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Optical coherence tomography algorithm failure to detect nerve fibre layer defects: report of two cases

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Glaucomatous damage typically causes retinal ganglion cell and retinal nerve fibre layer (RNFL) loss that can occur diffusely and focally. Optical coherence tomography (OCT) is a non-invasive, non-contact technology that allows cross-sectional high-resolution in vivo imaging of intraretinal layers. Since structural abnormalities may precede functional abnormalities, it might be expected that an OCT RNFL abnormality would be observed when glaucomatous visual field (VF) loss is present. We report two patients who demonstrated clinically evident focal RNFL defects with corresponding VF loss that failed to be recognised as outside normal limits by OCT analysis.

Case 1

The first subject had normal-tension glaucoma with a best-corrected visual acuity (BCVA) of 20/25 in the right eye and marked optic nerve head (ONH) cupping, inferior disc haemorrhage and inferotemporal RNFL wedge defect (fig 1A). VF showed a superior nasal step with an early arcuate scotoma (fig 1B). The OCT RNFL thickness profile (StratusOCT; Carl Zeiss Meditec, Dublin, California) revealed a narrow depression into the abnormal zone (red colour) in the inferotemporal region and borderline depression (yellow) in the superior and superonasal regions. The OCT demonstrated borderline thin superior sectors on clock-hour analysis when compared with the OCT normative database but failed to demonstrate thinner than normal RNFL in the inferotemporal sectors (fig 1C). The cross-sectional scans showed an overt narrowing of the RNFL that was markedly underestimated by the RNFL edge detection analysis by failing to follow the surface (fig 1D).

Case 2

The second subject had primary open-angle glaucoma in both eyes (OU) with BCVA 20/20 in the right eye (OD) and 20/30 in the left eye (OS). The patient had marked ONH cupping, attenuation of the rim in the inferior quadrants OU and a small inferior disc haemorrhage OD. Superotemporal and inferotemporal RNFL wedge defects were noted in OU, more pronounced in OS (fig 2A). VF showed an early inferior nasal step with superior paracentral

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scotomas OD and dense inferior arcuate and superior paracentral and nasal scotomas OS (fig 2B).

Questions & Answers

1. Describe the OCT RNFL thickness profile and clock-hour analysis (figs 1C, 2C).

The RNFL thickness profile revealed depressions in the inferotemporal region OU and in the superotemporal region OS. OCT demonstrated borderline thinning compared with the normative database at 7 o'clock and normal thickness in all other clock-hour and quadrants OD. In OS, the clock-hour analysis showed the 1 and 5 o'clock positions and the inferior quadrant to be borderline thin.

2. Describe the cross-sectional scans (figs 1D, 2D).

The cross-sectional scans showed localised thin RNFL within the normally thick superior and inferior areas. The areas of thin RNFL were smoothed out by the software algorithm and were not detected or detected as borderline.

3. How would you interpret OCT results in the future?

The OCT data require careful and critical analysis in order to interpret the information complementary to and in context of the conventional clinical and functional examination. Localised RNFL defects might be missed or underestimated by OCT analysis due to failure of the RNFL defect to thin to such an extent that it falls below the first percentile for the population represented by the device's normative database. It is important to critically analyse the graphic representation and OCT images. The averaging algorithm may "wash out" the data from the defect by averaging them with the data of the adjacent thicker areas. This is most pronounced when the localised defect occurs in an area with thick RNFL such as the superior and inferior regions.

Discussion

The StratusOCT software uses a normative database that allows excellent discrimination between healthy and glaucomatous eyes.¹ There are some patients, however, who may have thinning of the RNFL, yet remain within the normal range. In these patients, RNFL defects and even VF loss may be present, yet the OCT may give readings that do not fall into the borderline or abnormal zones in the clock-hours scheme. It is clear from the RNFL thickness profile that the shape of the RNFL curve is not normal in these patients. That is, instead of having the four elevations ordinarily seen, two superior and two inferior, an area of expected elevation may be flat or even depressed. Because the curve still lies within the boundaries of the normal or borderline range, this RNFL thinning is not flagged or flagged only as borderline. The clinician must identify the abnormal shape of the curve, which indeed deviates from the expected without dropping below the floor of "normal."

StratusOCT uses cross-correlation for alignment of adjacent A-scans and smoothing image processing procedures in order to provide homogenous scans and consistent results. The RNFL is differentiated from other retinal layers using an edge detection algorithm. Using this software, the OCT has been shown to provide reproducible quantitative RNFL data² and to enable good discrimination between healthy and glaucomatous eyes.³ However, this approach, in concert with the limitations of the normative database, is also vulnerable to missing well-established localised RNFL defects as we demonstrated in this study.

When narrow and deep RNFL defects are present, the smoothing algorithm may fail to recognise them and bridge the gaps, thus overestimating thinner RNFL area as seen in our

cases. This is most pronounced in places where the RNFL is thickest (superior and inferior regions). Furthermore, the quadrant and clock-hour sectors are arbitrarily defined and do not follow the actual anatomical distribution of the ganglion cell axons which might further affect the analysis output and obscure or underestimate thinning areas.

We therefore recommend that the routine OCT evaluation by the clinician should include careful attention to the thickness profile that might reveal RNFL thinning that is not flagged as borderline or outside normal limits in the quadrant and clock-hour analyses. In cases where there is a discrepancy between the clinical findings and OCT, further insight may also be gained by viewing the actual cross-sectional images, taking into account the limitations of the software as outlined above.

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Figure 1.

Red-free photograph demonstrating (A) an inferotemporal retinal nerve fibre layer (RNFL) wedge defect with (B) superior nasal step and early arcuate scotoma. (C) Optical coherence tomography (OCT) showing a thin RNFL in the superior sectors of the clock hour analysis, dropping into the borderline region. (D) OCT cross-section with RNFL narrowing that was markedly underestimated by the RNFL edge-detection analysis.

Figure 2. Red-free photographs demonstrating superotemporal and inferotemporal retinal nerve fibre layer (RNFL) wedge defects in both eyes (A), with corresponding scotoma (B). (C) Optical coherence tomography (OCT) showing thin RNFL at 7 o'clock in the right eye and at 1 and 5 o'clock and in the inferior quadrant in the left eye, all falling only into the borderline zone. (D) OCT cross-section with localised thin RNFL within the normally thick superior and inferior areas. The thin RNFL is masked by the software algorithm's smoothing procedure.