of prior neurosurgery, visual deficits or psychiatric illnesses. The controls were chosen from patients who underwent brain MRI for one of the following indications: chronic headache, trigeminal neuralgia, transient ischemic attack, optic neuritis and acute meningitis; but the brain parenchyma and the optic radiations were essentially normal. Also, it was undertaken in 25 consecutive patients, all right handed, with and without VFD after a standard ATL for refractory TLE of various etiologies (mesial temporal sclerosis-9, tumors-12, cavernoma-2, gliosis-2). Two neurosurgeons (MA and GV) experienced in performing epilepsy surgeries conducts a standard ATL in our center, a maximum of 6—6.5 cm of the non-dominant temporal lobe and 4.5—5 cm of the dominant temporal lobe are resected. The mesial resection includes the amygdala and approximately 3—4 cm of the hippocampus.

The Institutional Ethics committee approved the study and a written informed consent was obtained from all subjects (normal subjects and patients) after explaining the procedure and the utility of the study. All the participants co-operated with the study procedure. All patients were