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Perspectives of an innovative ophthalmological technology: Optical coherence tomography (OCT) – What should be of interest to the neurologist?

Tjalf Ziemssen[a,*], Focke Ziemssen[b]

[a] MS Center Dresden, Center of Clinical Neuroscience, Department of Neurology, University Hospital Carl Gustav Carus, Dresden University of Technology, Dresden, Germany
[b] Centre for Ophthalmology, Eberhard-Karl-University Tuebingen, Tuebingen, Germany

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ABSTRACT

Ocular coherence tomography has revolutionised the prospects of measuring the loss of retinal ganglion cells secondary to degenerative diseases and monitoring time-dependent changes of optic disc morphology, since the resolution has been improved considerably and the time required has been reduced. Although the non-invasive technique promises a high inter-session reproducibility, the limitations of retinal imaging and the problems of segmenting of the retinal layers have to be taken into account. While the first studies were limited to single sessions in small groups, further trials will elucidate how the retinal nerve fibre layer (RNFL) is altered in the course of different episodic forms of multiple sclerosis. This review points out that the examination technique already provides comprehensive information, valuable in the daily care of neurological patients.

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1. Introduction

The possibility of quasi in vivo histology has made way for new perspectives pertaining to the evaluating and quantifying of retinal nerve fibre layer. The further development of new devices has revolutionised the knowledge concerning optic nerve processes and retinal changes concomitant to CNS disorders. Neuroscience now has new objective parameters available as potential biomarkers for neurodegeneration. As an upstream part of the neurocranium, the retina is of special interest. The structure and thickness allow for conclusions to be made concerning the retinal ganglion cells [43].

2. Optical coherence tomography – the physical principle of the technique

The examination by optical coherence tomography (OCT) is based on the optical reflection and is, therefore, completely contact-free. The cross sections are created using coherent light beams from a diode (infrared range, $\lambda > 820$ nm) [48]. Different structures reflect the signal with a time offset. From the pattern of numerous axial individual scans, corresponding to the A scan of an ultrasound, a two-dimensional picture is calculated similar to that of the B scope. Even when the images are primarily dependent upon the optical properties of the examined structures, the process promises a resolution of the living tissue in such a manner which could only otherwise be achieved using microscopy histological thin-sections (Fig. 1).

Earlier generation devices (time domain) created the necessary interference pattern using a mobile reference mirror in such a manner that a recording speed of 400 scans/s and an axial resolution of approx. 10 μm were achieved. Because of the lengthy examination time, motion artefacts were also a common problem [42]. Currently, a stationary reference mirror and a multiple frequency separated light beam are mainly used. The high quality image information results from the interference pattern of various frequencies which are evaluated using a Fourier transformation after an analogue digital converter (spectral domain). With such devices, faster detection is possible (up to 40,000/s). Via an additional averaging by eye-tracking and brightness enhancement, correspondingly higher resolutions can be achieved (up to 5 μm longitudinal, 3 μm axial). When analysing retinal nerve fibre layer thickness a high reproducibility is achieved by increasing the amount of frames per measurement and by averaging values of repeated measurements per session [7,35].

Although significant diurnal variation was seen in pathologic findings as macular oedema or individual layers as the choroid [20,45], no major influence of the daytime was found regarding to the assessed retinal thickness [27].

* Corresponding author at: Center Dresden, Center of Clinical Neuroscience, Department of Neurology, University Hospital Carl Gustav Carus, Dresden University of Technology, Fetscherstr. 74, 01307 Dresden, Germany. Tel.: +49 351 458 4465; fax: +49 351 5717.
E-mail address: Tjalf.Ziemssen@uniklinikum-dresden.de (T. Ziemssen).

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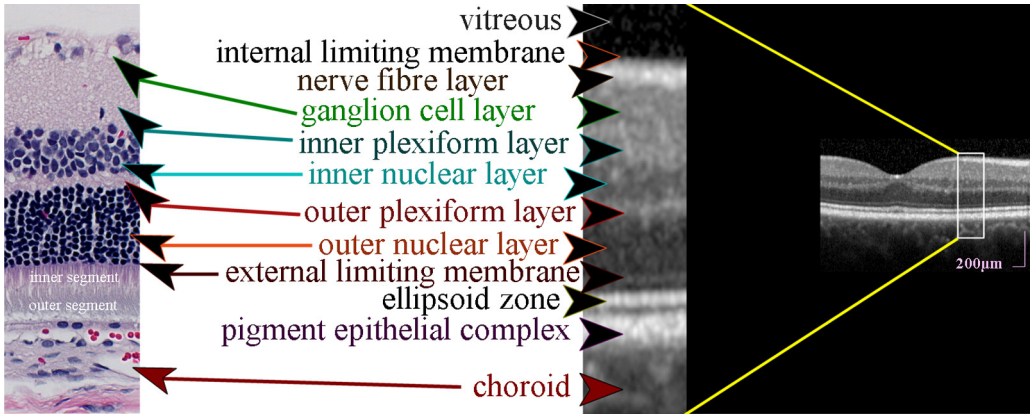

Fig. 1. The lines of optic reflectivity – as seen in spectral domain ocular coherence tomography – can be assigned to the histological layers of the retinal anatomy.

3. Scopes of application

The simultaneous topographical correlation with the fundus image can further increase the validity of the measurement. The planning of the sectional plane not only makes it possible to evaluate long-term changes, but also to observe target structures for pathology and therapy [15,23]. From the neurologic perspective, optic nerve processes are of special interest [5,43]. Due to the high spatial resolution, the technology seems to be ideal for an objective morphometry of the optic disc. Size, excavation and possible oedema/atrophy can easily be displayed (Fig. 2). The non-invasive technique is clearly superior to an ultrasound assessment and needs considerably less training resp. extensive devices in comparison to direct ophthalmoscopy or neuroradiology [9,34]. Altitudinal visual field defects can be assigned to the localised thinning of the nerve fibre layer (Fig. 3) [11]. The preserved nerve fibres also provide information concerning the recovery potential of compressive opticopathies, which for example concerns the gain of visual acuity after the resection of a tumour or decompression surgery [8]. The prominence of papilledema and of peripapillary exudation can be more precisely evaluated (Fig. 4) [4,38,40]. Functional effects of a chronic pseudotumor cerebri have their morphological correlate within the viewable atrophy of the nerve fibre layer. Deposits within the scope of optic disc drusen can be confirmed.

Newer ischaemia (e.g. anterior ischaemic optic neuropathy: AION or vascular occlusions) manifests in a localised swelling (Fig. 5). A central macular oedema, e.g. due to an accompanying uveitis, can be quantified. Furthermore, the distribution of intraretinal and subretinal fluid can be displayed within the scope of a neuroretinitis (Fig. 6).

4. Limitations and problems

Even though the temptation is strong, the calculated image must not be confused with the extension of actual structures. The displaying of retinal layers only shows reflection deviations of adjacent structures. Specifically within the area of outer retinal layers with their very close anatomical relationships, the histological assigning and the correlating of the displayed layers to the actual structures of the retina has not been finally clarified, yet. Here, the increasingly higher resolution of the images will deliver new information [41]. The measuring beam reflected from the retinal structures depends on the distance, thickness and reflectivity of the tissue. While strong defective vision has very little effect on the axial preciseness of the method, the transversal images (coronary plane) must be correspondingly corrected. It has been shown that in the case of reduced or doubtful discriminatory power the single layers

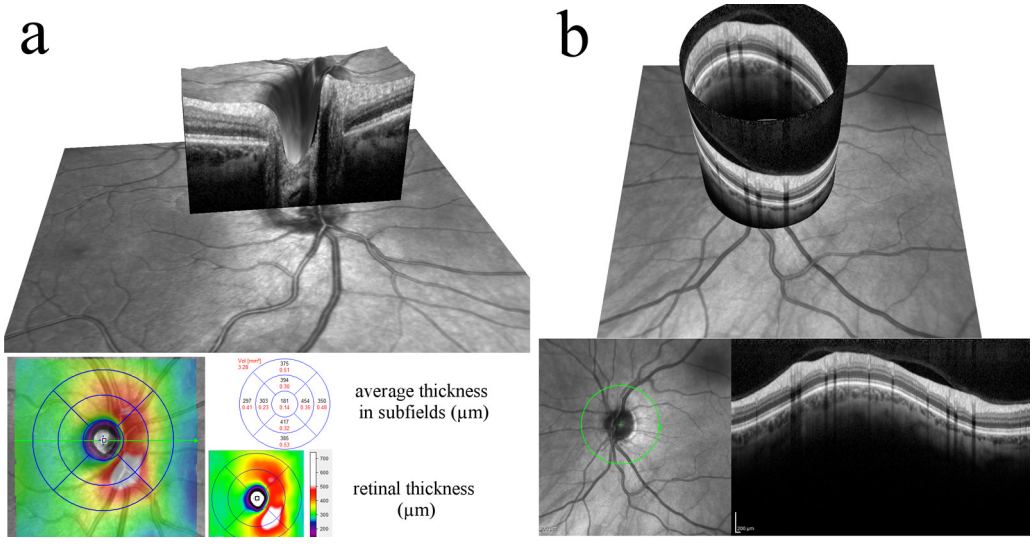

Fig. 2. The optic disc can be described either by contour analysis and volumetry (a) or measurements of the neuroretinal rim (RNFL: retinal nerve fibre layer) when assessed through a peri-papillary circle (b).

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