Morphological characterization of subretinal hyper-reflective material in posterior uveitis using swept-source optical coherence tomography and optical coherence tomography angiography

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Purpose: To analyze the structural features of subretinal hyper-reflective material (SHRM) in posterior uveitis using swept-source optical coherence tomography (SS-OCT) and optical coherence tomography angiography (SS-OCTA).

Methods: In this observational study, subjects with quiescent posterior uveitis and presence of SHRM on SS-OCT were subjected to SS-OCTA to identify the presence of an intrinsic choroidal neovascular (CNV) network. OCT features were compared for SHRM harboring CNV (vascular SHRM) with those without CNV network (avascular SHRM) to identify clinical signs pointing toward the presence of CNVM inside SHRM.

Results: Forty-two eyes of 33 subjects (18 males; mean age: 29.52 ± 12.56 years) were evaluated. Two-thirds (28/42) of eyes having SHRM on SS-OCT harbored intrinsic neovascular network (vascular SHRM). Increased reflectivity of SHRM (P < 0.001) and increased transmission of OCT signal underlying SHRM (P = 0.03) were suggestive of the absence of CNVM. The presence of intra/subretinal fluid (P = 0.08) and pitchfork sign (P = 0.017) were important markers of vascular SHRM.

Conclusion: SHRM is an important OCT finding in eyes with posterior uveitis. Meticulous assessment of SHRM characteristics on SS-OCT can aid in identifying the underlying intrinsic neovascular network.

Key words: Choroidal neovascularization, CNV, optical coherence tomography angiography, posterior uveitis, subretinal hyper-reflective material

Subretinal hyper reflective material (SHRM) is a morphologic feature seen on optical coherence tomography (OCT) as a hyper-reflective material located external to the neurosensory retina and internal to the retinal pigment epithelium (RPE). SHRM may be composed of neovascular tissue, hemorrhage, exudates, fibrosis, vitelliform material, or reticular pseudodrusen (subretinal drusenoid deposits). SHRM has been reported in various macular diseases such as age-related macular degeneration (AMD), myopia, pachychoroid spectrum, and macular dystrophies. Persistent SHRM has been associated with reduced response to anti-vascular endothelial growth factor (VEGF) therapy and poor visual acuity in these pathologies. However, SHRM has not been studied in eyes with posterior uveitis. SHRM is most often masked by the scarring seen in the eyes with choroiditis and thus no special attention is paid to it and not evaluated further. Also, in the presence of scarring and/or active inflammation, it becomes difficult to delineate the underlying neovascularization and differentiate it from fibrosis in such eyes despite performing conventional dye-based angiography and swept-source OCT (SS-OCT).

Although SHRM as an entity is well known in AMD, its presence is often ignored in eyes with uveitis due to unfamiliarity of uveitis experts and the lack of available literature. Because SHRM may be harboring new vessels that would respond to anti-VEGF therapy, it becomes imperative for uveitis experts to be familiar with this entity for judicious management of these eyes.

SHRM in uveitis may be the initial finding on OCT that points to developing choroidal neovascularization (CNV) or may represent fibrosis due to scarring of the inflammatory pathology. Optical coherence tomography angiography (OCTA) may be a useful tool in detecting CNV lesions with higher sensitivity and specificity compared to conventional imaging techniques.

Currently, there are no studies on the imaging characteristics of SHRM detected on OCT in patients with posterior uveitis. In the present study, we aimed to characterize SHRM in eyes with posterior uveitis using SS-OCT and SS-OCTA.
posterior uveitis and identify signs on OCT that may indicate the presence of intrinsic neovascular network within it.

**Methods**

This study was an observational study in which patients with posterior uveitis visiting the Retina and Uveitis Services of a tertiary care center in Northern India were enrolled. The study was approved by the Institutional Ethics Committee (IEC). Written informed consent was obtained from all study subjects. The study adhered to the tenets of the Declaration of Helsinki.

**Study subjects**

Subjects with quiescent posterior uveitis visiting the outpatient department between January 2019 to March 2020 were enrolled in the study. We included subjects with SHRM on SS-OCT. All subjects were required to have the absence of active inflammation. This was defined as 0 cells in the anterior chamber, ≤ 0.5 vitreous cells, absence of clinically active choroiditis lesions (confirmed on fluorescein angiography [FA] and indocyanine green angiography [ICGA]), and no macular edema. Only eyes that showed the absence of inflammatory activity for the past 6 months were enrolled. Maintenance therapy with ≤ 10 mg/day oral prednisolone (or equivalent) and stable immunosuppressive therapy (during the study period) were allowed. Exclusion criteria were the presence of concomitant retinal vascular diseases such as diabetic retinopathy, retinal vein occlusions, Age Related Macular Degeneration (AMD), and media opacity precluding good-quality OCT scan acquisition.

All study subjects underwent a complete ophthalmological examination along with the best-corrected visual acuity (BCVA) assessment on Snellen’s chart (converted to LogMAR for statistical analysis), intraocular pressure (IOP) measurement, and slit-lamp biomicroscopy evaluation. Fundus imaging with color fundus photography (Carl Zeiss VISUPAC FF450, Zeiss Meditech, La Jolla, CA), and FA and ICGA (Spectralis®, Heidelberg Engineering, Heidelberg, Germany) (at baseline in all subjects, and in the follow-up if deemed necessary by the treating uveitis specialist) was performed. SS-OCT and SS-OCTA (DRI Triton® Topcon, Topcon Inc., Japan) were done for all subjects.

**Study procedures**

At the time of enrollment, two uveitis specialists (AA and VG) analyzed the SS-OCT scans to confirm the presence of SHRM. All subjects with SHRM on SS-OCT underwent SS-OCTA to look for the presence of a neovascular network.

Subjects with no intra/subretinal fluid on OCT and the absence of neovascular network on OCTA were characterized as avascular SHRM and were kept on monthly follow-up. Subjects who showed the presence of CNV on OCTA were characterized as vascular SHRM. Subjects with vascular SHRM who showed the presence of intraretinal (IRF) or subretinal fluid (SRF) on SS-OCT or complained of decreased vision/m metamorphopsia received treatment with intravitreal injection ranibizumab (0.5 mg/0.05 mL). Those with vascular SHRM in the absence intraretinal (IRF) or subretinal fluid (SRF) were kept under observation with close follow-up.

For image acquisition, pupils were dilated by instilling one drop of phenylephrine 5% with tropicamide 0.8%. SS-OCT 3D and 5-line raster scans of the macula were obtained. OCTA was performed using a 3 × 3 mm scan protocol of the area of interest. The acquisition of the scans was repeated to select the best-quality image for further analysis.

**Image analyses**

For the purpose of analysis, the SS-OCT image with the largest visible SHRM area was chosen for each patient from raster line scans. For subsequent visits, the same tracked OCT scan at the same position was used. Each SHRM was evaluated using multiple pre-set boundary curves and manual adjustment of the anteroposterior positions of those curves were performed to correct the segmentation errors.

**SHRM characteristics**

The following SHRM characteristics were studied:

1. **Reflectivity:** Reflectivity of SHRM was noted compared to the nerve fiber layer (NFL). NFL was taken as the reference for high reflectivity rather than RPE as RPE was thought to be difficult to delineate in areas with SHRM.[10]

   **High reflectivity:** The reflectivity of SHRM was defined as high if the reflectivity was similar to that of the NFL.

   **Low reflectivity:** Reflectivity of SHRM less than NFL was considered low reflectivity.

2. **OCT transmission below SHRM**

   **Increased transmission:** SHRM that increased the transmission of OCT signal under the lesion as compared to the transmission through the choroid in the area adjacent to the SHRM.

   **Decreased/normal transmission:** SHRM that decreased/similar transmission of OCT signal under the lesion as compared to the adjacent area in the OCT scan.

3. **Pitchfork sign**

   The presence of multiple, distinctive finger-like projections extending from the area of SHRM is referred to as the “Pitchfork sign.” The Pitchfork sign is suggestive of type 2 neovascularization due to inflammatory pathology.[11] We looked for the presence of this novel sign on SS-OCT line scans passing through the SHRM area.

4. **Presence/absence of intra/subretinal fluid**

   Multiple single horizontal lines scans over the SHRM were scrolled through to look for the presence/absence of intra/subretinal fluid on SS-OCT.

**Statistical analysis**

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS version 16 for Windows). Quantitative variables were described using mean with standard deviation. Mann–Whitney U test was used to compare the quantitative data between the groups. Fisher’s exact test was used to compare SHRM parameters between the two groups. A P value of < 0.05 was considered significant in all tests.

**Results**

Forty-two eyes of 33 patients were enrolled in the study. Eighteen out of 33 subjects were male (54%). The mean age of the patients was 29.52 ± 12.56 years. The etiologies of uveitis included tubercular choroiditis (38.09%), idiopathic multifocal choroiditis (28.57%), punctate inner choroidopathy (19.04%), idiopathic panuveitis (9.52%), toxoplasmosa chorioretinitis (2.38%), syphilitic retinitis (2.38%). Sixteen patients (48.48%) were on systemic immunosuppressive therapy (azathioprine or methotrexate), whereas 7 (21.21%) also
received the maintenance dose corticosteroids (5–7.5 mg/d). The demographic and treatment details of the subjects are listed in Table 1.

Out of 42 eyes enrolled in the study, 28 eyes (66.67%) showed the presence of intrinsic neovascular network within the SHRM (vascular SHRM) on SS-OCT, whereas 14 eyes (33.33%) showed no neovascular network (vascular SHRM).

Out of 28 eyes with vascular SHRM, 6 eyes showed the presence of intra/sub-retinal fluid on SS-OCT at presentation and were treated with intravitreal injection ranibizumab (IVR). Seven out of 28 eyes with vascular SHRM but absence of intra/sub-retinal fluid had complain of metamorphopsia/decreased vision at presentation and were also treated with IVR. Fifteen eyes with vascular SHRM and absence of intra/subretinal fluid/symptoms were kept under observation. Four out of 15 eyes developed diminution in vision or metamorphopsia with intra/subretinal fluid on OCT during follow-up. These eyes also received IVR.

Baseline demographic features and etiology of uveitis were comparable for the eyes with avascular and vascular SHRM [Table 2].

OCT characteristics of SHRM
Different OCT characteristics of the eyes with vascular and avascular SHRM are provided in Table 3.

Reflectivity
In eyes with vascular SHRM, 4/28 (14.28%) had increased reflectivity (similar to nerve fibre layer [NFL]), whereas all 14/14 eyes (100%) with avascular SHRM had increased reflectivity (P = 0.00001) on SS-OCT [Figs. 1 and 2].

OCT transmission below SHRM
Of the 28 eyes with vascular SHRM, none of the eyes showed an increase in the transmission of OCT signal below SHRM. In contrast, 3/14 (21.42%) eyes with avascular SHRM showed an increased transmission of OCT signal below SHRM (P = 0.03) [Fig. 3].

Pitchfork sign
The pitchfork sign was present in 10/28 eyes (35.71%) with vascular SHRM, whereas none of the eyes with avascular SHRM showed this sign (P = 0.0174) [Fig. 4].

Intra/Subretinal fluid
Six out of 22 eyes (27.27%) with vascular SHRM showed the presence of intra/subretinal fluid on SS-OCT. None of the eyes with avascular SHRM, in contrast, had intra/subretinal fluid (P = 0.08) [Fig. 5].

Correlation of the presenting visual acuity with baseline SHRM characteristics
Univariate analysis did not reveal any of the baseline SHRM characteristics to be predictive of presenting visual acuity [Table 4].

Discussion
Subretinal hyper reflective material (SHRM) is an optical coherence tomography (OCT) terminology used to describe hyper-reflective material located external to the neurosensory retina and internal to the retinal pigment epithelium (RPE). SHRM has been studied extensively in the eyes with nAMD. As an OCT biomarker, SHRM has been shown to be a predictor of poor visual outcomes and macular atrophy in AMD eyes.[13,14] In contrast, the resolution of SHRM or reduction in SHRM dimensions is associated with favorable treatment response to anti-VEGF agents.[3,4,12] The association of OCT characteristics and the composition of SHRM with visual acuity have also been studied. Subretinal hyper-reflective exudation (SHE) is associated with good response to anti-VEGF and improvement in visual acuity, whereas the presence of intrinsic neovascularization and hemorrhage inside SHRM are markers of poor visual outcome.[14] In a study by Pokroy et al., high reflectivity of SHRM at baseline was associated with poor visual acuity at 12 months of follow-up on univariate analysis. Similarly, increased reflectivity of SHRM was associated with worse visual acuity at 12 and 24-week follow-ups in patients with nAMD in a study by Kumar et al.[9]

Table 1: Demographic and treatment details of the subjects included in the study (n=42 eyes; 33 subjects)

| Subject detail | Observation |
|----------------|-------------|
| Age (years)    | 29.52±12.56 |
| Gender, n, (%) | Male: 18 (54.54), Female: 15 (45.45) |
| Diagnosis      | Tubercular choroiditis: 16 eyes (38.09%), Multifocal choroiditis: 12 eyes (28.57%), Punctate inner choroidopathy: 8 eyes (19.04%), Idiopathic panuveitis: 4 eyes (9.52%), Toxoplasma chorioretinitis: 1 eye (2.38%), Syphilic retinitis: 1 eye (2.38%) |
| Treatment      | Immunosuppressive therapy: 16 (48.48%), Oral steroids: 7 (21.21%) |

Table 2: Baseline demographic features and etiology of uveitis in eyes with avascular and vascular SHRM

| Age (years) | 32.78±5.59 | 28.6±9.93 |
|-------------|------------|-----------|
| Gender, n, (%) | Male: 66.66% (7/13) | Male: 50% (11/20) |
| Diagnosis | Tubercular choroiditis: 7 | Tubercular choroiditis: 11 |
| | Multifocal choroiditis: 6 | Multifocal choroiditis: 6 |
| | Punctate inner choroidopathy: 1 | Punctate inner choroidopathy: 5 |
| | Idiopathic panuveitis: | Idiopathic panuveitis: 4 |
| | Syphilis: 1 | Syphilis: 1 |
| | Toxoplasma retinochoroiditis: 1 | Toxoplasma retinochoroiditis: 1 |

* Mann-Whitney U test. * Fischer exact test
However, there still exists a lacuna in the characterization of SHRM in uveitic eyes in the ophthalmic literature. SHRM is commonly observed in posterior uveitis and may represent CNV, subretinal fibrosis, exudation, or hemorrhage. The appearance of SHRM on OCT may be an initial finding indicating the development of choroidal neovascularization. However, it becomes difficult to differentiate SHRM with underlying vascular component from scaring seen in posterior uveitis either clinically or even on fluorescein angiography. OCTA provides distinct advantage in detecting CNV lesions in uveitic eyes, and we found that two-thirds of eyes with SHRM showed the presence of intrinsic CNV on SS-OCTA. The detection of CNV is important as early injection of anti-VEGF therapy may help in vision restoration in these eyes with extensive scarring.\textsuperscript{[16,17]} This becomes even more important in posterior uveitis as the early CNVs may be missed clinically or angiographically due to the presence of extensive fibrosis and scarring secondary to healed inflammation.

Many times, patients with healed uveitis come back with complaints of recent onset metamorphopsia or difficulty in reading. Because there is so much scarring, one cannot appreciate any changes clinically. It thus becomes imperative to recognize important biomarkers on OCT so that the patients who show the presence of these biomarkers undergo OCTA to look for intrinsic CNV. Low reflectivity of subretinal material has been shown to be an indicator of FA leakage from choroidal neovascularization.\textsuperscript{[18,19]} In this study, we found that all the eyes with avascular SHRM (14/14) had high reflectivity. Also, 24/28

\begin{table}[h]
\centering
\caption{SS-OCT characteristics of eyes with vascular and avascular SHRM}
\begin{tabular}{|l|l|l|l|}
\hline
SHRM characteristic & Vascular SHRM (28 eyes) & Avascular SHRM (14 eyes) & \(P^*\) \\
\hline
Reflectivity & High reflectivity : 4 & High reflectivity : 14 & \(P<0.00001\) \\
 & Low reflectivity : 24 & Low reflectivity : 0 & \\
OCT transmission below SHRM & Increased: 0 & Increased: 3 & \(P=0.03\) \\
 & Normal/decreased transmission: 28 & Normal/decreased transmission: 11 & \\
Pitchfork sign & Present: 10 & Present: 0 & \(P=0.0174\) \\
 & Absent: 18 & Absent: 14 & \\
Intra/subretinal fluid & Present: 6 & Present: 0 & \(P=0.08\) \\
 & Absent: 22 & Absent: 14 & \\
\hline
\end{tabular}
\flushleft\textsuperscript{*Fischer Exact test}
\end{table}

\begin{table}[h]
\centering
\caption{Univariate analysis of SHRM characteristics predictive of visual acuity}
\begin{tabular}{|l|l|}
\hline
SHRM characteristic & \(P\) \\
\hline
Reflectivity & 0.483 \\
OCT transmission below SHRM & 0.776 \\
Pitchfork sign & 0.245 \\
Intra/subretinal fluid & 0.644 \\
\hline
\end{tabular}
\end{table}

Figure 1: High reflectivity of SHRM on swept-source optical coherence tomography (SS-OCT): SS-OCT shows the reflectivity of SHRM, similar to the nerve fiber layer (NFL)/high reflectivity (d) in a patient with Serpiginous-like choroiditis (a). SS-OCTA shows the absence of the neovascular complex (c) with paucity of flow on corresponding B scan (b) (yellow arrow)
eyes (85.7%) with vascular SHRM had low reflectivity, whereas only 14.3% (4/28) eyes had increased reflectivity ($P < 0.00001$). Thus, increased reflectivity of SHRM may rule out the presence of intrinsic CNV.

Increased transmission of OCT light into the choroid on SD-OCT has been described as a sign of macular atrophy$^{[20]}$ and is considered as diagnostic sign for geographic atrophy in patients with AMD.$^{[21]}$ In our series, none of the eyes (0/28) with vascular SHRM showed increased transmission of OCT light, whereas 3/14 eyes with avascular SHRM had increased transmission on SS-OCT ($P = 0.03$).

"Pitchfork sign" showing the presence of multiple, distinctive finger-like projections extending from the area of SHRM has been reported to be suggestive of underlying inflammatory

Figure 2: Low reflectivity of SHRM on swept-source optical coherence tomography (SS-OCT): Panel d shows SHRM with reflectivity less than NFL (low reflectivity) in a patient with punctate inner choroidopathy (a). The neovascular network was visible on en face OCTA (white arrow) (c) with the presence of flow in the corresponding OCTA B-scan (b). Fundus fluorescein angiography shows the leakage of dye from choroidal neovascularization (e), whereas the membrane complex is visible on indocyanine green angiography (f).
Figure 3: Baseline and follow-up SS-OCT and SS-OCTA images of a patient with vascular SHRM. Baseline OCTA B-scan showed SHRM with the intrinsic flow (white arrow) (c) and neovascular network on en face OCTA (b). SS-OCT line scan passing through the lesion showed the transmission of OCT signal under the lesion that was similar as compared to the adjacent area in the OCT scan (yellow arrow) (d). The patient received was treated with intravitreal ranibizumab resulting in the resolution of the neovascular network (f,g), and resolution of SHRM on SS-OCT with an increase in the transmission of OCT signal under the lesion (yellow arrow) (h)
In our series, the Pitchfork sign was seen in 35.7% of eyes with vascular SHRM, whereas none of the eyes with avascular SHRM had this sign \((P = 0.0174)\). The presence of the “Pitchfork sign” is therefore, an important marker of underlying neovascularization in SHRM and patients showing this sign need further imaging to look for underlying CNV.

The presence of intra/subretinal fluid in the absence of active inflammation points toward the presence CNV network, especially in the eyes with extensive scarring/RPE damage.\[^{[23]}\] In our study, 6/28 (21.42%) eyes with vascular SHRM showed the presence of intra/subretinal fluid on SS-OCT and received treatment with anti-VEGF (Lucentis ®). None of the eyes with avascular SHRM, in contrast, had intra/subretinal fluid on SS-OCT \((P = 0.08)\).

Our study highlights vital SS-OCT biomarkers to identify the neovascular network inside SHRM. CNV is an important cause of vision loss in patients with both infectious and non-infectious posterior uveitis.\[^{[6-8,24-26]}\] This warrants early identification and treatment to preserve visual acuity, especially in the eyes in which inflammation has been controlled. Using non-invasive SS-OCT and careful analysis of morphological features of SHRM, the presence of CNV can be suspected, which can then be confirmed with SS-OCTA.

Limitations of our study include a limited sample size. Because both the eyes of certain patients were included, we used patient identification number as a random factor to compensate for within-subject correlations.

**Conclusion**

In conclusion, SHRM is an important OCT finding in eyes with posterior uveitis. Two-thirds of the eyes with SHRM in our study harbored intrinsic neovascular membrane. Meticulous
assessment of SHRM characteristics on SS-OCT can aid in identifying the underlying CNVM. High reflectivity of SHRM and an increased OCT transmission through it indicates that SHRM is avascular, whereas the presence of the Pitchfork sign, intra/subretinal fluid suggests the presence of CNV complex.

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Conflicts of interest
There are no conflicts of interest.
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