Dehazing of Visible-light OCT B-scans using Deep Neural Model improves Visualization and Quantification of Retinal Sub-layers

ARVO 2022 Travel Grant Recipient

Rozita Zeinab Ghassabi[1], Joel S. Schuman[1-3], Ting-Fang Lee[1,5], Jiyuan Hu[1,5], Eitan Shemuelian[1], Ronald Zambrano[1], Roman V. Kuranov[6], Ian Rubinoff[7], Gadi Wollstein[1,3,4], Hiroshi Ishikawa[1,8,9], Hao F. Zhang[6,7]

[1]Department of Ophthalmology, NYU Langone Health, New York, NY; [2] Department of Electrical and Computer Engineering, New York University Tandon School of Engineering, New York, NY; [3]Center for Neural Science, NYU College of Arts and Sciences, New York, NY; [4] Department of Biomedical Engineering, New York University Tandon School of Engineering, New York, NY; [5]Division of Biostatistics, Departments of Population Health and Environmental Medicine, NYU School of Medicine, New York, NY; [6]Opticent Inc., Evanston, IL; [7]Department of Biomedical Engineering, North Western University, Evanston, IL; [8]Department of Ophthalmology, Casey Eye Institute, Oregon Health & Science University, Portland, OR; [9]Department of Medical Informatics and Clinical Epidemiology, Oregon Health & Science University, Portland, OR.

NYU Langone Health

PURPOSE

- Multiple sublayers of retina can be visualized with visible light (vis-) OCT [1]. However, image quality can be compromised due to patient movement, cataracts, small pupil size, and light scattering causing haziness and variability in signal to noise ratio in individual A-scans and in entire B-scans.
- The purpose of this study was to examine the effect of conventional and deep neural network dehazing and denoising techniques on the visibility and quantitative assessment of retinal sub-layers on vis-OCT images.

METHODS

- 9 healthy and 5 glaucoma subjects were scanned 3 times during one session. Scanning was done on the superior nasal side of para-foveal region,1.5 mm from the fovea with a 3D speckle reduction raster scanning protocol (3x3x1.6 mm with 8192x16x1024 samplings) using a prototype vis-OCT system.
- 16 A-scan lines were averaged to reduce speckle noise. Gray-scale image dehazing guided by depth information and pretrained Dehazenet deep model following deep convolutional neural network with residual learning (DnCNN) were applied on original B-scans.
- For each subject, the dehazed B-scan of Dehazenet and DnCNN from a fixed location adjacent to the fovea were selected.
- The distances between each of 3 bright inner plexiform layers (IPL) and retinal pigment epithelium (RPE) sublayers were segmented manually for thickness measurements using an 8 A-scan averaged profile (Fig.).
- Quality improvement were evaluated using quality index (QI) and contrast to noise ratio (CNR) on dehazed B-scans.
- Coefficient of variations (CVs) were calculated to assess the measurement repeatability of the sublayers on original and dehazed B-scans.

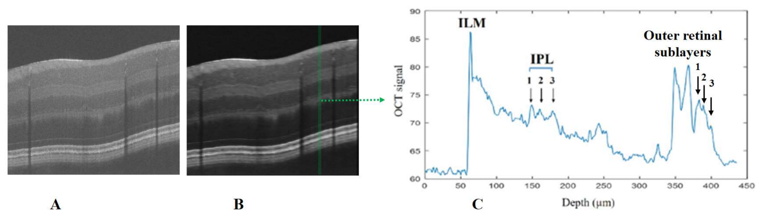

Fig. Illustration of the vis-OCT B-scan. An Original B-scan (A), Dehazed B-scan by Dehazenet and DnCNN (B) with the averaged A-scan over the width of the green box (C)

Table 1: QI and CNR for gray-scale image dehazing and deep neural dehazing and denoising (n=14).

	QI (mean±SD)	CNR (mean±SD)
Original	57.21±5.71	4.21±1.02
Gray-scale image Dehazing	68.47±6.12 (p<0.001)	3.51±1.02 (p<0.001)
Dehazenet and DnCNN	98.71±5.21 (p<0.001)	6.03±1.22 (p<0.001)

p value is computed in comparison with the original using t-test.

Table 2: IPL thickness measurements (mean±SD) and CVs on original and dehazed B-scans.

	Sublayer 1	Sublayer 2	Sublayer 3	Entire
Thickness of 9 Healthy Original B-scans	11.27±1.00	17.64±1.43	11.31±0.81	40.22±2.14
Thickness of 5 Glaucoma Original B-scans	11.04±0.93	14.15±1.76	10.61±0.73	35.80±1.50
Thickness of 9 Healthy Dehazed B-scans	11.23±0.50	17.84±0.75	11.18±0.52	40.30±1.14
Thickness of 5 Glaucoma Dehazed B-scans	11.04±0.45	14.00±1.19	11.00±0.49	35.95±1.01
Intra-subject CV (%) of Original B-scans (n=14)	5.89	6.76	6.51	2.69
Intra-subject CV (%) of Dehazed B-scans (n=14)	0.023	0.027	0.039	0.013
p value (Original vs. Dehazed Intra-subject CV)	<0.001	<0.001	0.001	0.015

Table 3: Outer retinal layers thickness measurements and CVs on original and dehazed B-scans.

	Sublayer 1	Sublayer 2	Sublayer 3	Entire
Thickness of 9 Healthy Original B-scans	8.82±0.78	11.75±0.98	8.19±0.63	28.75±1.41
Thickness of 5 Glaucoma Original B-scans	9.02±0.66	12.41±0.80	7.94±0.52	29.99±0.03
Thickness of 9 Healthy Dehazed B-scans	9.02±0.60	11.67±0.82	8.18±0.55	28.87±1.50
Thickness of 5 Glaucoma Dehazed B-scans	9.02±0.53	12.48±0.06	7.93±0.53	29.45±1.02
Intra-subject CV (%) of Original B-scans (n=14)	0.060	0.054	0.065	0.021
Intra-subject CV (%) of Dehazed B-scans (n=14)	0.015	0.018	0.022	0.012
p value (Original vs. Dehazed Intra-subject CV)	<0.001	<0.001	0.002	0.010

RESULTS

- Healthy and glaucoma subjects were 45.7±11.7 and 59.6±13.4 years old (p=0.07, t-test), visual field mean deviation (MD) was -1.55 to 1.20 dB, and from -26.42 to -7.70 dB (p=0.003, Wilcoxon), and global mean circumpapillary retinal nerve fiber layer (RNFL) thickness was 96.33±12.20 and 59.80±9.09 µm (p<0.001, Wilcoxon), respectively.
- Dehazed and denoised B-scans obtained by deep models have statistically significant better QI and CNR (Table 1).
- The results support that intra-subject CV before dehazing and denoising is greater than after dehazing (Tables 2,3).

DISCUSSION

- Overall intra-subject CVs showed significantly improved reproducibility on all measured sub-layers of dehazed and denosied B-scans by deep models compared to original B-scans for all subjects.

CONCLUSION

- Vis-OCT image quality can be improved using deep neural network dehazing and denoising models resulting in higher reproducible thickness measurements of retinal sublayers within subjects in dehazed, denoised B-scans.

References

1. Ghassabi Z., Kuranov R. V., Schuman J. S., et al, In Vivo Sublayer Analysis of Human Retinal Inner Plexiform Layer Obtained by Visible-Light Optical Coherence Tomography, Invest. Ophthalmol. Vis. Sci. 2022;63(1):18.

Author Financial Disclosure Information: Joel S Schuman: Zeiss (patent) and Opticent Inc (personal financial interests), Hao F Zhang: Opticent Inc (personal financial interests), Roman V Kuranov: Opticent Inc (Employment), Support: NIH R01-EY013178, U01-EY033001, P30EY013079, unrestricted grant from Research to Prevent Blindness

National Eye Institute
NATIONAL INSTITUTES OF HEALTH

Research to Prevent Blindness