Comparing six cases of external macular holes and literature review

Comparação de seis casos de buracos maculares externos e revisão de literatura

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ABSTRACT

The characteristic optical coherence tomography finding in solar maculopathy is a well-defined outer retinal hyporeflective space primarily involving the photoreceptor inner and outer segment layers. This typical optical coherence tomography image may be present in a few other pathologies, which currently constitute their main differential diagnoses. Our study shows the report of 12 eyes of 6 patients treated at the *Hospital de Olhos do Paraná*, presenting their clinical history and diagnostic images, with the purpose of comparing the findings of the first 3 patients (diagnosed with solar maculopathy) with the last 3 patients, which are also cases of external macular holes.

RESUMO

O achado característico da tomografia de coerência óptica na maculopatia solar é um espaço hiporrefletivo retiniano externo bem definido, envolvendo principalmente as camadas dos segmentos interno e externo dos fotorreceptores. Essa imagem típica da tomografia de coerência óptica pode estar presente em algumas outras patologias, que atualmente constituem seus principais diagnósticos diferenciais. Nosso estudo mostra o relato de 12 olhos de 6 pacientes atendidos no Hospital de Olhos do Paraná, apresentando sua história clínica e imagens diagnósticas, com o objetivo de comparar os achados dos 3 primeiros pacientes (diagnosticados com maculopatia solar) com os 3 últimos pacientes, que também são casos de buracos maculares externos.

INTRODUCTION

Solar maculopathy from prolonged exposure to solar light is a rare but well-recognized clinical cause of vision loss and macular damage. The occurrence of the macular injury is often reported in eclipse viewing,[1-9] but it is also seen outside eclipse episodes on very sunny days[1], or even without the presence of sungazing.[10,11] Solar maculopathy has a higher incidence in specific populations with the habit of sungazing like psychiatric patients,[12-15] in some religious practices[16-19] or with the use of psychoactive drugs.[20-22] Patients may complain of visual loss or may be asymptomatic. Symptomatic patients complain of metamorphopsia and central scotoma, which, if large enough, can reduce visual acuity (VA) permanently.[23]

The ophthalmoscopic signs of solar maculopathy are limited to the fovea. There is a wide variety of ophthalmic diseases that occur with isolated macular alterations. Examples may include a full-thickness macular hole, an inner lamellar macular hole, a pseudo hole associated with an epiretinal membrane, focal geographic atrophy, limited choroidal neovascularization, a small focal area of central serous retinopathy, cystoid macular edema with a large central cyst, idiopathic juxtafoveal telangiectasia (MacTel), a congenital optic pit, whiplash injuries, a solitary macular cyst, and others.[24]

Imaging with fluorescein or indocyanine angiography is not very useful to distinguish all these macular lesions above, since the retinal pigment epithelium (RPE) in the foveal area is more pigmented than elsewhere in the fundus, reducing light transmission from the choroid.[25]

It was with the advent of optical coherence tomography (OCT) imaging as a diagnostic tool that we were able to clearly differentiate most of these pathologies above with relative ease. A full-thickness macula hole in B-scan, for instance, can be easily distinguished from an outer macular hole. However, there are still challenging cases. The characteristic OCT finding in solar maculopathy is a well-defined outer retinal hyporeflective space primarily involving the photoreceptor inner and outer segment layers.[26] This typical OCT image may be present in a few other pathologies, which currently constitute their main differential diagnoses.

Our study shows the report of 12 eyes of 6 patients treated at the *Hospital de Olhos do Paraná*, presenting their clinical history and diagnostic images, with the purpose of comparing the findings of the first 3 patients (diagnosed with solar maculopathy) with the last 3 patients, which are also cases of external macular holes.

METHODS

Twelve eyes of six patients who attended the *Hospital de Olhos do Paraná* were featured in this study with similar OCT findings. Because the hospital has diagnostic imaging centers with different devices and the cases were collected at different times, diagnostic images were obtained by different devices. Retinography images were done with Canon CX-1 Digital Retinal Camera. Optical coherence tomography images from Patients A, D, and E were obtained by Spectralis Spectral-domain (SD) OCT. Optical coherence tomography from Patients B, C, and F were obtained from Stratus time domain (TD) OCT.

This study was approved by the Research Ethics Committee of the Hospital de Clínicas da Universidade Federal do Paraná, PR, Brazil, CAAE: 50963021.0.0000.5411.

RESULTS

Twelve eyes of six patients were analyzed. Patient A is a 21-year-old woman with a history of worsening VA in both eyes a week before the exam after looking at a solar eclipse without adequate protection just before symptom onset. Her best-corrected acuity (BCVA) is 20/50 in the right eye (OD) and 20/70 in the left eye (OS). After 6 months of follow-up, her best VA became 20/30 OD and 20/20 OS. Patient B is a 42-year-old man who reported worsening central vision for approximately 4 weeks in both eyes, denying events related to the onset of the low acuity episode, even sungazing. His BCVA was 20/40 OD and 20/50 OS. Fundoscopy showed a hypopigmented lesion in the foveal region in both eyes. The patient had complete visual recovery after 6 months. Patient C is a 55-year-old man with a history of low VA in both eyes, but more intense in the OD for approximately 3 months. He mentioned that he worked as a bricklayer with sun exposure at various times of the day and without using eyeglasses to protect him from sun exposure. However, no particular moment of sungazing was cited. His BCVA was 20/50 OD and 20/30 OS. Biomicroscopy showed a 2+/6+ nuclear cataract in the OD, and a well-positioned intraocular lens in the OS, with no other changes. Fundoscopy showed a mild decrease in foveal reflex and appearance of a small foveal hole in both eyes. After 6 months, he recovered VA to 20/30 OD and 20/25 OS. Patient D is a 20-year-old man who visited our hospital reporting low VA in the OD for approximately 2 weeks. He denied traumatic ocular antecedents and a particular moment of sungazing, although referring to daily activities under sun exposure. On examination, he had a BCVA of CF 1m OD and 20/20 OS. Fundoscopy showed a yellowish spot in the fovea of the OD, with no changes in

OS. Follow-up of 6 months showed OD recovery to 20/25. Patient E was an 8-year-old boy who reported low VA in the OD at the same day of the consultation. His mother reported exposure to a laser pointer for 2 seconds just before the low vision symptom. On examination, he had a BCVA of 20/20 in both eyes; however, mentioned some blurring in the OD. Fundoscopy showed a yellowish spot discreetly nasal to the exact center of the fovea of the OD, and with no changes in OS. We have not had follow-up visits of this patient yet. Finally, Patient F is a 63-year-old woman who reported low bilateral VA in the last year. Her BCVA was 20/50 OD and 20/30 OS. At fundoscopy, she had a foveal well-circumscribed lesion in the OD and foveal reflex attenuation in the OS. The patient stayed with 20/50 OD and recovered OS completely.

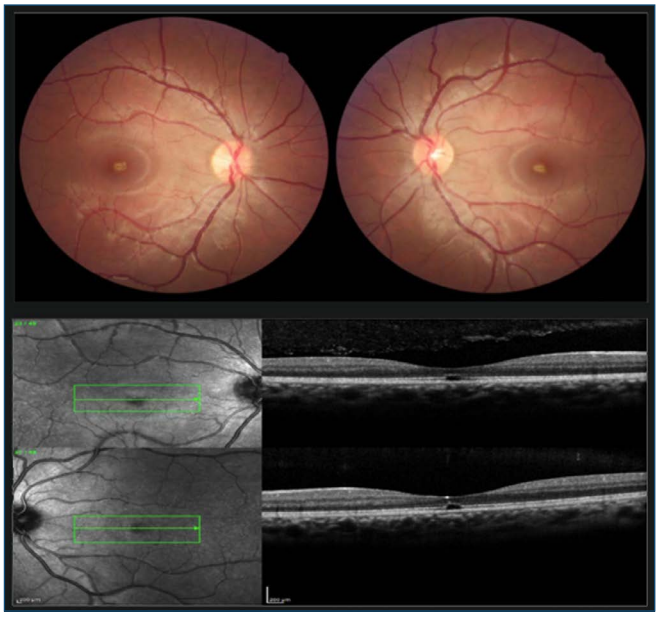

Figure 1. Fundus findings and optical coherence tomography findings in patient A with classic solar maculopathy findings. (Top) A color fundus photograph shows a yellowish spot in the macula. (Bottom) Optical coherence tomography B-scan shows a rectangular-shaped outer retinal hole.

Figure 1 shows the imaging results from both eyes of Patient A, which we evaluated as a classic case of solar maculopathy, that is, with a history of eclipse exposure and bilateral findings. This patient had the typical acute process macular lesion found in solar maculopathy, which is a bilateral yellowish hypopigmented lesion in the macula. OCT shows the disruption of the outer layers of the retina distributed from the RPE layer to the external limiting membrane.

Figure 2 shows a magnification of the macular area of Patients A, B, and C. These patients had a diagnosis of solar maculopathy with bilateral involvement. A presentation of bilateral hypopigmented macular lesion on Retinography and bilateral outer macular holes on OCT was found in all three patients. Figure 3 shows a magnification of the macular area of Patients D, E, and F. Patient D had a unilateral presentation. The right eye showed a fundoscopy image similar to the cases of solar maculopathy, with a yellow-white spot at the fovea, with the difference that this yellowish granulation affected a relatively more extensive and less circumscribed area than in the first three cases. In the OCT, there was also a disruption of the outer layers of the retina, but the lesion was more enlarged and partial, with the presence of hyperreflective spots in the area of disruption, assuming a more multifocal involvement. The left eye had no changes, which puts this case as atypical; however; solar maculopathy persists as the most likely diagnosis. Patient E, in turn, also has a unilateral involvement, but it is restricted to a smaller area than in Patient D and is located in a parafoveal area, in addition to having had a history of laser exposure.

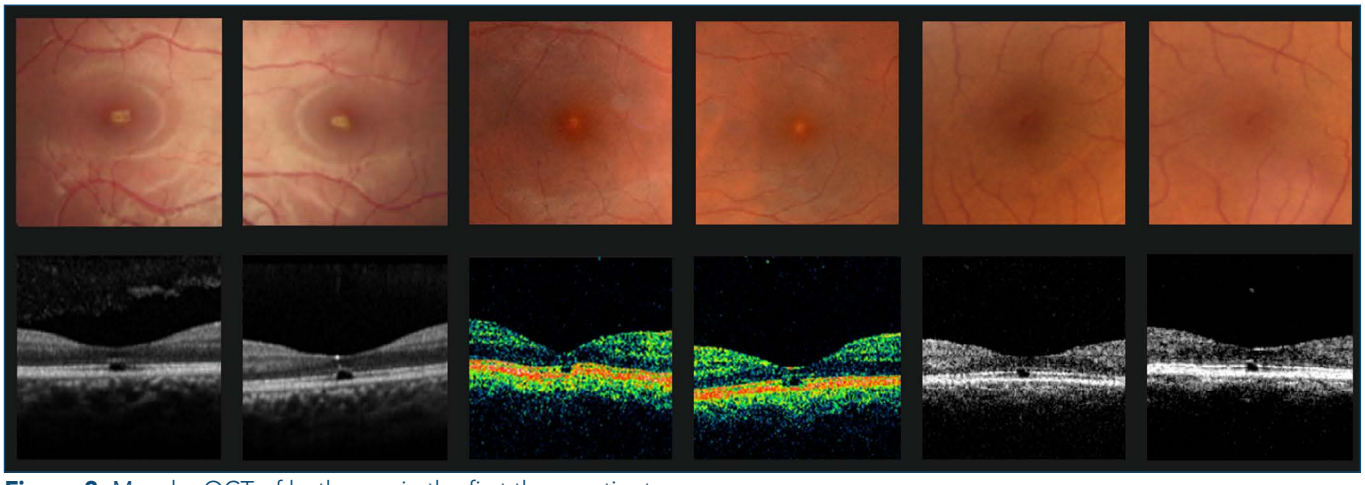

Figure 2. Macular OCT of both eyes in the first three patients

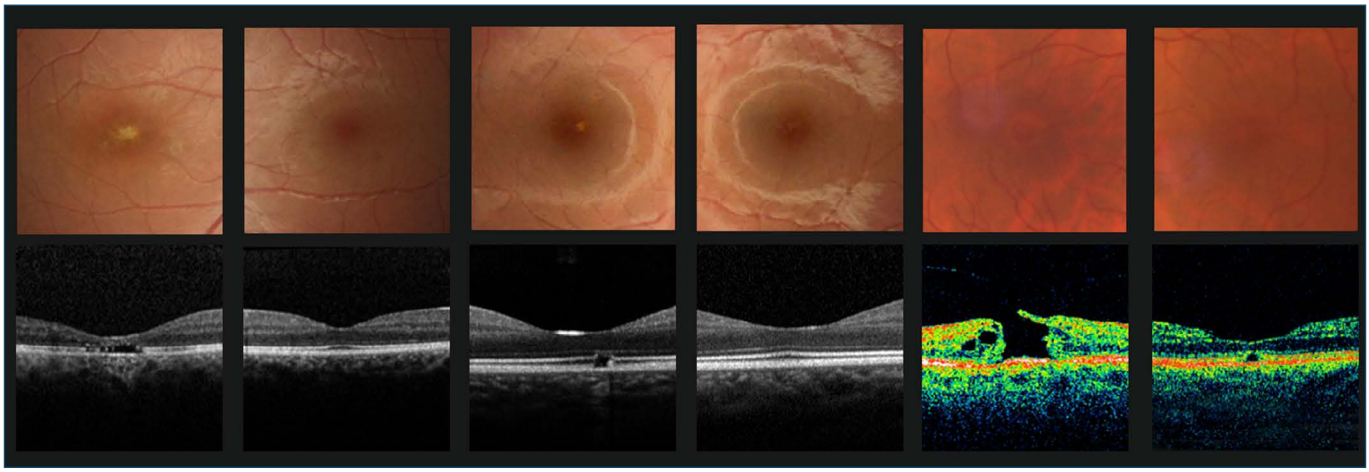

Figure 3. Macular OCT of both eyes in the last three patients

Finally, Patient F had a grade 2 macular hole in the OD, which could easily be distinguished from the external macular holes of the other patients by the OCT image. In the OS, there was an outer macular hole. Comparing the OCT image with the first three cases of solar maculopathy, Patient E had a more triangle-shaped alteration, with a decrease in the width of the disruption in the uppermost area of the hole. In addition, OD of the same patient showed incomplete posterior hyaloid detachment, still showing traction on the operculum. In OS, we did not see vitreomacular traction on the B-scan images.

DISCUSSION

The data above shows three cases of bilateral solar maculopathy, a possible case of unilateral solar maculopathy with an atypical presentation, a case of a laser pointer maculopathy and a case of macular hole with a contralateral outer macular hole due to vitreoretinal disease.

In solar maculopathy, fundoscopy usually shows a white-yellowish lesion with a granular appearance in the fovea region in acute cases. In longstanding solar maculopathy, a small multifaceted outer retinal hole (or holes) with a pigment halo is observed.[24] In OCT B-scan, the lesion usually appears as a hyporeflective rectangle with straight edges. The hole stretches from the RPE band to the external limiting membrane corresponding to the IS/OS (inner segment/outer segment) junction.[23] This outer lamellar cystic change is believed to be produced by either the thermal or the thermally enhanced phototoxic reaction at the photoreceptor level and surface of the RPE.[1]

Optical coherence tomography images from Patient A, D, and E were obtained by spectral-domain OCT, and from Patient B, C, and F, they were obtained from time-domain OCT. Unsurprisingly, comparisons between the images of the two OCT machines that we have at our disposal suggest that the spectral domain version is more accurate for identifying smaller lesions and their detailed pathologic findings.

The first three patients had different fundoscopy appearances, probably correlated with the time of onset of the macular lesion. In OCT imaging, all three patients showed a typical outer macular hole seen in solar maculopathy described in the paragraphs above. Patient D also had a disruption in the same area but assumed a greater extension. As cited by Duker et al., the hole(s) may be solitary or multifocal and may occasionally be ample.[27] A multifocal presentation was observed in the OS of Patient B and in the OD of Patient D, although Patient D has a greater disruption with greater multifocality, also with hyperreflective dots present at the location of the outer layers. Patient E, like Patient D, has a unilateral involvement, but it is restricted to a smaller area than in Patient D, it is unifocal and located in a parafoveal area, in addition to having had a history of exposure to laser.

Patient F had a full-thickness macular hole grade 2 in the OD and an outer macular hole in the OS. Johnson et al. call an outer retinal hole caused by early foveolar vitreomacular traction or from a partially closed microhole a "foveal red spot".[28] Emerson et al., in turn, called such alterations "microcysts", to differentiate from the "microhole" entity, which before OCT imaging were not differentiated from external macular holes.[29] This entity is not associated with sungazing, whiplash injuries, or other known macular diseases and is stable over extended follow-up.[28]

Partial healed full-thickness macular microholes probably account for a large subset of patients that show the same alteration correlated to posterior vitreous detachment (PVD) (check Figure 6; middle; of Johnson's),[28]

but they also can be seen in eyes with vitreous traction from stage 1 PVD in the absence of a full-thickness foveal break (check Figure 6; bottom; of Johnson's).[28] We did find partial Vitreomacular traction in the OD with a remaining operculum, but we did not find vitreoretinal traction in the OS, which had an outer macular hole. The absence of traction may support the diagnosis of a previously partially closed macular microhole in this patient. Lastly, a macular hole undergoing closure surgery can result in a later external macular hole (see Figure 1d and 2d from Asaad SZ).[30]

Still reasoning about the same case, we can observe the disruption of the outer layers assuming a triangular shape. This shape can be theoretically explained by the vector forces that are part of the pathophysiology of vitreomacular traction and macular hole formation. The traction with superior vector force of the vitreous would form this triangular aspect that would remain in the case of a prior microhole closure that has already had traction in the past or evolve to a complete hole in the next stage of the PVD. If carefully observed, this characteristic of triangular aspect can be seen in other OCTs images with the same diagnosis (Figure 6; bottom; of Johnson's; Figure 1; Type5b; of Takezawa's; Figures 2 and 3; from Yıldırım)[31,32] and it may be an essential finding in the OCT for the differential diagnosis between solar retinopathy and external macular hole by vitreomacular traction, especially in cases where we have an external macular hole with no history of sun exposure.

Another detail that differentiates Patient F from the first three patients is the irregularity of the foveal surface, often observed in patients with vitreomacular traction, which can be seen in the OS of Patient E and also in all three reports shared in the last paragraph. This particularity happens due to the physical traction of the vitreous and subsequent deterioration of the surface regularity.

We need to make it clear, however, that both signs could not be used as a pathognomonic aspect, since we have outer macular holes caused by vitreomacular traction without these aspects as mentioned above. Also, this triangle-shaped alteration is found to be quite similar in some cases of Popper's Maculopathy (see Figure 1 of Docherty),[33] but in this case, we would have a history of popper's substance use.[33]

Patient D's unilateral findings have also been described as solar maculopathy, most frequently being worse in the dominant eye.[34] Rai et al. showed 60 unilateral cases of solar maculopathy in a study carried out in Nepal with a certain peculiarity of these patients. They were mostly Hindu, who shared a tradition of sun worship in which the hands are used to leave a hole to make only the dominant eye see the sun. Mehlan et al. described a unilateral case, but with proven eclipse viewing.[34,35] MacFaul et al. described nine cases of unilateral solar maculopathy[36] and Dhir et al. described seven eyes with the unilateral presentation,[6] but both studies were carried out at a time when OCT did not exist, which could bring interpretation bias. Possible differential diagnoses for a unilateral external retinal defect could include laser pointer maculopathy, unilateral inflammatory maculopathy, unilateral acute idiopathic maculopathy, acute macular neuroretinopathy, and white dot syndromes.[24,37]

Visual acuity of the first three patients at diagnosis ranged from 20/30 to 20/70, with a higher prevalence of mild to moderate visual impairment. The finding is in agreement with the literature, which cites VA in solar maculopathy generally from 20/40 to 20/60, ranging from 20/20 to CF.[20,38,39]

Regarding the VA of the last three patients at diagnosis, Patient D had a vision of CF at 1m in his affected eye. Although vision differs greatly in relation to the first three, this magnitude of visual loss in solar maculopathy has already been described in several cases in the literature, being related to macular thickness and disruption width – changes that were in fact observed in the patient's OCT. Patient E had a central VA of 20/20 in the OD, but always citing a visual field defect right next to the Snellen optotypes. In laser pointer maculopathy, VA is typically worse than what we saw in our Patient E, commonly being 20/200 or worse.[40] However, as mentioned in the same study, patients with paramacular involvement usually have a VA of 20/40 or better, since the central fovea was not fully damaged.

Patient F had a vision of 20/50 in the macular hole eye and 20/30 in the outer macular hole eye, very similar to Yıldırım et al.,[32] who cited vision of 20/25, 20/25, and 20/50 in three very similar cases of outer macular hole comparing to our report.

Regarding visual recovery of the first three patients, the first and third cases had partial recovery, while the second case had a complete recovery. There seems to be much individual variation in the susceptibility to developing permanent vision loss in solar maculopathy.[23] Correlating with the OCT findings, a full-thickness involvement of the photoreceptor layer of the entire fovea indicates an association with permanent vision loss, whereas isolated involvement of the outer or inner segments or a lesion outside the center of the fovea results in a better visual outcome.[41] We

can see that the OD of Patient A, which had a wider disruption of the outer layers of the retina, had a worse recovery than the OS. This greater involvement of the outer layers of the retina may be related to the lower visual recovery in this case. Also, Patient C's cataract in the OD may have acted as a confounder, causing the same patient's OD to improve more modestly than the OS.

Regarding the visual recovery of the last three patients, Patient D had a broad recovery compared to his low vision at diagnosis, even with greater disruption of the outer layers. Patient E was seen recently, and we do not have visual recovery data at this time, even knowing that the patient will maintain 20/20 vision and may only evolve with a slight defect in the parafoveal visual field. Patient F did not undergo macular hole surgery in the OD; therefore, in this eye, there was no improvement. She had complete recovery of vision in the OS, corroborating the data from the same study mentioned above,[32] with complete recovery in all three similar cases of foveal red spots.

Concerning the act of sungazing in the first five patients, we had Patient A with proven exposure to the eclipse, Patient B with no reported exposure, Patient C with a probable but not acutely reported exposure, and Patient D also with no reported sungazing. Patient E also reportedly had light exposure, but to the laser pointer, not to the sun. In the literature, we classically have case reports with reported light exposure; however, we also have cases with no report of sun observation.[10,11] Rai et al.[42] found in a large sample of cases of solar maculopathy that half did not report a history of sun exposure. Tso e La Piana found that solar maculopathy can occur after less than a minute of sungazing, which may be the reason why many patients do not remember a specific time that they had looked at the sun.[43]

These cases of absence of sun exposure could also lead to a differential diagnosis of foveomacular retinitis, which has been described a few times in the literature as a form of primary maculopathy distinct from solar maculopathy where there is no sun exposure.[44,45] The disease can be viral in etiology and is usually self-limiting.[44] However, Wergeland et al. compared 36 patients in clinical history and examination findings and concluded that, apart from the report of sun exposure, they are identical diseases, if not the same disease[46]. In fact, some studies report both diseases as alike, while others report some differences in etiology[23].

Comparing even more deeply the possible differences between solar maculopathy and laser pointer maculopathy, there are other points to consider.

First, in relation to epidemiology, recent studies show that solar maculopathy continues without an increase in incidence in recent years, while laser maculopathy continues to rise.[47-49] This increase is even more prominent in children, who are increasingly exposed to toys with lasers and are unaware of the danger of the tool.[50] This can be explained by the growth of the laser device market and the increasing variety of their applications, as well as an apparent negligence on the part of companies not respecting the power limit allowed by governments. Recent years have seen increased availability of high powered lasers and mislabeled handheld presentation lasers.

A study conducted to measure the power of 122 laser pointers labeled as having a power of 1 to 5mW in United States found that 44% of red laser pointers and 90% of green laser pointers tested had a power output greater than 5mW.[51] In Brazil, the inspection of laser power is the responsibility of the *Instituto Nacional de Metrologia, Qualidade e Tecnologia* (Inmetro). Since a 2014 resolution, the body prohibits the manufacture and sale of toys that emit laser beams with a power greater than 1mW. The institute carried out a comparative study between red and green laser pointers and found that 25% of the samples had a higher radiation than 1mW and 50% of the products analyzed did not have the necessary information on the packaging, exposing the health and safety of society to the risks that the product can offer.[52]

With regard to the pathophysiology of the lesions, higher power lasers induce photothermal retinal damage within microseconds to seconds while longer retinal exposure to sunlight leads to photochemical damage.[40] De Silva et al. demonstrated that near-infrared reflectance autofluorescence imaging may facilitate discriminating between these disease entities, and that the involvement due to laser exposure is more likely to be multifocal, unlike solar maculopathy, which is usually unifocal.[53] Our patients proved that this is not a rule: Patients B and D with solar maculopathy had multifocal involvement and Patient E had unifocal involvement. Our small sample, however, cannot be the basis for inferring another type of involvement pattern than what was shown in De Silva's study. Silva postulated that unifocal burns in the external layers might indicate sudden accidental viewing of a laser beam prior to aversion with the blink reflex.[53] Patient E's mother reported exposure to a laser pointer for 2 seconds just before the low vision symptom.

Other cases can produce pretty similar findings in OCT images, such as welder's maculopathy, popper's maculopathy, tamoxifen retinopathy, juxtafoveal macular

telangiectasia, foveolar vitreomacular traction, a closed macular hole, whiplash injuries, and Stargardt disease.

Optical coherence tomography findings in Welder's Maculopathy are essentially identical to the findings seen in our case report (see Figure 1 at Lucas).[54] This is not surprising, as the two diseases share similar photochemical injury mechanisms.[55] History of welding practice or welding keratitis would differentiate the two conditions. The same happens with Laser pointers as Patient E, or using microscopes and endoilluminators - instruments that can mimic the action of sun exposure.[55]

Idiopathic juxtafoveal macular telangiectasia can commonly produce foveal cystic changes on OCT images. MacTel can produce cavities between the outer layers of the neurosensory retina, and atrophy of the photoreceptor layer.[56] This thinning, disruption or loss of the photoreceptor layer is particularly seen on the temporal side of the fovea and extends to the whole fovea in advanced cases.[57] The differences are that MacTel shows cysts that are generally rounded and are often not restricted to the outer retina as in solar maculopathy.[58] Also, these patients show alterations of the outer plexiform layer that have been described as "wrinkling" toward the outer retina, as seen in Wu's Figure 2.[57] In order to rule out this diagnostic possibility, it is important to assess the presence of telangiectasias or of a right-angle vessel diving down into the outer retina in the temporal fovea.

Tamoxifen retinopathy is a disease that may also have the finding of a rectangular outer retinal cyst, with a nearly full-thickness foveal cyst, or with florid cystoid macular edema.[59] White crystalline deposits in the inner retina can be found and, in severe cases, white/gray spots at the level of RPE.[59] A history of long-term tamoxifen use confirms the diagnosis.

An outer retinal hole can be a rare presentation of early Stargardt disease.[60] Macular microholes and retinal outer layer holes were both also seen after eye traumas and whiplash injuries[61]. Considering the pathophysiology of the lesion, it can be thought that the secondary effects of trauma and sudden anteroposterior vitreofoveal retraction cause detachment in the retinal outer layers and atrophy in the photoreceptor outer layers[61].

In conclusion, solar maculopathy results in an outer retinal hole image in OCT. Our objective in this comparative study was to show a series of 12 eyes with cases of solar maculopathy and cases that constitute its differential diagnoses of outer macular holes. We did a literature review showing the main differential diagnoses of solar maculopathy cases that produce pretty similar findings in OCT images, such as welder's maculopathy, popper's maculopathy, tamoxifen retinopathy, juxtafoveal macular telangiectasia, foveolar vitreomacular traction, closed macular hole, ocular trauma, whiplash injuries, and rarely Stargardt disease.

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