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Application of diffusion tensor imaging and tractography of the optic radiation in anterior temporal lobe resection for epilepsy: A systematic review

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ABSTRACT

Background: Approximately 50–100% of patients with temporal lobe epilepsy undergoing anterior temporal lobe resection (ATLR) will suffer a postoperative visual field defect (VFD) due to disruption of the optic radiation (OpR).
Objective: We conducted a systematic review of the literature to examine the role of DTI and tractography in ATLR and its potential in reducing the incidence of postoperative VFD.
Methods: We conducted an electronic literature search using PubMed, Embase, Web of Science and BMJ case report databases. Eligibility for study inclusion was determined on abstract screening using the following criteria: the study must have been (1) an original investigation or case report in humans; (2) investigating the OpR with DTI in cases of ATLR in temporal lobe epilepsy; (3) investigating postoperative VFD. All forms of ATLR and ways of assessing VFD were included to reflect clinical practice.
Results: 13 studies (four case reports, eight prospective observational studies, one prospective comparative trial) were included in the review, 179 (mean ± SD, 13.8 ± 12.6; range, 1–48) subjects were investigated using DTI. The time of postoperative VFD measurement differed between the detected studies, ranging from two weeks to nine years following ATLR. A modest number of studies and insufficient statistical homogeneity precluded meta-analysis. However, DTI methods were consistently accurate at quantifying and predicting postoperative damage to the OpR. These methods revealed a correlation between the extent of OpR damage and the severity of postoperative VFD. The first and only trial with 15 subjects compared to 23 controls reported that using intraoperative tractography in ATLR significantly reduces the occurrence of postoperative VFD on comparison to conventional surgical planning.
Conclusions: DTI shows potential to be an effective method used in planning ATLR. Findings from a single modest sized study suggest that tractography may be employed as part of intraoperative navigation techniques in order to avoid injury to the OpR. Further research needs to be conducted to ensure the applicability and effectiveness of this technology before implementation in routine clinical practice.

Contents

Abbreviations: ADC, apparent diffusion coefficient; A–P, antero–posterior; ATLR, anterior temporal lobe resection; DTI, diffusion tensor imaging; FA, fractional anisotropy; MD, mean diffusivity; MRI, magnetic resonance imaging; n/a, not applicable; OpR, optic radiation; ROI, region of interest; SAH, selective amygdalohippocampectomy; TLE, temporal lobe epilepsy; VFD, visual field defect; 3D, three-dimensional.

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1. Introduction

Temporal lobe epilepsy (TLE) is the most common type of surgically treated epilepsy in adults and has a high rate of seizure freedom following surgery [1]. Anterior temporal lobe resection (ATLR) procedures (including but not restricted to en bloc resection and selective amygdalohippocampectomy (SAH)) can ameliorate drug-resistant TLE [2], however 50–100% [3,4] of patients will suffer a postoperative visual field defect (VFD) [5]. VFD are the most common complications following ATLR [6]. Even if rendered seizure-free from ATLR, patients who suffer VFD may not be able to drive. This has psychosocial implications, particularly in younger patients where the inability to drive may inhibit social independence or may disable certain occupations [7]. Pathak-Ray et al. revealed in their study that 7/14 (50%) patients who underwent ATLR for TLE failed to meet UK Driving and Vehicle Licensing Agency standards [3]. Furthermore, a larger study of patients undergoing temporal lobe surgery ($n = 135$) found that 64% of patients suffered a VFD and 50% of these patients had a VFD that prevented them from meeting the German legal requirements to drive [8]. Taylor et al. revealed that the ability to drive is considered by patients to be one of the five most important outcomes following epilepsy surgery [9]. Consequently, a priority for ATLR candidates is avoiding postoperative VFD [10].

VFD occurs when patients suffer disruption to the optic radiation (OpR), including the 'Meyers loop' (the most anterior portion of the OpR), during ATLR. Therefore, employing imaging techniques in surgical planning and guidance that delineate the OpR in relation to epileptogenic foci could facilitate the prevention of postoperative VFD.

The anatomy and definitions of the OpR remain controversial. In part this is because the structures of the temporal stem lack anatomic landmarks [11], either in surgical or structural imaging investigation, and in part because the exact position and limits of the OpR have been found to be highly variable between individuals [12]. However, in recent studies, diffusion tensor imaging (DTI) has been used to more reliably reveal the anatomy of the OpR.

DTI is a relatively novel application of magnetic resonance imaging (MRI) in the planning of epilepsy surgery and is not routinely utilised alongside conventional imaging modalities. DTI exploits the diffusion principles of water in the cerebral white matter tracts in order to create a three-dimensional (3D) representation of diffusion within each voxel [13]. Commonly, scalar metrics such as fractional anisotropy (FA) and mean diffusivity (MD) are derived from this diffusion 'tensor' in order to provide further insight into the microstructural architecture of the brain [14]. Further manipulation of the diffusion tensor can also allow the 3D visualisation of the white matter tract anatomy, coined 'tractography' or 'fibre tracking'. DTI can be used to reveal the neuroradiological relationships and proximity between epileptogenic brain regions and important white matter tracts. Thus, the deviation, displacement and destruction of OpR white matter fibres caused either by epileptogenic regions or surgical intervention may be directly assessed using DTI.

We conducted a systematic review of the literature in order to examine the potential use of DTI and tractography in surgical planning and intraoperative guidance to correlate, predict and/or prevent VFD in ATLR.

2. Materials and methods

2.1. Search strategy

One investigator (RJP) conducted an electronic literature search using PubMed, Embase, Web of Science and the BMJ case report databases. Searching strategies used a combination of the following terms: epilepsy, diffusion tensor imaging, tractography, fibre tracking, surgery, visual field deficit/defect, optic radiation, and Meyer's loop. The citations listed in the found studies and reviews were manually screened for relevant studies not detected using the electronic search. In cases where the full-text was not available, most commonly in conference abstracts, personal communication was made to the corresponding author and the full-text or relevant data was requested. Alternatively, the full text not available electronically was sought out in paper copy. The search aimed to detect all of the literature meeting our selection criteria and was initially carried out on the 19th of June, 2013, and then updated on the 5th of March, 2014.

2.2. Selection criteria

Eligibility for inclusion in the review was determined on abstract screening using the following inclusion criteria: (1) the study reports an original investigation or case report in humans (i.e. not a review, comment or response); (2) the study investigated the OpR using pre-, intra- or postoperative DTI assessment in the management of ATLR in TLE; and (3) the study must have investigated a measure of VFD. We intentionally included all forms of ATLR and ways of assessing VFD to reflect clinical practice.

3. Results

3.1. Search results

46 studies were initially detected using our search strategy (nine PubMed, seven Embase, 29 Web of Science, zero BMJ case