Parkinsonism and Related Disorders 19 (2013) 1–14

Contents lists available at SciVerse ScienceDirect

Parkinsonism and Related Disorders

journal homepage: www.elsevier.com/locate/parkreldis

Review

Foveal vision is impaired in Parkinson's disease

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ARTICLE INFO

Article history:
Received 6 July 2010
Received in revised form
16 July 2012
Accepted 21 July 2012

Keywords:
Retina
Visual cortex
Fovea
Contrast sensitivity
Isoluminance colour contrast
PERG
Optical coherence tomography (OCT)
ERG/VEP
Dopamine
Higher visual dysfunction

ABSTRACT

Purpose: The article aims to review foveal involvement in Parkinson's disease.
Scope: Clinical observations as well as electrophysiological and anatomical studies in animal models provide evidence that Parkinson's disease (PD) affects vision. The retina is the most distal locus of visual dysfunction in PD as shown by electroretinographic (ERG) and optical coherence tomographic (OCT) studies. Thinning of the retinal nerve fibre layer (RNFL) and the fovea has been reported in PD. This review summarises retinal physiology and foveal visual dysfunction in PD and quantification of retinal thinning as reported in different studies and using different instruments. At this point due to methodological diversity and relatively low number of subjects studied, a meta-analysis is not yet possible. Results obtained on one equipment are not yet transferable to another. The author also briefly alludes to some links of visual processing deficits beyond visual detection, such as visual discrimination, visual categorisation and visuospatial orientation in PD.
Conclusions: There are some promising results suggesting the potential applicability of ST-Oct as a biomarker in PD. Furthermore, these data raise some interesting neurobiological questions. However, there are identifiable pitfalls before OCT quantification may be used as a biomarker in PD. Analysis standardisation is needed on a larger than existing healthy and patient population. Furthermore, longitudinal studies are needed. The exact relationship between retinal foveal deficits and visuo-cognitive impairment in PD remains a challenging research question.

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http://dx.doi.org/10.1016/j.parkreldis.2012.07.012

This review examines the effects of Parkinson's disease (PD) on foveal vision in humans and in primate models of the disease. Several comprehensive reviews on dopamine in retinal processing have been published previously [1–5]. The current review focusses on foveal signal processing and PD, and considers its potential contribution to higher order visual processing.

Although the fovea represents a tiny anatomical region of the retina, the number of cortical neurons per unit of visual field devoted to foveal input is much larger and contains more neurons than the network devoted to perifoveal vision [6–8]. Functionally, the fovea mediates the highest contrast sensitivity (CS) [9]. CS is a critical, low-level visual process involved in object recognition [10]. Electroretinography (ERG) and optical coherence tomography (OCT) [11,12] reveal retinopathy in PD. The amplitude of the pattern ERG (PERG) and the multifocal ERG (mfERG) are dominated by foveal processing [13,14] and are reduced in PD.

A comparison of different OCT studies is difficult because of differences in equipment and varying factory algorithms of analysis. In addition, as with many imaging techniques, OCT yields masses of data.

Foveal CS contributes to both the detection and discrimination of visual stimuli [15]. It was originally suggested in 1984 [16] that visual impairment is relevant to gait and balance, which are among the major movement defects in PD. Some studies [17–20] suggest that even in early stages of PD, patients demonstrate decreased stability and that changes in the visual input impair their postural control [18–20]. However, it remains to be seen whether or not impaired foveal visual processing in PD causes visuospatial deficits [19] and upsets multisensory interactions necessary for maintaining gait and posture [18–20]. The potential effect of impaired vision on motor impairment in PD is beyond the scope of this review.

1. Foveal vision – the retina and primary visual cortex

Fixating on visual targets for better scrutiny enlists the fovea, which is the region of the retina containing the highest concentration of photoreceptors. Additional foveal processing occurs within the retina before ganglion cell axons (comprising the nerve fibre layer – NFL) leave the retina to carry this information to the brain via the optic nerve. The density of the photoreceptors per unit area in the fovea provides exquisite visual acuity, and interactions between these and other retinal neurons are responsible for high CS. The foveal–extrafoveal distinction is more complicated when moving stimuli are used, but evidence shows that motion processing may also be affected in PD, although this is not discussed in this chapter.

Retinal output from the fovea is further augmented by the computational properties of the visual cortex, which participates in object recognition. Foveal vision is subserved by a small area of the retina that is greatly magnified in the representation of the central visual field in the visual cortex [6–8]. Furthermore, object selection and visual attention is mediated by the processing that takes place in the connections between visual cortical areas in the occipital lobe and additional visual cortical areas in the temporal and parietal lobes. Receptive fields of neurons located nearest to the foveola have amplified signals that capture attention for relatively small stimuli in a complex, large-scale visual scene [21].

In summary, three important properties of foveal vision include: a) high CS; b) high density of cortical neurons per unit area of this part of the visual field; and c) preference for these signals in visuospatial attention in realistic visual scenes containing many potential targets.

2. Retinal architecture and visual functions of the fovea

The retina is a multilayered structure with distinct neural elements in each layer (Fig. 1). Receptors in the outer layers convert light energy to a change in membrane potential, signalling the bipolar cells in the middle of the retina, which then synapse onto ganglion cells in the inner layer. The axons of the ganglion cells leave the retina as the optic nerve. Lateral and feedback connections are mediated by two other cell types: horizontal cells and amacrine cells. Amacrine cells, including those that use the neurotransmitter dopamine, are located in the layer closest to ganglion cells (Fig. 2). The inner retina (IRL) includes the NFL, the ganglion cell layer and the inner plexiform and inner nuclear layers, while the outer retina (ORL) consists of layers starting from inner nuclear layer up to and including the retinal pigment epithelium.

The special role of the fovea in anthropoids is subserved by its architecture. All vertebrates have a central retinal area, often called area centralis, mediating the highest visual acuity. It is called fovea because in several species it appears as a depression or pit in cross-section. The fovea of anthropoids is characterised by a high density of cone photoreceptors underneath the depression. In humans, this area is approximately 1.5–2 mm in diameter within the larger macula lutea where the retina thins out greatly. The term macula refers to a circular area including and surrounding the fovea. The

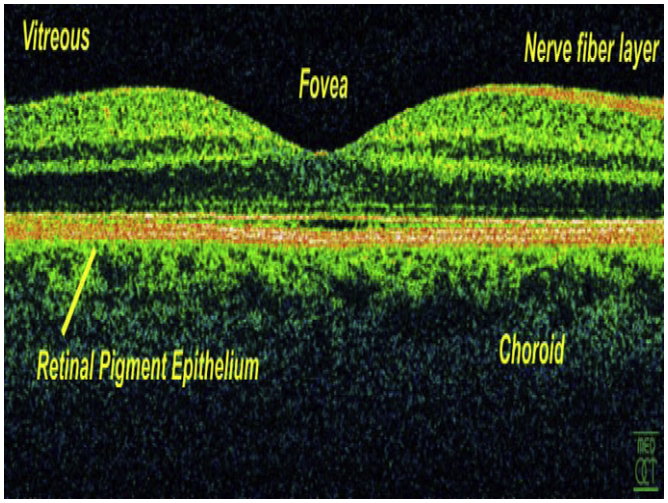

Fig. 1. The foveal region of the human retina. The colour coded illustration is an average, derived from a spectral domain optical coherence tomography (SD-OCT) study. Different retinal layers can be visually identified above the layer labelled retinal pigment epithelium. For further explanation and not averaged, but for single passage OCT-s see Fig. 10. (From an on-line Wikipedia entry).