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Imaging, Digital, Angiography Symposium

Subclinical Coronary Atherosclerosis and Retinal Optical Coherence Tomography Angiography: Observational Cohort Study

- Young Hee Yoon, MD, PhD
- Jee Myung Yang, MD, PhD

Objective:
There are limited data on the association between retinal optical coherence tomography angiography (OCTA) and coronary computed tomography angiography (CTA).

Purpose:
We hypothesized that reduced retinal vascular density is associated with subclinical atherosclerosis in asymptomatic individuals.

Methods:
Clinic-based cohort of participants who underwent detailed assessments of both retinal and coronary vasculature using coronary CTA and OCTA were analyzed. OCTA image analysis provided measures of superficial and deep vessel density (VD), foveal avascular zone area, and retinal thickness. Coronary CTA provided values of atherosclerotic plaques.

Results:
A total of 1682 eyes from 1682 participants were analyzed (mean age 64.1 years, male 62.1%). Coronary artery calcium score (CACS), presence of plaque, as well as its subtypes, obstructive coronary artery disease (CAD), high-risk CAD, segment stenosis score (SSS), and segment involvement score (SIC), were significantly increased across the quartiles of superficial and deep parafoveal VD (all $P < 0.05$). When modeled as continuous variables, superficial and deep parafoveal VD were the most significant metrics correlated with CACS, number of coronary vessel involvement, SSS, and SIS (all $P < 0.05$). Superficial and deep parafoveal VD significantly enhanced the AUC values for risk of obstructive CAD, high-risk CAD, and CACS over 400 beyond traditional risk factors for CAD (all $P < 0.05$). After multivariable adjustment, lower superficial and deep parafoveal VD showed an increased likelihood of obstructive CAD [adjusted odds ratio (aOR) 1.50, 95% CI 1.12–2.01 for superficial and aOR 1.38, 95% CI for deep parafoveal VD] and high-risk CAD [aOR 1.55, 95% CI 1.04–2.29 for deep parafoveal VD]. Moreover, the risk of developing obstructive CAD, any plaque, high-risk CAD, and CACS over 400 also increased across superficial and deep parafoveal VD quartiles.

Conclusion:
Reduced retinal parafoveal VD is independently associated with subclinical atherosclerosis. Reduced retinal parafoveal VD may indicate coronary insufficiency and the potential of a cardiac event. Therefore, appropriate coronary screening may be required in patients with low parafoveal VD to reduce future cardiac events.

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Level of Diabetic Retinopathy Severity Correlates to Degree of Quadrant Asymmetry in Both Single and Averaged Imaged OCTA Metrics

- Jesse Jung, MD, FASRS
- Shen Yi Lim
- Xavier Chan
- SriniVas Sadda, MD
- Quan Hoang, MD, PhD

Objective:
To determine if the level of diabetic retinopathy (DR) affects quadrant asymmetry (QA) of optical coherence tomography angiography (OCTA) metrics differentially

Purpose:
Asymmetry among the ETDRS quadrants on en-face OCTA metrics (superficial [SRL] and deep retinal layer [DRL] perfusion density [PD] and vessel length density [VLD]) allows for intra-eye comparisons and should mitigate inter-eye variabilities such as refractive error, age, axial length, and magnification. Herein, we assess if the level of diabetic retinopathy (DR) affects quadrant asymmetry (QA) differentially in both single (sgl) and averaged (avg) en-face OCTA images.

Methods:
90 eyes (60 patients) [27 non-diabetic (noDM); 12 diabetics without DR (noDR); 11 mild, 10 moderate (mod) and 7 severe (sev) non-proliferative DR (NPDR); and 23 proliferative DR (PDR)] underwent 3x3mm OCTA scans (signal >7, fovea-centered, auto-segmented for SRL/DRL) and repeated 5 times with the Cirrus Angioplex. Post-processing image averaging of the 5 en-face images was completed as previously published by Uji et al. 2017. QA was defined as the max-min value among 4 ETDRS quadrants for a given eye in terms of OCTA metrics for the SRL and DRL and was compared to DR severity by linear regression including fixed effects for each individual eye.

Results:
Mean age of the cohort was 55.5 years (range 24-88) and 60% were male. QA for sgl SRL VLD was 1.87, 1.95, 1.69, 2.37, 2.38 and 3.13; for avg SRL VLD was 2.14, 2.13, 1.71, 2.25, 2.25 and 2.97; for sgl SRL PD was 0.028, 0.035, 0.028, 0.046, 0.045 and 0.061; for avg SRL PD was 0.046, 0.044, 0.0.38, 0.043, 0.047, 0.064; for sgl DRL VLD was 2.17, 1.76, 1.78, 2.38, 2.90 and 3.25; for avg DRL VLD was 2.27, 1.86, 2.35, 2.99, 3.21, and 3.44; for sgl DRL PD was 0.037, 0.036, 0.033, 0.056, 0.071 and 0.069; and for avg DRL PD was 0.042, 0.045, 0.049, 0.069, 0.076 and 0.075 for noDM, noDR, mild, mod, sev and PDR, respectively. Linear regression demonstrated for every step increase in DR severity in sgl images, there was a 0.34 increase in QA ($p<0.001$) for SRL VLD, +0.008 SRL PD ($p<0.001$), +0.41 DRL VLD ($p<0.001$), and +0.010 DRL PD ($p<0.001$). Linear regression demonstrated for every step increase in DR severity in avg images, there was a 0.26 increase in QA ($p<0.001$) for SRL VLD, +0.006 SRL PD ($p<0.001$), +0.38 DRL VLD ($p<0.001$), and +0.008 DRL PD ($p<0.001$). QA for both SRL VLD and PD were significantly higher in eyes with sev or PDR when compared to noDM or noDR eyes in both sgl (+0.23 and +0.004, $p<0.001$) and avg (+0.23, $p=0.003$ and +0.005, $p=0.002$) images. QA for both DRL VLD and PD were significantly higher in eyes with mild or mod when compared to noDM or noDR eyes in sgl (+0.15, $p=0.04$ and +0.003, $p=0.02$) and avg (+0.19, $p<0.001$ and +0.004, $p= 0.003$) images.

Conclusion:
DR severity affects PD and VLD more asymmetrically across the 4 ETDRS quadrants with a linear increase in QA for each worsening level of DR. Clinically significant increase in QA occurs when eyes are worse than mod NPDR in the SRL and > mild NPDR in the DRL. QA in DR was present in both sgl and avg images. Individual intra-eye metrics such as QA can be utilized to quantify DR severity without concerns for inter-eye variabilities that could affect the reproducibility and reliability of OCTA quantification.

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Retinal Displacement On Fundus Autofluorescence Imaging: Only The Tip Of the Iceberg

- Koby Brosh Heshin, MD, MHA
- eduardo roditi
- Michael Potter, MD, FRCS(C)
- Hashem Totah, MD
- Harel Cain
- Michal Devir
- Aditya Bansal, MD
- Rajeev Muni, MD, MSC, FRCS(C), FASRS

Objective:
To assess the accuracy with which fundus autofluorescence (FAF) imaging detects retinal displacement after rhegmatogenous retinal detachment (RRD) repair using a novel image processing algorithm.

Purpose:
Retinal displacement has been documented to occur commonly following pars plana vitrectomy for RRD repair and has been associated with worse functional outcomes, particularly postoperative aniseikonia. Although FAF imaging can identify retinal displacement, also referred to as a low-integrity retinal attachment (LIRA), there is a concern regarding the accuracy of detection. This study assesses the sensitivity and specificity of detecting retinal displacement/LIRA with FAF imaging utilizing a novel image processing algorithm.

Methods:
A retrospective study of all patients with infrared (IR) images available before the occurrence of RRD and after RRD repair. At least 4 corresponding RPE and choroidal landmarks were marked on pre-RRD & post-RRD IR images extracted from the Heidelberg optical coherence tomography (OCT) software. Overlay of IR images based on the marked landmarks utilized a computer code in Python to compute the homography and then align the two images. The same procedure was carried out in the contralateral normal eyes to validate the technique. Two masked graders analyzed both the post-operative FAF and the IR overlay images to detect the presence and extent of retinal displacement.

Results:
15 eyes had both a pre-RRD & post-RRD repair OCT and a post-RRD FAF. In 8 patients, the contralateral eye had no other pathology or history of RRD. Homography was able to perfectly align the contralateral eye IR images in 100% (8/8) of cases (Fig 1). Retinal displacement was detected in 73.3% (11/15) of FAF images and in 93.3% (14/15) of IR overlay images respectively. FAF had specificity and sensitivity of 100% and 78.6%, respectively in detecting retinal displacement when using the IR overlay images as a gold standard. The extent of retinal displacement was far greater when observed on the IR overlay images with a mean number of displaced vessels of 1.1 ± 0.88 in the FAF group and 2.9 ± 1.05 in the IR overlay group ($p=0.00004$). Qualitatively, the IR overlay method was superior at demonstrating both the presence and extent of retinal displacement compared to FAF (Fig 2). IR overlay showed more extensive displacement in 93.3% (14/15) of cases.

Conclusion:
FAF does not demonstrate the full extent of retinal displacement that is present and reveals only the “tip of the iceberg”. Furthermore, although FAF detects the presence or absence of retinal displacement/LIRA with excellent specificity, some cases with true retinal displacement could be missed on FAF. This likely explains the variability in the rate of detection of retinal displacement across studies. When available, overlay of pre-RRD & post-RRD repair IR images generated by OCT provides a better assessment of retinal displacement. Advancements in multimodal imaging and image processing are required to detect the full extent of retinal displacement with greater sensitivity.

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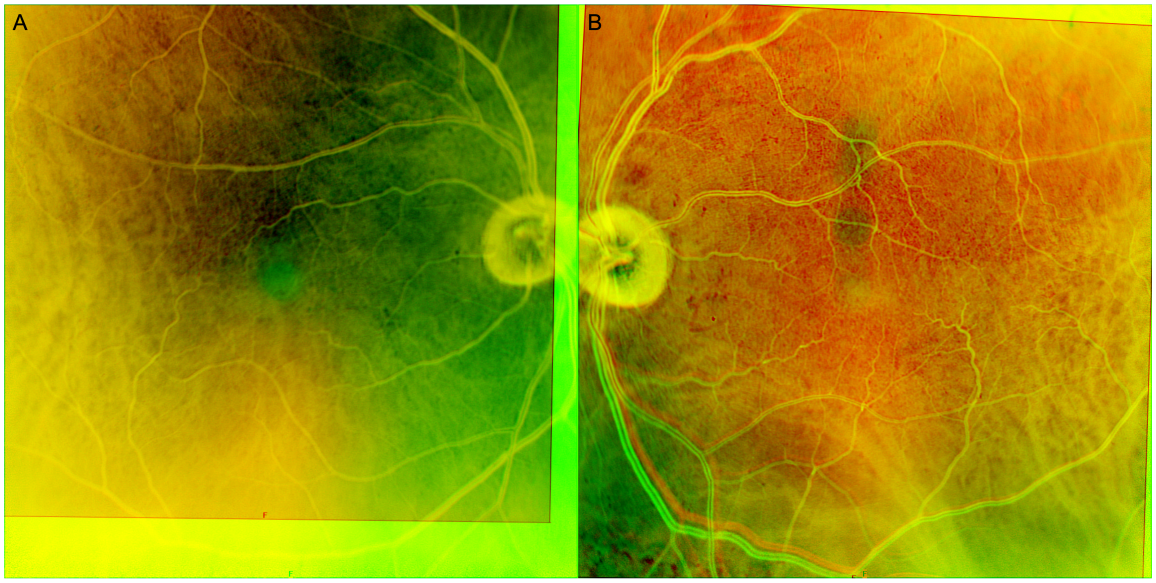
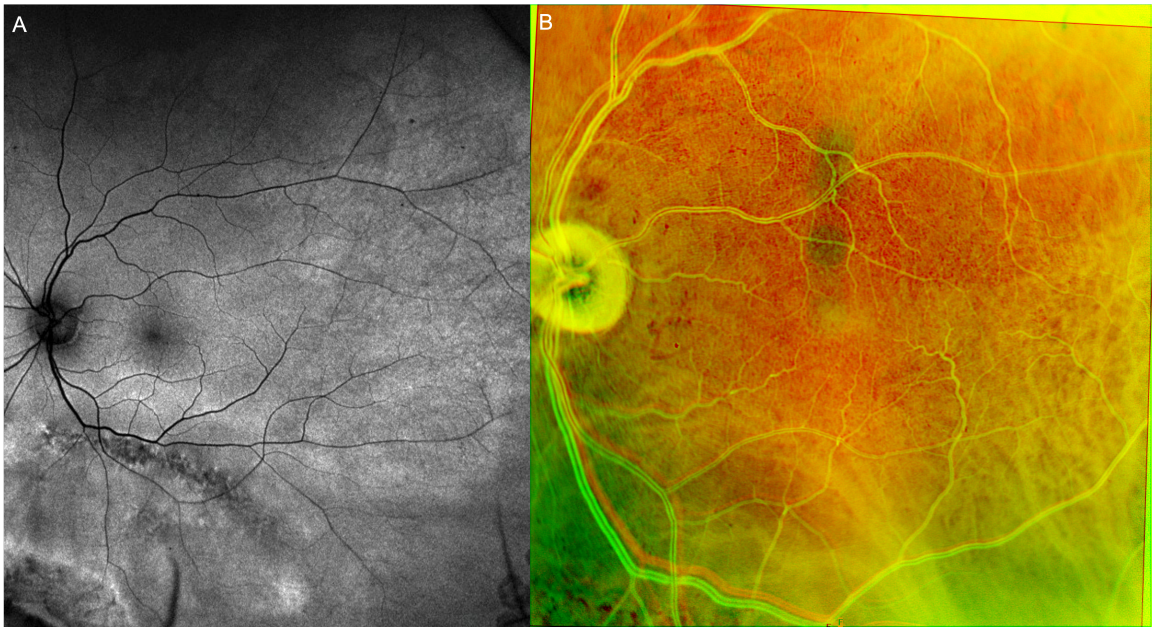


Infrared overlay images



Fundus autofluorescence and infrared overlay images

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Infrared Video for the Demonstration and Quantification of Macula-Involving Symptomatic Vitreous Opacities

- Shawn Kavoussi, MD

Objective:
Can infrared video supplement traditional examination and imaging methods to better demonstrate and quantify symptomatic vitreous opacities?

Purpose:
Traditional examination and imaging modalities have limitations for the demonstration of vitreous opacities. Fundus biomicroscopy has the advantages of stereopsis and dynamic assessment but can cause significant patient discomfort: Patient lid squeezing and saccadic movements away from the biomicroscopic light source can limit the examiner's assessment of the opacities. Color fundus photography has the advantage of widefield capability but opacities can less visible against the red reflex versus infrared photography which enhances contrast of the black opacities against a white fundus. However both color and infrared still photography are limited by a single, static demonstration of opacity location and may fail to capture intermittent foveal obscuration. While optical coherence tomography (OCT) of the posterior vitreo-retinal interface is useful for capturing posterior hyaloid location and confirming posterior vitreous detachment status, it often cannot visualize and demonstrate the largest and most symptomatic opacities.

Methods:
This prospective, non-randomized, non-masked series included 52 eyes of 40 consecutive patients with a primary complaint of symptomatic vitreous opacities in either one or both eyes. Eyes with history of prior vitrectomy, YAG laser capsolotomy or vitreolysis were excluded. Comfort score (1-4) was obtained at the time of video acquisition (1= extremely comfortable, 2= somewhat comfortable, 3= somewhat uncomfortable, 4= extremely uncomfortable). A macular vitreous opacity score (MVOS) was developed to grade the size of opacities in relation to the macula and the percentage of time the opacities obscure the infrared reflection of the fovea following blink and re-fixation after up/down/left/right saccades:

MVOS	% Macula Obscured	Time Fovea Obscured >50%
0	None	-
1A	1-25	No
1B	1-25	Yes
2A	26-50	No
2B	26-50	Yes
3A	51-75	No
3B	51-75	Yes
4A	76-100	No
4B	76-100	Yes

Results:
A comfort score of 1 was reported by 34 of 40 patients (85%). The remaining 6 patients (15%) reported a comfort score of 2. Thirty two patients (62%) with symptomatic vitreous opacities were MVOS 1A. Six patients (11%) were MVOS 2A, six patients (11%) were MVOS 2B, five patients (10%) were MVOS 3B, and three patients (6%) were MVOS 4B.

Conclusion:
Infrared video imaging is well-tolerated from the patient's perspective and can be a useful supplement to traditional examination and imaging for the demonstration and quantification of symptomatic vitreous opacities, particularly in patients with MVOS 2. By rendering the opacities black in front of a white

fundus, infrared imaging highlights the opacities while the video function allows for dynamic demonstration of foveal obscuration following blinks and directional saccades. The MVOS can be utilized in future study of the case selection and outcomes of interventions for symptomatic vitreous opacities.

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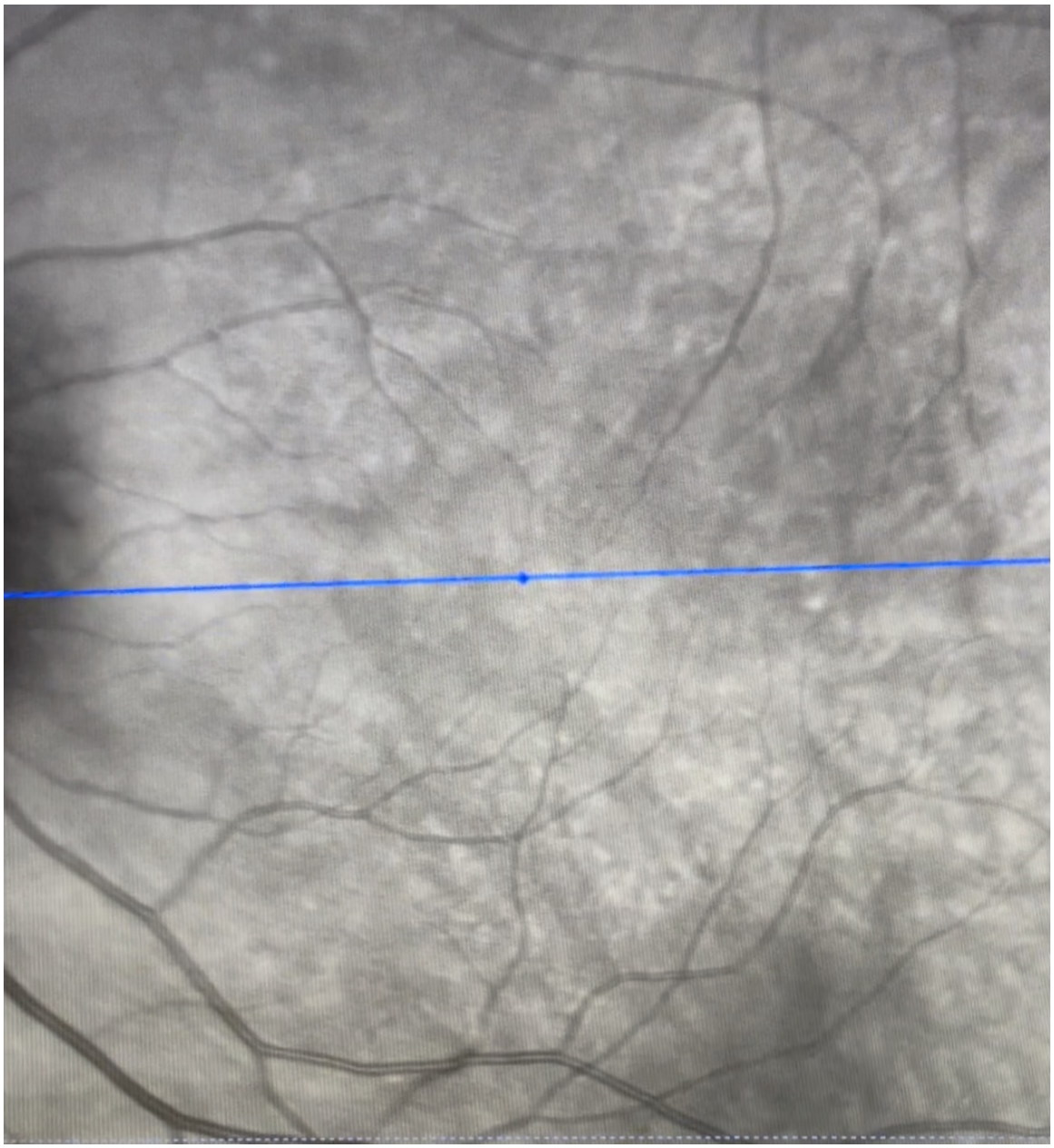

Infrared still photo capturing extra-foveal location of vitreous opacities

Infrared video of the same patient demonstrating MVOS 2B foveal involvement

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Regression Patterns of Central Serous Chorioretinopathy Using En Face Optical Coherence Tomography

- SUPRIYA ARORA, MS
- Brian Rosario
- Abdul Rasheed Mohammed, MSc
- Oliver Beale, MD
- Sumit Singh
- Amrish Selvam
- Gunjan Chhablani, Bachelor of Engineering
- Ramesh Venkatesh
- Nikitha Reddy
- Alexei Kulikov
- Dmitrii Maltsev
- Jay Chhablani, MD

Objective:
To study the regression patterns of subretinal fluid (SRF) in central serous chorioretinopathy (CSCR) on sequential en-face optical coherence tomography (OCT) and its relationship to leak locations.

Purpose:

Patients present at different stages of resolution of SRF, and persistence of subfoveal SRF raises concerns about the spontaneous resolution course duration. Currently, there is no knowledge on direction of fluid regression. This knowledge may be helpful in following up the patient and offering treatment at an appropriate time.

Methods:
Retrospective study on patients with acute CSCR. Inclusion criteria were i)availability of data, sequential OCT and OCT angiography (B scan and en-face OCT) every 2 weeks until resolution of SRF or 6 months, whichever is earlier ii)single active leak. Exclusion criteria were i)presence of macular neovascularization or atypical CSCR ii)Diffuse pigment epitheliopathy. Serial en-face OCT scans were evaluated and the area of SRF was measured using Image J software. The leak site was identified on fluorescein angiography and eyes divided into 2 groups based on whether the leakage site was < 1000 µ(Group A) or > 1000 µ(Group B) from the fovea. Correlation coefficient was calculated for the regression rate of SRF area and central retinal thickness(CRT) over first month of follow-up and the time of complete SRF resolution.

Results:
Out of the 25 eyes; 20 eyes demonstrated a centripetal regression, and 5 eyes demonstrated a centrifugal regression. There were 15 eyes in Group A and 10 eyes in Group B. On further evaluation of the 5 eyes which demonstrated centrifugal regression pattern, it was observed that the direction of SRF regression was towards the leak site in 3 eyes (SRF at the fovea resolved earlier than SRF at the leak site). Three of these 5 eyes were in group B. On evaluating 20 eyes with centripetal regression, 13 eyes were in group A. Among the remaining 7 eyes in group B, 4 eyes had a leak point >1000 µ away from fovea and 3 eyes had a leak point > 2-disc diameters from fovea. In Group A, 86% resolved in a centripetal fashion; and in Group B, 70% eyes resolved centripetally. Mean time of SRF resolution was 9±5.8 months for Group A and 11.57± 6.4 months for Group B. There was a good correlation(r=-0.47,p=0.018) of the rate regression of SRF area during the first month and timing of resolution. In contrast, this correlation was absent (r=-0.16,p=0.44) for CRT regression.

Conclusion:
Our en-face based analysis of sequential OCTs of regressing CSCR demonstrated a tendency for the subfoveal SRF to resolve towards the end or a centripetal pattern of regression. Currently CRT or the height of neurosensory detachment is the main parameter used for tracking the fluid dynamics. However, this could be

misleading as it may just indicate redistribution of SRF rather than the actual resolution. Assessment of height of the fluid along with the en-face area of SRF gives a more wholistic picture of fluid regression/ progression. Our study demonstrated that prediction of resolution of SRF at 1 month is better with en-face area of SRF in comparison to CRT.

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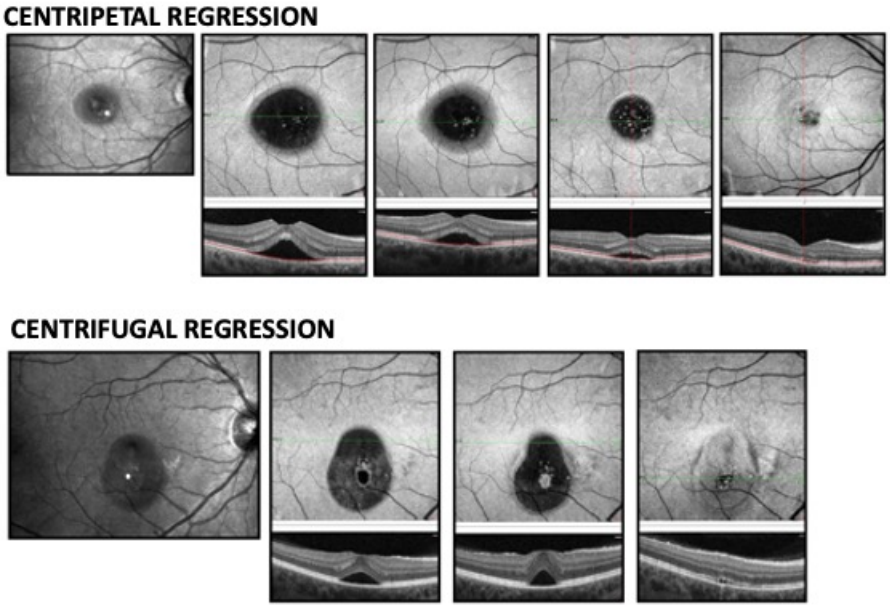
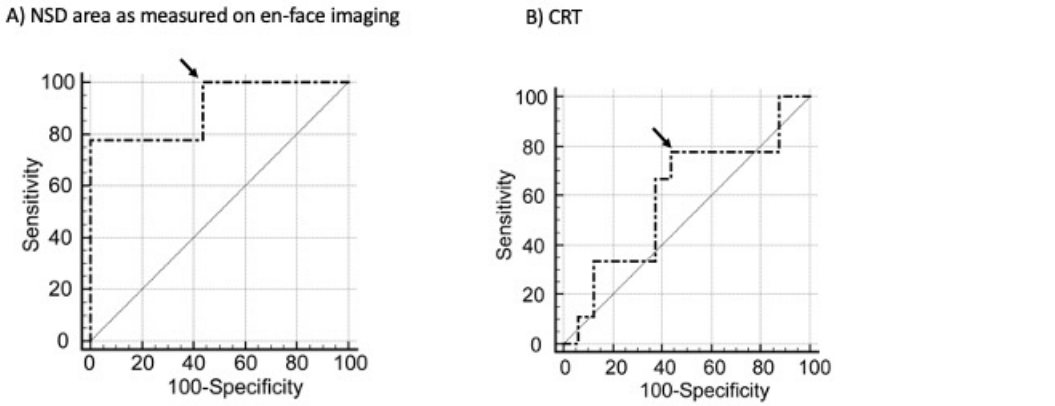


Regression pattern on sequential en-face images

Figure 2



The rate of first month Neurosensory detachment (NSD) area regression showed statistically significantly higher area under the curve (AUC) in identifying cases with resolution later than 2 months compared to the rate of first month central retinal thickness (CRT) regression, 0.903 and 0.57, respectively (p=0.012). Specificity at 77.8% sensitivity for the rate of first month regression of NSD area and CRT was 100% and 56.3%, respectively.

AUC plots for identifying cases with resolution later than 2 months