Original Article

Change In Vessel and Perfusion Densities with Varying Signal Strengths on Optical Coherence Tomography Angiography

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Abstract

Purpose: *To evaluate change in vessel and perfusion densities with varying signal strengths on optical coherence tomography angiography (OCTA).*

Materials and Method*: Quadrant wise vessel densities and perfusion densities in superficial capillary plexus were measured using 3*3 mm OCTA scans. Images were obtained in 26 normal eyes, out of which 10 were finally evaluated to study the variations in the aforementioned parameters with signal strengths (SS) 8, 9 and 10.*

Result: *The total vessel and perfusion densities increased significantly from SS 8 to 10 and 9 to 10. The mean vessel densities along the superior, inferior, temporal and nasal quadrants showed a consistent increase in values with a progressive increase in the scan strengths. Similarly, the perfusion densities along all four quadrants also showed a progressive increase in the percentage values with increasing signal strengths.*

Conclusion: *Even minor variation in signal strength of OCTA, even within the generally accepted scan strengths, affects the quantitative analysis. Therefore, future studies using OCTA must specify the signal strength of the scans for a head to head comparison or interval analysis.*

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Introduction

Following the introduction of optical coherence tomography angiography (OCTA), a significant number of studies have been performed to understand the anatomical changes along the retinal and choroidal microvascular networks.[1] It provides insights into capillary densities and the perfusion densities by analysing the white and dark pixels in a given area. The white pixels are assumed as areas with perfusion and the dark areas as non-perfused regions or areas lacking any form of vasculature. However, the brightness or the quality of the scan improves as the acquisition signal strength increases. Signal strength representation depends on the machine used to perform OCTA. OCTA (Ziessangioplex OCT, Carl Zeiss AG, Jena) used in our study represents the signal strength with score ranging from 1-10. In routine clinical practice on a scale of 10, scans with more than 7 signal strength are considered as adequate for assessment. [2-4]

Materials and Methods

Here in this observation, we assessed the effect of variation of signal strength from 8 to 10 on OCTA automated vessel density and perfusion density values. A total of 26eyes of 15 healthy ophthalmic residents were evaluated. However, only 10 eyes were considered for final assessment after excluding images with various artefacts. Under dim room light conditions and without use of any mydriatics, all subjects underwent 3*3 mm OCTA (Ziessangioplex OCT, Carl Zeiss AG, Jena) scan of the macula. Multiple scans were done for each eye to ensure that at least three scans with signal strengths of at least 8/10, 9/10 or 10/10 were obtained for each eye. All the scans were obtained by a single observer and the best scan in each category of individual signal strength was included for the final analysis. After auto segmentation, the acquired scans were assessed for the automated quadrantic vessel and perfusion densities along the superficial retinal plexus using in built proprietary software. Values were documented along each quadrant with increasing signal strengths (SS) for each individual. The data were entered in an excel sheet, statistical analysis was performed using strata software 12.2, and p values less than 0.05 were considered as statistically significant.

Results

The average age was 26 years and out of 10 eyes evaluated, six belonged to female subjects (M: F=2:3). The mean vessel densities along the superior, inferior, temporal and nasal quadrants showed consistent increase in values with progressive increase in the scan strengths (Figure 1, Table 1, graph 1). Similarly, the perfusion densities along all four quadrants also showed progressive increase in the percentage values with increasing signal strengths (Figure 1, Table 1, graph 2). The total vessel and perfusion densities increased significantly from SS 8 to 10 and 9 to 10 (Table 1, 2 and Graph 3). On inter strength density comparison, between 8 and 9 SS, the change in the values obtained were

Table 1: Vessel and perfusion density changes (total and quadrantic) with increasing signal strengths (8, 9, 10). (SS= Signal Strength)

	SS8	SS9	SS10	SS8	SS9	SS10
Superior	19.56±2.64	20.11±2.73	21.87±1.85	34.3±6.19	38.45±3.19	41.34±2.59
Inferior	19.3±2.37	20.18±2.15	21.59±1.90	35.26±*4.17*	38.22±3.78	40.7±2.45
Temporal	19.52±2.68	20.55±1.71	21.48±1.74	35.96±5.71	38.54±3.22	40.65±2.05
Nasal	19.73±2.33	20.24±2.27	21.81±1.77	34.94±3.09	37.56±3.59	41.05±*2.65*
Total	78.11±9.29	81.06±8.06	86.75±6.94	140.46±17.78	152.77±12.60	163.74±8.59

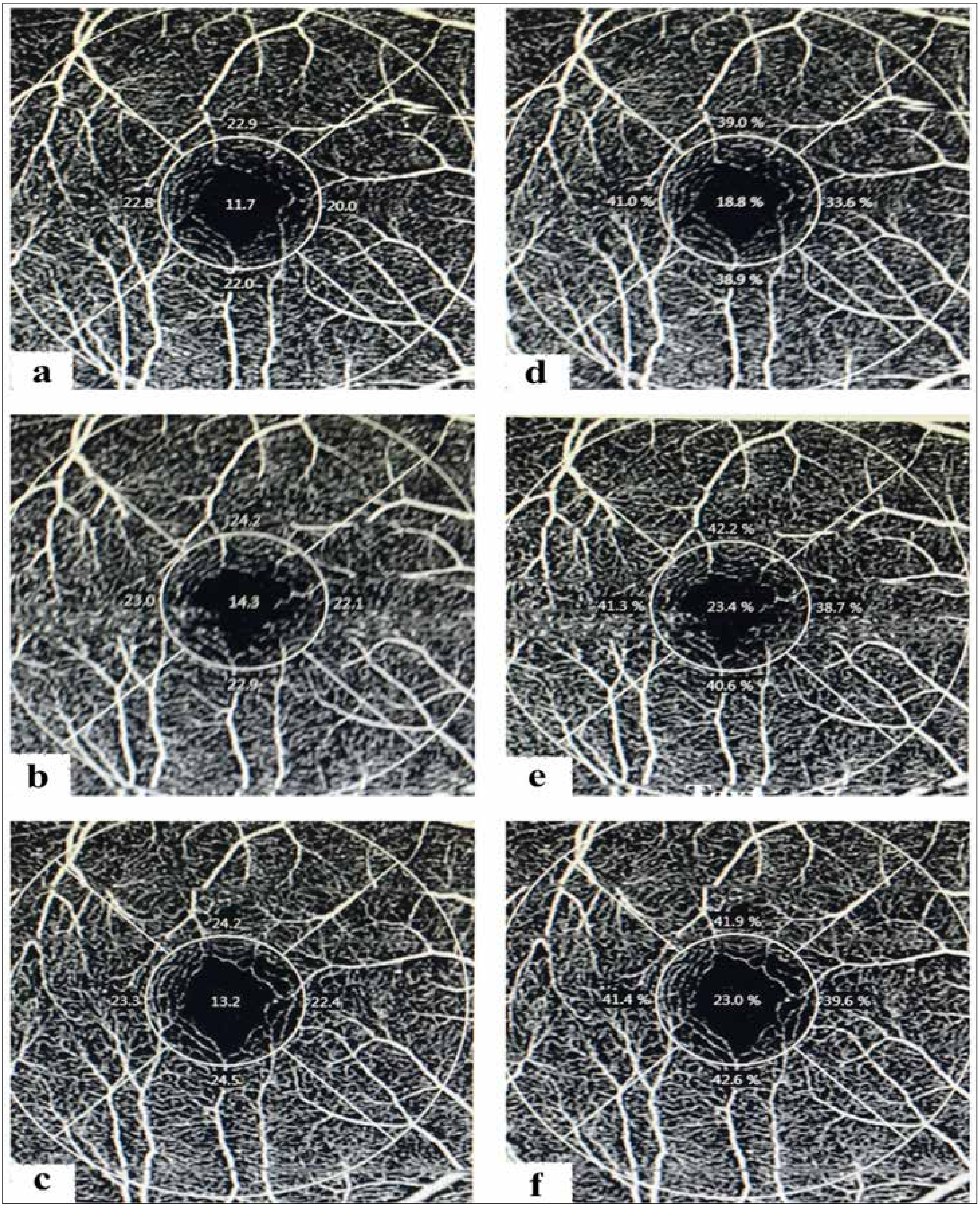
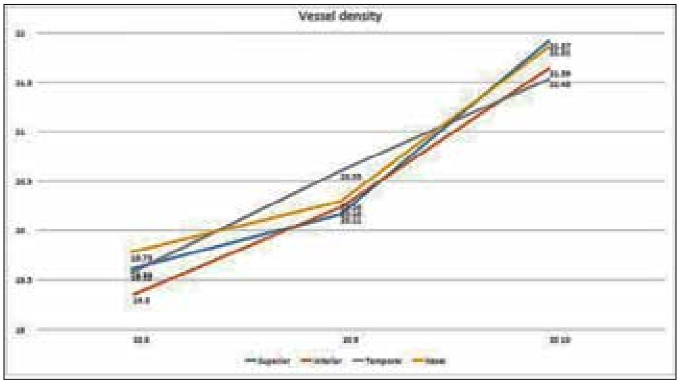
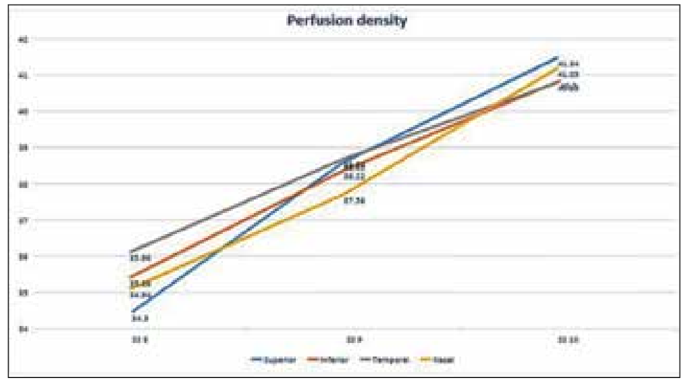


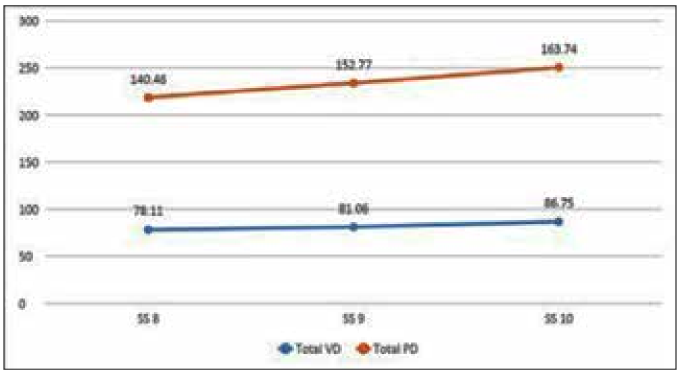
Figure 1: *(a,b,c) Automated vessel density values along four quadrants with increasing signal strength. (a=8 SS, b=9 SS, c=10 SS) (three images on the left side of panel);* ***(d,e,f)*** *Automated perfusion density values along four quadrants with increasing signal strength. (d= 8 SS, e=9 SS, f=10 SS) (three images on the right side of panel).*



Graph 1: *Vessel density changes along the four quadrants with increasing signal strength.*



Graph 2: *Vessel density changes along the four quadrants with increasing signal strength.*



Graph 3: *Total vessel and perfusion density changes with increasing signal strength.*

not statistically significant along any of the quadrants; [Table 2] whereas the values between SS 9 and 10, and 8 and 10showed a statistically significant increase in the superior, nasal and inferior quadrants ($p<0.05$). Likewise, changes in the perfusion density values were also statistically significant between SS 8 and 10, and between 9 and 10 along all four quadrants; and only along the inferior quadrant between the SS 8 and 9. Rest of the values, however, did not show any significant statistical difference (Table 2).

Discussion

OCTA with its three-dimensional imaging capability maps the vessels by observing the movement of the blood cells against the static retinal tissue background. Therefore, based on the perceived movements detected by analysing the decorrelation of the optical coherence tomography signals, a vascular map is constructed. The vessel areas are depicted with white pixels and the non-vessel or non-perfused areas as dark pixels. Therefore, the quantification of vascular parameters such as vessel density, perfusion density, non-perfusion areas and the longest vessel length are mere expressions of the perceived pixels within the captured image.[1] Vessel density is defined as the sum of the length of the vessels in the given map and perfusion density gives the percentage of the evaluated surface where circulation is present.

There are a different set of algorithms devised by the researchers for the quantification of pixels within a given image. But till now, there are no universally defined algorithms for these examinations. Studies have shown variation in macular vessel density with age and retinal diseases.[5,6] But their results are effected by signal strength of image which has been used for analysis. Better signal strength results in better image, higher pixel density and better auto segmentation. Different manufacturers give different measurements of signal strength in their machines with a scale of 1-10 being one of the most commonly used. In routine studies, signal strength of 7/10 or more is considered as satisfactory for the assessment of vascular changes.[1-4] But our study shows that even change in the signal strength by 1 point beyond 8/10 alters the vessel density by 3.5 % (min) to 9.9%(max), and perfusion density by 6.69%(min) to 14.21%(max) amongst the total values.

In certain pathological conditions of the eye with low vision, the scan qualities are often poor and this can alter the pixel densities significantly. Thus, results of the studies comparing the quantitative data of such poor scans with the data of scans in normal eyes may not be correct as they would have overlooked the bias/error which can occur by a mere variation of signal strength by 1 point. In a study by Lim et al, they noted significant changes in vessel and perfusion densities from signal strengths 7 to 9 but not between 9 and 10.[3] However, in our observation, we noted statistical significant changes in the values between the signal strengths of 9 and 10, and between 8 and 10.

Table 2: P value after comparing the signal strengths of 8 (S1, I1, T1, N1), 9 (S2, I2, T2, N2) and 10 (S3, I3, T3, N3). VD= Vessel density, PD= Perfusion density, S=Superior, I=Inferior, T=Temporal, N= Nasal. VDT= Vessel density total, PDT= Perfusion density total.

	S1 vs S2	S2 vs S3	S1 vs S3	11 vs 12	12 vs 13	11 vs 13	T1 vs T2	T2 vs T3	T1 vs T3	N1 vs N2	N2 vs N3	N1 vs N3
VD	0.311	0.017	0.005	0.260	0.012	0.010	0.175	0.085	0.052	0.267	0.048	0.013
PD	0.06	0.045	0.017	0.026	0.042	0.001	0.094	0.044	0.025	0.090	0.018	0.003

	VDT1 vs VDT2	VDT2 vs VDT3	VDT4 vs VDT3	PDT1 vs PDT 2	PDT2 VS PDT3	PDT1 vs PDT3
P Value	0.202	0.021	0.011	0.055	0.026	0.004

In our observation, even though we performed scans on twenty-five eyes, acquisition of scans without artefacts and with consistently high signal strengths (8, 9, and 10) was challenging. We could acquire 9/10 and 10/10 signal strengths in our subjects as they were very co-operative and young with 20/20 uncorrected visual acuity and very clear media. Though our sample size is small, it definitely highlights the variations in the automated vessel and perfusion density values obtained with change in signal strengths. Other limitations of this study are that we did not assess the deeper retinal and choroidal plexuses and it would be difficult to extrapolate the results in other protocols such as 6*6 or 9*9 mm scans.

To conclude, from our observations, it is evident that a minor variation in signal strength, even within the generally accepted scan strengths of OCTA, can affect the quantitative analysis. Therefore, future studies using OCTA must specify the signal strength of the scans for a head to head comparison or interval analysis.

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