Published in final edited form as:

Ophthalmol Retina. 2018 March ; 2(3): 244–250. doi:10.1016/j.oret.2017.06.005.

Quantitative OCT Angiography Evaluation of Peripapillary Retinal Circulation after Plaque Brachytherapy

Alison H. Skalet, MD PhD^{1,†}, Liang Liu, MD^{1,†}, Christina Binder, MD PhD², Audra K. Miller, MD¹, Jie Wang, MS¹, David J. Wilson, MD¹, Richard Crilly, PhD², Charles R. Thomas Jr, MD², Arthur Y. Hung, MD², David Huang, MD¹, and Yali Jia, PhD¹

¹Casey Eye Institute, Oregon Health and Science University, Portland ²Department of Radiation Medicine, Oregon Health & Science University, Portland

Abstract

Objective—To study peripapillary retinal capillary circulation in eyes treated with I-125 plaque brachytherapy for uveal melanoma using optical coherence tomography angiography (OCTA).

Design—Cross-sectional study of 10 subjects imaged with OCTA prior to uveal melanoma treatment and 15 subjects imaged after development of radiation retinopathy and/or optic neuropathy.

Participants—Following IRB approval, subjects were enrolled from an academic ocular oncology clinical practice. All subjects had uveal melanoma in one eye and treatment with I-125 plaque brachytherapy was planned or had previously taken place. Patients with low vision at baseline and uncontrolled hypertension were excluded. In the post-treatment group, seven subjects were male and eight were female; age range 38 to 81 years. Visual acuities in the irradiated eyes ranged from 20/20 to counting fingers. Visual acuities in the untreated fellow eyes were 20/25 or better.

Methods—Peripapillary retinal capillary circulation was measured by OCTA (Optovue, Inc). 4.5×4.5 mm optic disc scans were obtained. 10 subjects were imaged prior to brachytherapy

Corresponding author: Alison H. Skalet, 3375 SW Terwilliger Blvd, Portland, OR 97239, Tel: 503-494-7881, Fax: 503-494-7233, skalet@ohsu.edu.

[†]Authors sharing first co-authorship

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Author contributions:

Research design: AHS, CRT, DJW, AH, DH, YJ

Data analyses: AHS, LL, CB, AKM, JW, YJ

Manuscript preparation: AHS, LL, CB, AKM, DJW, DH, YJ

COI Disclosures:

Oregon Health & Science University (OHSU), David Huang and Yali Jia have a significant financial interest in Optovue, Inc., a company that may have a commercial interest in the results of this research and technology. Other authors do not have financial interest in the participant of this article.

Trial Registration: [Clinical trials.gov](https://clinicaltrials.gov) ID NCT01955941

treatment and 15 subjects were imaged after development of clinically apparent radiation retinopathy and/or radiation optic neuropathy post-brachytherapy.

Main Outcome Measures—The relationship of the peripapillary retinal capillary density (PPCD) as measured by OCTA to the calculated dose to the optic nerve (D50, the dose to 50% of the disc) and the LogMAR vision was evaluated.

Results—No significant difference was seen in the PPCD as measured by OCTA when comparing the eye with melanoma to the fellow eye prior to brachytherapy; however the PPCD was significantly lower in treated eyes (52.9% $\pm$ 22.4%) than in fellow eyes that did not receive radiation (73.3% $\pm$ 13.7%, $p = 0.004$). There was an inverse linear correlation between D50 and the PPCD (Pearson's; $r = -0.528$, $P = 0.043$) and between visual acuity and the PPCD (Pearson's; $r = -0.564$, $P = 0.028$).

Conclusions—Among patients with clinically apparent radiation retinopathy and/or radiation optic neuropathy, PPCD was lower in the treated eye and correlated with the radiation dose to the optic nerve and the visual acuity. OCTA provides a measure of capillary changes following radiation, and may serve as a quantitative endpoint to address visual prognosis.

Introduction

Uveal melanomas are the most common primary intraocular malignancy in adults, with an incidence of approximately 5–6 cases per million population.^{1–3} Eye-sparing treatment with radiation is an option for many patients diagnosed with uveal melanoma, but often leads to significant loss of vision. The degree of vision loss varies widely, with some patients experiencing only mild decline in measured visual acuity and others becoming entirely blind in the treated eye.^{4–7} In the landmark Collaborative Ocular Melanoma Study, 43% of patients treated with plaque brachytherapy were found to have measured visual acuity in the severely compromised range at 3 years post-radiation.⁸

Vision loss after radiation therapy typically occurs due to radiation optic neuropathy and retinopathy caused by vascular compromise leading to ischemia and edema.^{9–13} Advanced vascular compromise can be observed with traditional fluorescein angiography, which shows retinal vascular leakage and capillary drop out in eyes with radiation-induced damage.^{14,15} Optical coherence tomography angiography (OCTA) is a new, non-invasive method for imaging retinal vasculature and providing quantitative information regarding ischemia in the retina.^{16–20} The association of radiation maculopathy with decreased parafoveal capillary density as measured by OCTA has been previously reported.²¹ OCTA findings may allow for earlier detection of radiation maculopathy.²² We hypothesized that OCTA can measure radiotherapy-induced changes in retinal vasculature associated with radiation optic neuropathy. Herein, we describe for the first time the use of OCTA to evaluate radiation optic neuropathy by quantitatively measuring the peripapillary capillary density (PPCD) in eyes treated with plaque brachytherapy. We also demonstrate an inverse linear correlation between the calculated PPCD and the radiation dose to the optic nerve as well as the LogMAR visual acuity in the treated eye.

Methods

Study Subjects

Following IRB approval, subjects were enrolled from an academic ocular oncology clinical practice. All subjects had been diagnosed with ciliary body or choroidal melanoma in one eye and had previously undergone plaque brachytherapy or were scheduled to undergo this procedure for the treatment of their tumor. At the time of OCTA imaging post-brachytherapy, all subjects had clinically apparent radiation optic neuropathy and/or radiation retinopathy.

Plaque Brachytherapy

Brachytherapy was performed using I-125 seeds (IsoAid Model IAI-125A) inserted in a silastic carrier and mounted in gold COMS style plaques. Seed activity was calculated to deliver 85 Gy over 100 hours to a prescription depth dependent on tumor thickness. Starting with a minimum prescription depth of 3 mm, the depth was increased by multiples of 0.5 mm for thicker tumors to assure a margin 0.5 mm but < 1.0 mm up to tumor thickness of 5 mm. For tumor thicknesses larger than 5 mm, the prescription depth was set to the tumor depth.

The planned seed activity was calculated using Plaque Simulator (V6.4.1) by Eye Physics, LLC Los Alamitos CA. The software uses a superposition of a linear source model of all seeds as defined by the consensus data of AAPM TG-40 with corrections for the presence of the plaque, carrier attenuation, and air interface. Some of the plaques were modified 'in house' with cut notches to allow implantation around or near the optical nerve. These were specifically modeled to account for the lack of a lip on the notched edge normally found on commercially available notched COMS plaques. The size and variation of the plaque were determined by the surgeon based on the limitations of surgical practicality. The dose to 50% of the optic nerve at the retinal surface (D50) was calculated with positioning based on fundus images loaded into the planning software.

Optical Coherence Tomography Angiography Data Acquisition and Analysis

A spectral-domain 70kHz OCT instrument (RTVue-XR, Optovue) obtained 4.5×4.5mm optic disc scans for OCTA in tumor and fellow eyes. Two repeated B-scans, each consisting of 304 A-scans, were captured at each of 304 locations in 2.9 seconds. One x-fast and one y-fast scan were acquired, registered, and merged, minimizing motion artifacts. The split-spectrum amplitude-decorrelation angiography (SSADA) algorithm was applied to detect flow by calculating the decorrelation of the OCT reflectance signal between two consecutive B-scans at the same location, as previously described.²³ The projection-resolution algorithm²⁴ was applied to remove the projection artifacts throughout the whole volume.

The merged volumetric OCTA were exported for custom processing using the Center for Ophthalmic Optics & Lasers-Angiography Reading Toolkit (COOL-ART) software.²⁵ These custom programs were developed at the Casey Eye Institute using the MATLAB programming language. The OCTA scans contain both volumetric flow (decorrelation) data as well as structural (reflectance) data. Using the COOL-ART, an automated segmentation

algorithm isolated inner retina based on structural OCT (inner limiting membrane to the outer boundary of outer plexiform layer) and produced *en face* angiograms by projecting the maximum flow signal within the inner retina. The segmentation was manually corrected if needed. Prior to peripapillary capillary density measurement, the optic disc area ($D=2\text{mm}$) and large arterioles and venules were automatically identified and subtracted from the *en face* angiograms. The measurement was consistently performed on a $4.0\times 4.0\text{ mm}$ region centered on disc. Peripapillary capillary density (PPCD) is defined as the proportion of flow pixels within all valid pixels on the working region. The method for calculating PPCD has been described in our previous study.²⁵ Within-visit repeatability of the PPCD was calculated from normal eyes, with two sets of scans performed within a single visit. Using the radiation plans, the hemiretina within the peripapillary region receiving the most radiation was divided from the region receiving a relatively lower dose on the *en face* angiogram. The PPCD was then calculated for each hemiretina within the same eye to determine whether there was regional variation within the same treated eye. The relationship of the PPCD for the entire peripapillary region to the calculated dose to the optic nerve was assessed. Trained observers reviewed scans and those with poor image quality, as defined by the following criteria, were excluded: (1) signal strength index less than 50; (2) poor scan alignment or failed motion correction; (3) focal loss of reflectance signal due to vitreous floaters.

Statistical Analysis

Within-visit repeatability were assessed by the coefficient of variation (CV). The Mann-Whitney U test was used to compare groups between tumor and fellow eyes before and after radiation and between hemiretina with higher dose and opposite hemiretina on tumor eyes. Pearson correlation was used to determine the relationship between PPCD and radiation doses. All statistical analyses were performed with SPSS20.0 (SPSS Inc., Chicago, IL) and MedCalc 10.1.3.0 (MedCalc Software, Ostend, Belgium, www.medcalc.be).

Results

Both eyes of ten subjects recently diagnosed with ciliary body and/or choroidal melanoma were imaged with OCTA prior to planned I-125 plaque brachytherapy. Three subjects were male and seven subjects were female, with ages ranging from 43 to 70 years. Visual acuities in the eye with melanoma ranged from 20/20 to 20/40 and in the fellow eye ranged from 20/20 to 20/30. No significant difference was seen between PPCD in eyes with tumor ($71.6\pm 9.9\%$) and the fellow eye ($70.9\pm 9.7\%$) prior to radiation among subjects who were evaluated prior to brachytherapy (Wilcoxon Signed ranks test $P=0.838$). A representative example of OCTA imaging in a patient pre-brachytherapy is shown in Figure 1.

Fifteen subjects who had been treated with plaque brachytherapy for ciliary body or choroidal melanoma and had developed clinically apparent radiation optic neuropathy and/or radiation retinopathy were enrolled in the study. Seven subjects were male and eight were female, with ages ranging from 31 to 80 years at the time of melanoma treatment. There were no significant differences between the group imaged prior to brachytherapy and the group imaged after development of radiation side effects in terms of age ($P=0.54$, t test) or

gender ($P=0.68$, Fisher's exact test). Patients in the group with radiation retinopathy or optic neuropathy were treated between 1 and 9 years prior to being enrolled on the study. Each patient was treated with I-125 plaque brachytherapy per standard of care. The treated eye was the left eye in 10 subjects and the right eye in 5 subjects. Per their records, the baseline visual acuities ranged from 20/20 to 20/60 in the eye with the melanoma and from 20/20 to 20/40 in the fellow eye. One subject was also imaged prior to brachytherapy and is included in the pre-treatment analyses above.

Post-brachytherapy, the visual acuities in the irradiated eyes ranged from 20/20 to counting fingers, while visual acuities in the untreated fellow eye were 20/25 or better (Table 1, online only). After radiation treatment, the PPCD as measured by OCTA was significantly lower in treated eyes ($52.9\% \pm 22.4\%$) than in fellow eyes that did not receive radiation ($73.3\% \pm 13.7\%$, $p = 0.004$). The PPCD was lower in the portion of the peripapillary retina that received the higher radiation dose than in the opposite hemiretina. Representative examples of OCTA imaging in eyes treated for choroidal melanoma in various anatomic locations are shown in Figures 2–4. The most severe ischemia was seen in eyes treated for juxtapapillary or circumpapillary tumors, which was not unexpected, as these eyes typically had higher radiation doses to the optic disc.

There was an inverse linear correlation between radiation dose (D50, the dose to 50% of the disc) and the PPCD (Pearson's; $r = -0.528$, $P=0.043$) (Figure 5A). There was also a significant inverse correlation between the LogMAR visual acuity and the PPCD (Pearson's; $r = -0.564$, $P=0.028$) as shown in Figure 5B. When the PPCD was “normalized” by comparing it to the fellow eye ($\text{PPCD fellow eye} - \text{PPCD treated eye} = \text{PPCD}$), an even stronger correlation was seen between the PPCD and the D50 (Pearson $r=0.664$, $P=0.013$) (Figure 5C). The change of LogMAR visual acuity from baseline pre-treatment to visual acuity measured at the time of OCTA imaging correlated with the PPCD as well (Pearson's; $r=0.665$, $P=0.007$) (Figure 5D).

Discussion

Radiation optic neuropathy is a significant cause of morbidity in patients undergoing radiation therapy for uveal melanoma. OCTA provides a unique, quantitative method for evaluating regional retinal blood flow and vessel density in regions critical for vision. Here we demonstrate that OCTA can be used to evaluate vascular compromise after radiation therapy in eyes with uveal melanoma, and that this compromise can be observed as lower capillary vessel densities in the peripapillary regions. Furthermore, the degree of regional ischemia, as measured by the PPCD, correlates inversely with the calculated radiation dose to the optic nerve as measured by D50 and with the visual acuity in the eye. No significant differences were found when comparing PPCD in eyes with melanoma and fellow eyes prior to treatment. This suggests that the differences demonstrated here in PPCD between treated eyes with radiation optic neuropathy and fellow eyes are not due to the presence of the tumor.

OCTA measurements provide a highly reproducible, quantitative method for measuring retinal circulation and vessel density that may allow development of a model for clinicians to

better predict vision loss for patients treated with radiation for uveal melanomas and other ocular tumors. This technology may also assist in evaluating emerging therapies for radiation retinopathy, such as anti-VEGF, and in determining which patients may respond best to therapeutic interventions directed at reducing vision loss after radiation therapy. Future studies will further evaluate the relationship between visual acuity, radiation dose to the optic nerve and fovea, and degree of vascular compromise in these areas as detected by OCTA. In particular, a longitudinal study of the local microvascular response to radiation therapy as measured by OCTA will improve understanding of the timing and significance of decreased PPCD and macular capillary density.

The quantitative nature of OCTA is an important advantage over traditional fluorescein angiography, which has been the major method for observing radiation-induced changes in the eye in the past. In addition to being used for vessel density measurements, OCTA can also be used to evaluate perfusion by calculating the flow index as defined by the average decorrelation values in the segmented area. We found the flow index and vessel density provided similar results in prior studies,^{26,27} and therefore have focused upon reporting vessel densities for subsequent work, including the current study. OCTA provides a 3-dimensional volumetric scan, which can allow segmentation of blood circulation into individual plexi—something not possible with traditional fluorescein angiography. These analyses require segmentation of various tissue layers in the retina and choroid. In the current study, we limited calculations to the inner retina circulation (inner limiting membrane to outer plexiform layer) as accurate segmentation of each layer in eyes with retinal edema or atrophy remains challenging, as evidenced in the case shown in Figure 2. Similarly, retinal edema and atrophy also affected our ability to calculate choroidal blood perfusion. Efforts to optimize our algorithm for the quantification of choroidal layers are underway.

The data presented here, together with previously published work demonstrating macular changes post-brachytherapy as measured by OCTA,^{21,22} set a framework for future studies in which retinal microcirculation can be quantitatively assessed before and after radiation treatment, and correlated with vision outcome. Future studies using longitudinal data and emerging OCTA technologies that may allow wide-field imaging will improve our understanding of the microvascular changes associated with radiation therapy.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Support:

Supported by R01 EY027833, R01 EY023285, R01 EY024544, DP3 DK104397, P30 EY010572 from the National Institutes of Health (Bethesda, MD), and by a Lloyd Research Endowment Faculty Grant, OHSU Radiation Medicine Academic Development Fund, and an unrestricted grant from Research to Prevent Blindness (New York, NY).

Abbreviations

OCTA	Optical coherence tomography angiography
PPCD	Peripapillary capillary density
D50	Radiation dose to 50% of the optic disc

References

1. Wilkes SR, Robertson DM, Kurland LT, Campbell RJ. Incidence of uveal malignant melanoma in the resident population of Rochester and Olmsted County, Minnesota. *Am J Ophthalmol.* 1979; 87:639–41. [PubMed: 443334]
2. Singh AD, Turell ME, Topham AK. Uveal Melanoma: Trends in Incidence, Treatment, and Survival. *Ophthalmology.* 2011; 118:1881–1885. [PubMed: 21704381]
3. Mahendraraj K, Lau C, Lee I, Chamberlain R. Trends in incidence, survival, and management of uveal melanoma: a population-based study of 7,516 patients from the Surveillance, Epidemiology, and End Results database (1973–2012). *Clin Ophthalmol.* 2016; 10:2113–2119. [PubMed: 27822007]
4. Gragoudas ES, Li W, Lane aM, et al. Risk factors for radiation maculopathy and papillopathy after intraocular irradiation. *Ophthalmology.* 1999; 106 1571-7-8.
5. Gragoudas ES. Proton Beam Irradiation of Uveal Melanomas: The First 30 Years The Weisenfeld Lecture. *Investig Ophthalmology Vis Sci.* 2006; 47:4666.
6. Puusaari I, Heikkonen J, Kivelä T. Ocular complications after iodine brachytherapy for large uveal melanomas. *Ophthalmology.* 2004; 111:1768–1777. [PubMed: 15350335]
7. Puusaari I, Heikkonen J, Kivelä T. Effect of radiation dose on ocular complications after iodine brachytherapy for large uveal melanoma: empirical data and simulation of collimating plaques. *Invest Ophthalmol Vis Sci.* 2004; 45:3425–34. [PubMed: 15452045]
8. Melia BM, Abramson DH, Albert DM, et al. Collaborative ocular melanoma study (COMS) randomized trial of I-125 brachytherapy for medium choroidal melanoma. I. Visual acuity after 3 years COMS report no. 16. *Ophthalmology.* 2001; 108:348–66. [PubMed: 11158813]
9. Brown GC, Shields JA, Sanborn G, et al. Radiation retinopathy. *Ophthalmology.* 1982; 89:1494–501. [PubMed: 7162794]
10. Seibel I, Cordini D, Hager A, et al. Predictive risk factors for radiation retinopathy and optic neuropathy after proton beam therapy for uveal melanoma. *Graefes Arch Clin Exp Ophthalmol.* 2016; 254:1787–92. [PubMed: 27376824]
11. Yousef YA, Finger PT. Optical coherence tomography of radiation optic neuropathy. *Ophthalmic Surg Lasers Imaging.* 2012; 43:6–12. [PubMed: 22251840]
12. Wen JC, Oliver SC, McCannel TA. Ocular complications following I-125 brachytherapy for choroidal melanoma. *Eye (Lond).* 2009; 23:1254–68. [PubMed: 19265865]
13. Stack R, Elder M, Abdelaal A, et al. New Zealand experience of I125 brachytherapy for choroidal melanoma. *Clin Experiment Ophthalmol.* 2005; 33:490–4. [PubMed: 16181274]
14. Hayreh SS. Post-radiation retinopathy. A fluorescence fundus angiographic study. *Br J Ophthalmol.* 1970; 54:705–14. [PubMed: 5484737]
15. Guyer DR, Mukai S, Egan KM, et al. Radiation maculopathy after proton beam irradiation for choroidal melanoma. *Ophthalmology.* 1992; 99:1278–1285. [PubMed: 1325044]
16. Hwang TS, Gao SS, Liu L, et al. Automated Quantification of Capillary Nonperfusion Using Optical Coherence Tomography Angiography in Diabetic Retinopathy. *JAMA Ophthalmol.* 2016; 134:367–73. [PubMed: 26795548]
17. Hwang TS, Zhang M, Bhavsar K, et al. Visualization of 3 Distinct Retinal Plexuses by Projection-Resolved Optical Coherence Tomography Angiography in Diabetic Retinopathy. *JAMA Ophthalmol.* 2016; 134:1411–1419. [PubMed: 27812696]

18. Jia Y, Bailey ST, Hwang TS, et al. Quantitative optical coherence tomography angiography of vascular abnormalities in the living human eye. *Proc Natl Acad Sci.* 2015; 112:201500185.
19. Jia Y, Bailey ST, Wilson DJ, et al. Quantitative optical coherence tomography angiography of choroidal neovascularization in age-related macular degeneration. *Ophthalmology.* 2014; 121:1435–1444. [PubMed: 24679442]
20. Jia Y, Wei E, Wang X, et al. Optical coherence tomography angiography of optic disc perfusion in glaucoma. *Ophthalmology.* 2014; 121:1322–32. [PubMed: 24629312]
21. Shields CL, Say EAT, Samara WA, et al. Optical coherence tomography angiography of the macula after plaque radiotherapy of choroidal melanoma. *Retina.* 2016; 36:1493–1505. [PubMed: 26960015]
22. Veverka KK, AbouChehade JE, Iezzi R, Pulido JS. Noninvasive rading of radiation retinopathy: the use of Optical Coherence Tomography Angiography. *Retina.* 2015; 35:2400–10. [PubMed: 26502009]
23. Jia Y, Tan O, Tokayer J, et al. Split-spectrum amplitude-decorrelation angiography with optical coherence tomography. *Opt Express.* 2012; 20:4710–25. [PubMed: 22418228]
24. Zhang M, Hwang TS, Campbell JP, Bailey ST, Wilson DJ, Huang D, Jia Y. Projection-resolved optical coherence tomographic angiography. *Biomed Opt Express.* 2016; 7:816–828. [PubMed: 27231591]
25. Zhang M, Wang J, Pechauer AD, et al. Advanced image processing for optical coherence tomographic angiography of macular diseases. *Biomed Opt Express.* 2015; 6:4661. [PubMed: 26713185]
26. Liu L, Jia Y, Takusagawa HL, et al. Optical Coherence Tomography Angiography of the Peripapillary Retina in Glaucoma.
27. Jia Y, Morrison JC, Tokayer J, et al. Quantitative OCT angiography of optic nerve head blood flow. *Biomed Opt Express.* 2012; 3:3127. [PubMed: 23243564]

Optical coherence tomography angiography provides a quantitative measure of peripapillary retinal capillary density that correlates to radiation dose and visual acuity in patients with radiation optic neuropathy and retinopathy.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Figure 1.

Representative example of peripapillary capillary density (PPCD) prior to treatment in an eye with uveal melanoma located in the superonasal periphery as compared with the normal fellow eye. The cross-sectional OCTA (A, B) for each eye is shown in the top panel (retinal flow shown in purple, choroidal flow shown in red). The *en face* OCTA of the peripapillary region shown in the bottom panel (D, E). The location of the cross-sectional OCTA image is indicated with a yellow arrow (D, E). The PPCD for each eye is shown. The clinical imaging including Optos fundus photograph (C) and longitudinal B-scan ultrasound (F) are shown. PPCD= peripapillary capillary density; OCTA= optical coherence tomography angiography.

Figure 2.

Peripapillary capillary density in an eye treated with I-125 plaque brachytherapy for a circumpapillary choroidal melanoma. The calculated D50 (dose to 50% of the optic disc) for this eye was 62 Gy. The clinical imaging (A, B) at the time of diagnosis and radiation plan (C) are shown in the top panel. The clinical photograph at the time of OCTA imaging post-brachytherapy is shown in the bottom panel (D), alongside the cross-sectional OCTA (E) (retinal flow shown in purple, choroidal flow shown in red). The *en face* OCTA of the peripapillary region (F) is also shown. The location of the cross-sectional OCTA image is indicated with a yellow arrow on the *en face* OCTA (F). The vessel densities in the peripapillary hemiretina receiving the higher radiation dose (superonasal retina) as compared to the lower regional dose (inferotemporal retina) are shown, with the blue line dividing the calculated regions. OCTA= optical coherence tomography angiography; PPCD= peripapillary capillary density.

Figure 3.

Peripapillary capillary density in an eye treated with I-125 plaque brachytherapy for a choroidal melanoma in the posterior pole. The calculated D50 (dose to 50% of the optic disc) for this eye was 53 Gy. The clinical imaging (A, B) at the time of diagnosis and radiation plan (C) are shown in the top panel. The clinical photograph (D) at the time of OCTA imaging post-brachytherapy is shown in the bottom panel, alongside the cross-sectional OCTA (E) (retinal flow shown in purple, choroidal flow shown in red). The *en face* OCTA of the peripapillary region (F) is also shown. The location of the cross-sectional OCTA image is indicated with a yellow arrow. The vessel densities in the peripapillary hemiretina receiving the higher radiation dose (inferotemporal retina) as compared to the lower regional dose (superonasal retina) are shown, with the blue line dividing the calculated regions. OCTA= optical coherence tomography angiography; PPCD= peripapillary capillary density.

Figure 4.

Peripapillary capillary density in an eye treated with I-125 plaque brachytherapy for a choroidal melanoma in the temporal periphery. The calculated D50 (dose to 50% of the optic disc) for this eye was 14 Gy. The clinical imaging (A, B) at the time of diagnosis and radiation plan (C) are shown in the top panel. The clinical photograph (D) at the time of OCTA imaging post-brachytherapy is shown in the bottom panel, alongside the cross-sectional OCTA (E) (retinal flow shown in purple, choroidal flow shown in red). The *en face* OCTA of the peripapillary region (F) is also shown. The location of the cross-sectional OCTA image is indicated with a yellow arrow. The vessel densities in the peripapillary hemiretina receiving the higher radiation dose (temporal retina) as compared to the lower regional dose (nasal retina) are shown, with the blue line dividing the calculated regions. OCTA= optical coherence tomography angiography; PPCD= peripapillary capillary density.

Figure 5.

Peripapillary capillary density correlates with the radiation dose to the optic nerve as measured by D50 and with the LogMAR visual acuity. The relationship between PPCD and D50 was examined using the Pearson's correlation coefficient. Each subject is indicated with a point on the plot. A best-fit line is shown (A). The LogMAR visual acuity was inversely correlated with the PPCD (B). The relationship between the D50 and the difference in PPCD between the treated eye and the fellow eye (Δ PPCD) was also evaluated (C). The change in LogMAR visual acuity from time of tumor diagnosis and time of OCTA imaging was

correlated with the PPCD (D). D50= radiation dose to 50% of the optic disc; PPCD= peripapillary capillary density; LogMAR= logarithm of the minimum angle of resolution.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Table 1

Subject characteristics at the time of OCTA for measurement of radiation optic neuropathy (online only).

Gender	Age (yrs)	Treated eye	Va treated eye	Va fellow eye	PPCD treated eye	PPCD fellow eye	D50 (Gy)	Elapsed time (yrs)
Male	63	Left	20/70	20/20–	46.39	83.20	57	1.52
Female	68	Left	CF	20/25+	31.42	64.70	36	1.04
Female	50	Right	20/20	20/20	55.37	86.45	63	2.15
Female	66	Left	20/20	20/20–	53.83	43.51	21	1.98
Male	81	Right	20/60	20/20	23.91	57.81	41	1.46
Female	43	Right	20/20–	20/20	78.54	89.82	14	1.61
Male	63	Left	20/25–	20/20	89.16	87.73	17	3.59
Female	55	Left	20/25+	20/20–	81.68	78.15	32	2.21
Male	81	Left	CF	20/25	23.61	ND	29	3.76
Female	61	Left	20/40–	20/20	41.15	ND	53	3.1
Female	60	Right	20/20–	20/20	72.52	79.85	20	8.29
Male	71	Left	20/30–	20/20–	14.50	56.36	62	9.33
Female	38	Left	20/20	20/20–	54.99	84.02	15	6.75
Male	74	Left	20/100–	20/20	43.76	68.89	76	4.18
Male	75	Right	20/125	20/20	34.23	74.41	91	1.9

Yrs= years; Va= Snellen visual acuity; PPCD= peripapillary capillary density; Gy= gray; D50=dose to 50% of the optic disc. Elapsed time is the time from the brachytherapy treatment to the OCTA imaging.