Ocular manifestations of COVID-19

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Abstract: COVID-19 is a disease caused by a SARS-CoV-2 viral infection, a disease that was first detected in December 2019 in Wuhan, Hubei Province, China. COVID-19, formerly known as 2019 Novel Coronavirus (2019-nCoV) respiratory disease, was officially named COVID-19 by the World Health Organization (WHO) in February 2020. By 25 May 2021, there were 33,579,116 confirmed cases with 599,109 COVID-19 deaths worldwide. The purpose of this review article is to provide an update on what is currently known about COVID-19 ocular symptoms in adults, the elderly, and children in the literature. Finally, this article will review the eye protection precautions that should be implemented in our clinics. To assess the current literature, PubMed was searched from December 2019 to 25 May 2021. Randomized trials, observational studies, case series or case reports, letters of research, and letters to editors were selected for confirmed cases of COVID-19. According to current scientific literature since the outbreak in December 2019, 205 articles have been published. Conjunctivitis, conjunctival hyperemia, and chemosis have been reported in adults with COVID-19. There have been few studies on children and elderly patients, and further research in these age groups is needed. Finally, wearing eye protection when seeing patients on a daily basis during the pandemic is essential.

Keywords: adults, children, conjunctivitis, COVID-19, episcleritis, geriatric patients, ocular manifestations, SARS-CoV-2

COVID-19 is a disease caused by a SARS-CoV-2 virus infection first reported in Wuhan city, Chinese province of Hubei, in December 2019. COVID-19 presents with a wide range of severities and presentations for unclear reasons/mechanisms that may range from asymptomatic infection to severe disease and mortality. Systemic manifestation may precede ocular manifestation in around 0.28% of COVID-19-related patients with ocular symptoms. Furthermore, ocular manifestation was not linked to a severe type of COVID-19. One study reported that one-third of patients with COVID-19 had ocular abnormalities, which occurred more frequently in patients with more severe COVID-19.

COVID-19 ocular symptoms have been related to positive upper respiratory infection symptoms and decreased creatine phosphokinase levels. Despite negative nasal swab tests, the presence of SARS-CoV-2 viral RNA in aqueous indicates the persistence of virus beyond the blood-ocular barrier in asymptomatic people, raising the potential that the virus might survive in immunoprivileged spaces despite the lack of symptoms. The discovery of SARS-CoV-2 RNA in ocular samples emphasizes the importance of the eye as a potential route of disease transmission. SARS-CoV-2 RNA was found in the tears of 24% of individuals with laboratory-confirmed moderate to severe COVID-19. SARS-CoV-2 can be found in tears and conjunctival secretions and can be transmitted through the eyes.

Conjunctival swab is still the gold standard for reverse transcription polymerase chain reaction (RT-PCR) tear collection. Patients with moderate to severe COVID-19 have a substantially increased risk of viral transmission through tears. Severe pneumonia was seen in 6.9% of patients with ocular manifestations.

Conjunctivitis and keratoconjunctivitis are the most prevalent ocular symptoms in adults.
Conjunctival irritation was the most prevalent ophthalmological finding (50.8%), followed by diplopia (27.8%) and cotton wool patches (27.8%). Males have been diagnosed with viral conjunctivitis at a higher rate than females. The majority of the cases were acute COVID-19 cases, with some chronic COVID-19 cases observed in each case. Chronic COVID-19 cases have been termed ‘Long COVID’ or ‘COVID Long-Haulers’. In China, Long COVID-19 has been reported, with COVID-19 symptoms lasting 6 months after the hospital discharge.

A number of literature reviews in ocular manifestations have been published, and couple of the review articles concluded that further studies are required to determine the ocular manifestations in children and geriatric patients. This article will examine the gaps by including ocular manifestations in children and geriatric patients, in addition to currently reported ocular manifestations in adults. Finally, the eye protection precautions that should be applied in our clinics will be covered.

**Search strategy**
PubMed search was performed from December 2019 to 25 May 2021. The key words ‘COVID-19’, ‘Ocular Manifestations’ and ‘SARS-COV-2’ were used individually or in combination. Randomized trials, observational studies, case series or case reports, letters of research, and letters to editors for confirmed cases of COVID-19 were covered. According to current scientific literature since the outbreak in December 2019, 205 papers have been written (Figure 1).

**Adults’ ocular manifestations**

**Anterior segment**
According to several studies, ocular symptoms are uncommon and unlikely to represent the presenting clinical impression in COVID-19 infection. Furthermore, no epiphora, no secretion, or decreased vision has been reported. Other studies concluded no eye problem reports in Thailand that could be related to the severity of the disease and low sample size.
In a study covering 43 COVID-19 patients, only one developed conjunctivitis with a foreign body sensation (2.3%). Conversely, another study reported that 31.63% of COVID-19 confirmed cases demonstrated ocular symptoms, including conjunctiva hyperemia, chemosis, epiphora, and elevated secretions suggesting acute conjunctivitis. 

Ocular symptoms were found to be present in 2–32% of COVID-19-infected patients. The prevalence rate of acute conjunctivitis has been shown to range from 1.1% to 31.6%. Aggarwal et al. performed a meta-analysis with a total of 16 investigations, including 2347 verified COVID-19 cases. Ocular surface manifestations were found in 11.64% of COVID-19 patients, according to pooled data. The most common symptoms were ocular discomfort (31.2%), discharge (19.2%), redness (10.8%), and follicular conjunctivitis (7.7%). Severe pneumonia was seen in 6.9% of patients with ocular symptoms. In 3.5% of patients, viral RNA was found in their ocular sample. Ocular discomfort, redness, discharge, and follicular conjunctivitis were the most commonly reported ocular manifestations of COVID-19. In a small number of patients, viral RNA was found in their conjunctival/tear samples. There is a lot of publication bias and heterogeneity in the research that are available.9

Cavalleri et al. hypothesized that although ocular symptoms are common in COVID-19 patients, the presence of SARS-CoV-2 in ocular secretions is rare. Ocular symptoms in COVID-19 hospitalized patients can also be caused by respiratory support treatment. It is nevertheless suggested to avoid potential transmission via ocular secretions.27

Paradoxically, a large number of studies have reported ocular manifestations in COVID-19 patients. As shown in a meta-analysis study of the prevalence of COVID-19 ophthalmic manifestations, the prevalence of ocular manifestations in COVID-19-infected individuals ranged from 2% to 32%.15,25

Daruich et al. reported unilateral conjunctivitis as first sign of COVID-19 in 27-year-old male. The study by Bozkurt et al. found that COVID-19 patients showed pathological conjunctival abnormalities and that pathological ocular surface abnormalities can occur even before clinically relevant ocular manifestations. Because viral RNA was found in 7% of patients’ conjunctival secretions, the possibility of ocular transmission should be considered even in the absence of visual symptoms.

Conjunctivitis was the most common ocular condition among COVID-19 patients, accounting for 88.8% of all reported ocular disorders such as foreign body sensation, tearing, and dry eyes. According to the findings, one out of every 10 COVID-19 patients had at least one eye symptom. The sensitivity of COVID-19 detection among patients can be improved by paying attention to ocular symptoms, particularly conjunctivitis. Positive upper respiratory infection symptoms were linked with conjunctival congestion in these patients. Conversely, meta-analysis study showed that the non-severe COVID-19 patients appeared to be more likely to develop conjunctivitis.

Ocular symptoms might develop as a prodromal symptom in the presymptomatic phase (12.5%, 13/104 cases), implying viral transfer through the conjunctiva34 and due to viral shedding of tears, extreme care must be taken. Conjunctival injection was the most frequent ocular abnormality, followed by visual changes and ocular irritation. Méndez Mangana et al. reported the first 31 White female who had episcleritis in a COVID-19-positive patient. Sriwastava et al. reported the first case of myasthenia gravis in a 65-year-old female COVID-19-positive patient. HSV-1 keratitis had been reported in five cases. Other ocular manifestations include dry eye syndrome and episcleritis. Follicular conjunctivitis, conjunctival hyperemia, chemosis, epiphora, and increased secretions have been reported. Increased conjunctival secretions, ocular pain, ocular discharge and redness, photophobia, dry eye, tearing, and conjunctival congestion, as well as xerophthalmia and keratitis, are chronic COVID-19 ocular manifestations.

Acute follicular conjunctivitis with preauricular lymphadenopathy (LAP) and anterior uveitis were observed. Other study reported severe viral conjunctivitis with pseudomembranes on the tarsal conjunctiva with enlarged submaxillaries and preauricular lymph nodes.
Hemorrhagic conjunctivitis with pseudomembranes was reported in a 63-year-old male COVID-19 patient. In one case study, a 53-year-old white male COVID-19 patient was diagnosed with blepharitis, and he was advised to keep using the warm compresses and take 100 mg of doxycycline if the symptoms persisted or did not improve.

This study found the same rate of positive findings in groups with and without conjunctivitis, indicating that identifying SARS-CoV-2 in ocular secretions is not dependent on conjunctivitis.

The SARS-CoV-2 virus can produce ocular symptoms such as viral conjunctivitis. Infected individuals with conjunctivitis and fever may benefit from conjunctival sampling.

As a diabetic, hypertensive, and asthmatic 65-year-old COVID-19 patient, while on a ventilator, he developed severe follicular conjunctivitis of the right eye. The resolution of visual symptoms was observed over a period of 2 weeks with no problems. This case discussed and illustrated the sequence of events in individuals with COVID-19 infection who have long COVID-19 late ophthalmic symptoms.

During a lengthy COVID-19 lockdown, contact lens compliance was low, particularly in terms of handwashing and storage case cleanliness, emphasizing the necessity for patient–practitioner communication methods to reduce the risk of ocular transmission and viral tropism. Despite the fact that the influence of eye allergy on everyday activities and emotions was limited, the influence of eye allergy symptoms during the quarantine period was determined to be considerable.

Posterior segment

Optic neuritis, disk edema, vascular tortuosity, acute macular neuroretinopathy (AMN), vasculitis retinal occlusion (RVO), retinal artery occlusions, intraretinal hemorrhages, cotton wool spots, uveitis, and endogenous endophthalmitis have all been reported in COVID-19 patients.

A 22-year-old female with a history of absolute inferior scotoma in the right eye for 4 days and a fever and sore throat 10 days prior presented with parainfectious optic neuritis associated with acute COVID-19. Disk edema and vascular tortuosity were seen on a fundus examination.

A 33-year-old Malay man with concurrent cytomegalovirus (CMV) and COVID-19 infection was the first case of frosted branch angiitis (FBA) in a HIV-infected patient. He complained of impaired vision, ocular redness, dryness, and a foreign body sensation.

AMN as the presenting symptom of active COVID-19 infection is reported in this case report in a 70-year-old man. Sheth et al. reported a 52-year-old man who had RVO as a result of COVID-19 and experienced vision loss in his left eye 10 days after testing positive for SARS-CoV-2.

Retinal artery occlusions and hemorrhages, as well as cotton wool spots induced by complement-mediated thrombotic angiopathy, are all possible intraocular consequences. Miller-Fisher syndrome or infarct-related central blindness are two neuro-ophthalmological consequences that might develop in extremely uncommon situations.

A 59-year-old man with COVID-19 was reported to have bilateral intraretinal hemorrhage.

Three days after COVID-19 infection, a 66-year-old Asian man developed a vascular occlusion with panuveitis. A case of unilateral panuveitis and optic neuritis as initial presentation of acute COVID-19 has been reported in a 60-year-old woman. Less commonly, hemorrhagic conjunctivitis or retinal involvement might develop.

A COVID-19 patient with a systemic inflammatory syndrome had uveitis, erythema, and skin nodules, as well as cardiovascular (edema) signs. The anterior uveitis caused a rise in intraocular pressure that did not respond to therapeutic therapy, necessitating surgery to save the vision. This is the first case of COVID-19-related ocular hypertension to be reported.

In 7% of patients, patients with severe COVID-19 presented with abnormal magnetic resonance imaging (MRI) results of the globe. Cavernous sinus thrombosis associated with central retinal artery occlusion in a 37-year-old male COVID-19 patient. There is no light sensitivity in the left eye, as well as optic atrophy and macular pucker.
His previous medical history indicated severe pneumonia caused by a SARS-CoV-2 infection 3 months before. A healthy 33-year-old male probable COVID-19 patient presented with unilateral central retinal vein occlusion (CRVO), which might be a COVID-19 consequence. Four cases of suspected fungal endogenous endophthalmitis in individuals who recovered from COVID-19 have been reported which could be an example of long COVID-19 sequence of events.

Following COVID-19 infection, a 42-year-old Asian Indian female developed unilateral multifocal central serous retinopathy (CSCR). As a result, CSCR can develop during COVID-19 therapy due to steroid administration, and patients should be sent to an ophthalmologist as soon as possible.

Infection with COVID-19 causes recurrent manifestations in individuals. Infections such as endogenous endophthalmitis, candida retinitis, tubercular choroidal abscess, and bilateral prefoveal hemorrhages were among the vision-threatening symptoms. Paracentral acute middle maculopathy, central serous chorioretinopathy, and voriconazole-induced visual complaints were among the milder signs.

In conclusion, long-term COVID-19 patient follow-up is recommended to identify any posterior segment manifestations that may develop over time.

**Neuro-ophthalmology and neurological manifestations**

Diplopia, ocular pain, and myasthenia gravis are among the reported neuro-ophthalmology signs and symptoms.

Vertical diplopia has been present for 10 days in a 58-year-old male. Internuclear ophthalmoplegia was suspected based on extraocular movement testing findings. Fever, cough, and headache were followed by retro-ocular pain and reading impairment in a 51-year-old woman. She was diagnosed with Adie’s syndrome and multifocal chorioretinitis.

Lidder et al. reported the first case of a Kawasaki-like syndrome in a COVID-19-infected adult.

A 25-year-old man with no history of coagulopathy was reported to have experienced a COVID-19 cytokine storm, which resulted in Lock In Syndrome secondary to pontine strokes.

The neurological symptoms linked with acute COVID-19 include acute cerebellar ataxia and myoclonus (ACAM) with or without opsoclonus.

Myasthenia gravis has been diagnosed in a 21-year-old female COVID-19 patient. Table 1 summarizes the ocular manifestations.

The risk factors of ocular involvement include older age, high fever, elevated neutrophil/lymphocyte ratio, and elevated levels of acute phase reactants.

Finally, the presence of neuro-ophthalmologic symptoms may increase the viral infection likelihood, especially if fever and respiratory symptoms are present.

**Ocular COVID-19 and children**

The most recent recommendations state that all individuals, including children, are generally vulnerable to SARS-CoV-2. According to preliminary research, children in China are equally as likely as adults to be infected with COVID-19, although they are less likely to become symptomatic or develop severe symptoms. However, it is unknown how crucial children are in terms of viral transmission. When compared with adults, children experience greater gastrointestinal symptoms.

Children hospitalized with COVID-19 in Wuhan, China, had symptoms including fever, cough, and ocular signs such conjunctival discharge, eye rubbing, and conjunctival congestion, according to this cross-sectional study. Ocular symptoms were linked to patients’ systemic clinical symptoms, such as cough. Eventually, ocular problems recovered or improved.

A low incidence of COVID-19 infection was identified among babies in an uncontrolled case series of Brazilian newborns of women with COVID-19 infection, and none exhibited ocular abnormalities.

Fifteen SARS-CoV-2-positive infants had ocular symptoms. Cotton wool patches, vitreous hemorrhage, and microvascular damage appeared on fluorescein angiography as patchy choroidal filling, peripapillary hyperfluorescence, delayed retinal
Table 1. COVID-19 Ocular signs and symptoms.

| Ocular manifestations and COVID-19 | References |
|-----------------------------------|------------|
| Prevalence rate of ocular symptoms 2–32% | Aggarwal et al.9  
Al-Namaeh15  
Ulhaq and Soraya25 |
| Prevalence rate of conjunctivitis 1.1–15.9% | Wu et al.2  
Chen et al.26  
Lai et al.23  
Al-Namaeh15 |
| Adults | |
| Conjunctivitis | Colavita et al.72  
Daruich et al.28  
Drozd et al.24  
Karimi et al.22  
Lai et al.23  
Liu et al.33  
Salducci and La Torre46  
Wu et al.2  
Xia et al.6  
Zhang et al.73 |
| Hemorrhagic conjunctivitis | Rokohl et al.41 |
| Conjunctival hyperemia | Chen et al.24  
Drozd et al.24  
Lai et al.23  
Wu et al.2 |
| Chemosis | Drozd et al.24  
Lai et al.23  
Salducci and La Torre46  
Wu et al.2 |
| Epiphora | Drozd et al.24  
Lai et al.23  
Wu et al.2 |
| Follicular conjunctivitis | Benito-Pascual et al.61  
Wu et al.2 |
| Increased secretions | Drozd et al.24  
Lai et al.23  
Wu et al.2 |
| Fibrin pseudomembranes and inflammatory cells on tarsal conjunctiva | Salducci and La Torre46 |
| Foreign body sensations | Karimi et al.22 |
| Episcleritis | Méndez Mangana et al.38 |
| Vertical diplopia | Vasanthapuram and Badakere68 |

Table 1. (Continued) COVID-19 Ocular signs and symptoms.

| Ocular manifestations and COVID-19 | References |
|-----------------------------------|------------|
| Internuclear ophthalmoplegia | Vasanthapuram and Badakere68 |
| Kawasaki-like syndrome | Lidder et al.69 |
| Retro-ocular pain | Ortiz-Seller et al.66 |
| Reading impairment | Ortiz-Seller et al.66 |
| Adie’s syndrome | Ortiz-Seller et al.66 |
| Multifocal chorioretinitis | Ortiz-Seller et al.66 |
| Acute cerebellar ataxia and myoclonus | Foucard et al.71 |
| Myasthenia gravis | Huber et al.67 |
| Optic neuritis | Sharma et al.53 |
| Disk edema | Sharma et al.53 |
| Vascular tortuosity | Sharma et al.53 |
| Impaired vision | Lim et al.59 |
| Ocular redness | Lim et al.59 |
| FBS | Lim et al.59 |
| Dryness | Lim et al.59 |
| Acute macular neuroretinopathy | Preti et al.54 |
| Vacuities retinal vein occlusion | Sheth et al.55 |
| Retinal artery occlusions and hemorrhages | Rokohl et al.41 |
| Bilateral intraretinal hemorrhage | Monferrer-Adsuara et al.56 |
| Panuveitis | Benito-Pascual et al.61  
Sanjay et al.44 |
| Unilateral panuveitis | |
| Endogenous endophthalmitis | Goyal et al.65  
Goyal et al.65  
Shah et al.58 |
| Candida retinitis, tubercular choroidal abscess, bilateral prefoveal hemorrhages | |
| Paracentral acute middle maculopathy, voriconazole-induced visual complaints | Goyal et al.65  
Sanjay et al.44 |
| Central serous chorioretinopathy | |

(Continued)
In children with multisystem inflammatory syndrome (MIS-C) caused by COVID-19, bilateral non-granulomatous acute anterior and corneal punctate epitheliopathy was reported. Inflammatory ocular symptoms in MIS-C can be found as a result of COVID-19.85 COVID-19 was evaluated in children with a mean age of 84 months; of the 27 patients, 4 (15%) were asymptomatic, 15 (56%) had respiratory symptoms, and 8 (30%) had gastrointestinal symptoms. In four patients, ocular symptoms consistent with moderate viral conjunctivitis were found (15%). COVID-19 ocular symptoms appear to have a milder clinical course in young patients than in adults in their study population. SARS-CoV-2 transmission through tears may be possible, despite the low incidence and rapid resolution of viral presence in the conjunctiva, even in patients who do not appear to have ocular involvement.77 Late-onset rash and transient loss of taste were reported by a 15-year-old boy. Furthermore, infection with the SARS-CoV-2 virus in children and adolescents can be asymptomatic, but it can also cause fever, dry cough, tiredness, and gastrointestinal symptoms.86 Conversely, some studies did not report any ocular manifestations of COVID-19 in children.73,87 The most common symptoms and signs in 551 COVID-19 children aged 1–17.5 years old were 53% fever, 39% cough, and 14% sore throat/pharyngeal erythema; however, 18% were asymptomatic.73 74% of patients were administered antivirals, six patients required invasive mechanical ventilation, and one of them died.

Future research
Only a few studies in the geriatric population and children have been published. To assess the ocular symptoms in children and geriatric patients, more retrospective studies are needed.

Conclusion
The probability of viral transmission through tears is much higher in patients with moderate to
severe COVID-19. For RT-PCR tear collection, the conjunctival swab remains the gold standard. In addition, wearing eye protection when seeing patients on a daily basis during the pandemic is essential. Follicular conjunctivitis, conjunctival hyperemia, chemosis, and epiphora are the most prevalent ocular symptoms in adults. Optic neuritis, disk edema, retinal artery occlusions, intraretinal hemorrhages, cotton wool spots, and uveitis have all been reported in COVID-19 patients as posterior segment ocular manifestations. Finally, neuro-ophthalmology signs and symptoms include ocular pain, diplopia, and myasthenia gravis. Long-term follow-up is advised to determine the long-term COVID-19 ocular manifestations that may develop over time. Finally, more retrospective studies in the geriatric and pediatric populations are required.

**Author contributions**

**Mashael Al-Namaeh:** Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing.

**Conflict of interest statement**
The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

**Funding**
The author received no financial support for the research, authorship, and/or publication of this article.

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**References**

1. La Distia Nora R, Putera I, Khalidia DF, et al. Are eyes the windows to COVID-19? Systematic review and meta-analysis. BMJ Open Ophthalmol 2020; 5: e000563. DOI: 10.1136/bmjophth-2020-000563.

2. Wu P, Duan F, Luo C, et al. Characteristics of ocular findings of patients with coronavirus disease 2019 (COVID-19) in Hubei Province, China. JAMA Ophthalmol 2020; 138: 575–578. DOI: 10.1001/jamaophthalmol.2020.1291.

3. Yahalomi T, Pikkel J, Arnon R, et al. Central retinal vein occlusion in a young healthy COVID-19 patient: a case report. Am J Ophthalmol Case Rep 2020; 20: 100992. DOI: 10.1016/j.ajoc.2020.100992.

4. Koo EH, Eghrari AO, Dzhaber D, et al. Presence of SARS-CoV-2 viral RNA in aqueous humor of asymptomatic individuals. Am J Ophthalmol 2021; 230: 151–155. DOI: 10.1016/j.ajo.2021.05.008.

5. Güemes-Villahoz N, Burgos-Blasco B, Arribivilela A, et al. Detecting SARS-CoV-2 RNA in conjunctival secretions: is it a valuable diagnostic method of COVID-19? J Med Virol 2021; 93: 383–388. DOI: 10.1002/jmv.26219.

6. Xia J, Tong J, Liu M, et al. Evaluation of coronavirus in tears and conjunctival secretions of patients with SARS-CoV-2 infection. J Med Virol 2020; 92: 589–594. DOI: 10.1002/jmv.25725.

7. Kumar K, Prakash AA, Gangasagara SB, et al. Presence of viral RNA of SARS-CoV-2 in conjunctival swab specimens of COVID-19 patients. Indian J Ophthalmol 2020; 68: 1015–1017. DOI: 10.4103/ijo.IJO_1287_20.

8. Arora R, Goel R, Kumar S, et al. Evaluation of SARS-CoV-2 in tears of patients with moderate to severe COVID-19. Ophthalmology 2021; 128: 494–503. DOI: 10.1016/j.ophtha.2020.08.029.

9. Aggarwal K, Agarwal A, Jaiswal N, et al. Ocular surface manifestations of coronavirus disease 2019 (COVID-19): a systematic review and meta-analysis. PLoS ONE 2020; 15: e0241661. DOI: 10.1371/journal.pone.0241661.

10. Maychuk DY, Atlas SN and Loshkareva AO. [Ocular manifestations of coronavirus infection COVID-19 (clinical observation)]. Vestn Oftalmol 2020; 136: 118–123. DOI: 10.17116/ofalma2020136041118.

11. Chen L, Liu M, Zhang Z, et al. Ocular manifestations of a hospitalised patient with confirmed 2019 novel coronavirus disease. Br J Ophthalmol. Epub ahead of print March 2021. DOI: 10.1136/bjophthalmol-2020-316304.

12. Hutama SA, Alkaff FF, Intan RE, et al. Recurrent keratoconjunctivitis as the sole manifestation of COVID-19 infection: a case report. Eur J Ophthalmol. Epub ahead of print March 2021. DOI: 10.1177/11206721211006583.

13. Al-Namaeh M. COVID-19 in the light of current clinical eye research. Eur J Ophthalmol 2021; 31: 904–908. DOI: 10.1177/1120672121998911.

14. Khan SI, Versha F, Bai P, et al. Frequency of ophthalmological findings in hospitalized COVID-19 patients. Cureus 2021; 13: e14942. DOI: 10.7759/cureus.14942.
27. Cavalleri M, Brambati M, Starace V, et al. Ocular features and associated systemic findings in SARS-CoV-2 infection. Ocul Immunol Inflamm 2020; 28: 916–921. DOI: 10.1080/09273948.2020.1781198.

28. Daruich A, Martin D and Bremond-Gignac D. Ocular manifestation as first sign of coronavirus disease 2019 (COVID-19): interest of telemedicine during the pandemic context. J Fr Ophthalmol 2020; 43: 389–391. DOI: 10.1016/j.jfo.2020.04.002.

29. Ozturker ZK. Conjunctivitis as sole symptom of COVID-19: a case report and review of literature. Eur J Ophthalmol 2021; 31: NP161–NP166. DOI: 10.1177/1120672120946287.

30. Bozkurt E, Özteş S, Muhaflız E, et al. Ocular surface and conjunctival cytology findings in patients with confirmed COVID-19. Eye Contact Lens 2021; 47: 168–173. DOI: 10.1097/icl.0000000000000752.

31. Gao H and Shi WY. [A special on epidemic prevention and control: ophthalmologic research and prevention of 2019 novel coronavirus based on ocular manifestations of viral diseases]. Zhonghua Yan Ke Za Zhi 2020; 56: 414–417. DOI: 10.3760/cma.j.cn112142-20200216-00068.

32. Nasiri N, Sharifi H, Bazrafshan A, et al. Ocular manifestations of COVID-19: a systematic review and meta-analysis. J Ophthalmic Vis Res 2021; 16: 103–112. DOI: 10.18502/jovr.v16i1.8256.

33. Liu M, Dai C, Lv X, et al. Letter to the editor: are severe COVID-19 patients more susceptible to conjunctivitis? J Med Virol 2020; 92: 2394–2395. DOI: 10.1002/jmv.26084.

34. Inomata T, Kitazawa K, Kuno T, et al. Clinical and prodromal ocular symptoms in coronavirus disease: a systematic review and meta-analysis. Invest Ophthalmol Vis Sci 2020; 61: 29. DOI: 10.1167/iovs.210.10.29.

35. Devilliers MJ, Ben Hadi Salah W, Barreau E, et al. [Ocular manifestations of viral diseases]. Rev Med Interne 2021; 42: 401–410. DOI: 10.1016/j.revmed.2020.08.022.

36. Kaya H, Çalışkan A, Okul M, et al. Detection of SARS-CoV-2 in the tears and conjunctival secretions of coronavirus disease 2019 patients. Infect Dev Ctries 2020; 14: 977–981. DOI: 10.3855/jidc.13224.

37. Feng Y, Park J, Zhou Y, et al. Ocular manifestations of hospitalized COVID-19 patients in a tertiary care academic medical center in the United States: a cross-sectional study. Clin Ophthalmol 2021; 15: 1551–1556. DOI: 10.2147/OPTH.S301040.

38. Méndez Mangana C, Barraquer Kargacín A and Barraquer RI. Episcleritis as an ocular...
manifestation in a patient with COVID-19. *Acta Ophthalmol* 2020; 98: e1056–e1057. DOI: 10.1111/aos.14484.

39. Srivastava S, Tandon M, Kataria S, et al. New onset of ocular myasthenia gravis in a patient with COVID-19: a novel case report and literature review. *J Neurrol* 2021; 268: 2690–2696. DOI: 10.1007/s00415-020-10263-1.

40. Majtanova N, Kriskova P, Keri P, et al. Herpes simplex keratitis in patients with SARS-CoV-2 infection: a series of five cases. *Medicina (Kaunas)* 2021; 57: 412. DOI: 10.3390/medicina57050412.

41. Rokohl AC, Grajewski RS, Matos PAW, et al. Ocular involvement in COVID-19: conjunctivitis and more. *Klin Monbl Augenheilkd* 2021; 238: 555–560. DOI: 10.1055/a-1344-8138.

42. Dockery DM, Rowe SG, Murphy MA, et al. The ocular manifestations and transmission of COVID-19: recommendations for prevention. *J Emerg Med* 2020; 59: 137–140. DOI: 10.1016/j.jemermed.2020.04.060.

43. Ho D, Low R, Tong L, et al. COVID-19 and the ocular surface: a review of transmission and manifestations. *Ocul Immunol Inflamm* 2020; 28: 726–734. DOI: 10.1080/09273948.2020.1772313.

44. Sindhuja K, Lomi N, Asif MI, et al. Clinical profile and prevalence of conjunctivitis in mild COVID-19 patients in a tertiary care COVID-19 hospital: a retrospective cross-sectional study. *Indian J Ophthalmol* 2020; 68: 1546–1550. DOI: 10.4103/ijo.IJO_1319_20.

45. Boz AAE, Atum M, Çakır B, et al. Outcomes of the ophthalmic examinations in patients infected by SARS-CoV-2. *Ocul Immunol Inflamm* 2021; 29: 638–641. DOI: 10.1080/09273948.2020.1844904.

46. Salducci M and La Torre G. COVID-19 emergency in the cruise’s ship: a case report of conjunctivitis. *Clin Ter* 2020; 171: e189–e191. DOI: 10.7417/CT.2020.2212.

47. Navel V, Chiambaretta F and Dutheil F. Haemorrhagic conjunctivitis with pseudomembranous related to SARS-CoV-2. *Am J Ophthalmal Case Rep* 2020; 19: 100735. DOI: 10.1016/j.ajoc.2020.100735.

48. Ahuja AS, Farford BA, Forouhi M, et al. The ocular manifestations of COVID-19 through conjunctivitis. *Cureus* 2020; 12: e12218. DOI: 10.7759/cureus.12218.

49. Lim LW, Tan GS, Yong V, et al. Acute onset of bilateral follicular conjunctivitis in two patients with confirmed SARS-CoV-2 infections. *Ocul Immunol Inflamm* 2020; 28: 1280–1284. DOI: 10.1080/09273948.2020.1821901.

50. Nayak B, Poddar C, Panigrahi MK, et al. Late manifestation of follicular conjunctivitis in ventilated patient following COVID-19 positive severe pneumonia. *Indian J Ophthalmol* 2020; 68: 1675–1677. DOI: 10.4103/ijo.IJO_1682_20.

51. Cardona G, Alonso S and Busquets A. Patient – practitioner communication and contact lens compliance during a prolonged COVID-19 lockdown. *Cont Lens Anterior Eye* 2021; 44: 101433. DOI: 10.1016/j.clae.2021.02.019.

52. Al-Dairi W, Al Saeed AA and Al Sowayigh OM. Impact of quarantine during COVID-19 pandemic on the quality of life of patients with allergic conjunctivitis. *Cureus* 2020; 12: e12240. DOI: 10.7759/cureus.12240.

53. Sharma A, Kudchadkar US, Shirodkar R, et al. Unilateral inferior altitudinal visual field defect related to COVID-19. *Indian J Ophthalmol* 2021; 69: 989–991. DOI: 10.4103/ijo.IJO_3666_20.

54. Preti RC, Zacharias LC, Cunha LP, et al. Acute macular neuroretinopathy as the presenting manifestation of COVID-19 infection. *Retin Cases Brief Rep* 2022; 16: 12–15. DOI: 10.1097/ict.000000000001050.

55. Sheth JU, Narayan R, Goyal J, et al. Retinal vein occlusion in COVID-19: a novel entity. *Indian J Ophthalmol* 2020; 68: 2291–2293. DOI: 10.4103/ijo.IJO_2380_20.

56. Monferrer-Adsuara C, Castro-Navarro V, González-Girón N, et al. A case of bilateral unusual retinal hemorrhages in a COVID-19 patient. *Eur J Ophthalmol*. Epub ahead of print December 2020. DOI: 10.1177/1120672120984381.

57. Alonso RS, Alonso FM, Fernandes BF, et al. COVID-19-related ocular hypertension secondary to anterior uveitis as part of a multisystemic inflammatory syndrome. *J Glaucoma* 2021; 30: e256–e258. DOI: 10.1097/ijg.0000000000001835.

58. Shah KK, Venkatramani D and Majumder PD. A case series of presumed fungal endogenous endophthalmitis in post COVID-19 patients. *Indian J Ophthalmol* 2021; 69: 1322–1325. DOI: 10.4103/ijo.IJO_3755_20.

59. Lim TH, Wai YZ and Chong JC. Unilateral frosted branch angiitis in an human immunodeficiency virus-infected patient with concurrent COVID-19 infection: a case report. *J Med Case Rep* 2021; 15: 267. DOI: 10.1186/s13256-021-02826-1.
60. Sanjay S, Srinivasan P, Jayadev C, et al. Post COVID-19 ophthalmic manifestations in an Asian Indian male. Ocul Immunol Inflamm 2021; 29: 656–661. DOI: 10.1080/09273948.2020.1870147.

61. Benito-Pascual B, Gégundez JA, Díaz-Valle D, et al. Panuveitis and optic neuritis as a possible initial presentation of the novel coronavirus disease 2019 (COVID-19). Ocul Immunol Inflamm 2020; 28: 922–925. DOI: 10.1080/09273948.2020.1792512.

62. Lecler A, Cotton F, Leroy F, et al. Ocular MRI findings in patients with severe COVID-19: a retrospective multicenter observational study. Radiology 2021; 299: E226–E229. DOI: 10.1148/ radiol.2021204394.

63. Raj A, Kaur N and Kaur N. Cavernous sinus thrombosis with central retinal artery occlusion in COVID-19: a case report and review of literature. Indian J Ophthalmol 2021; 69: 1327–1329. DOI: 10.4103/ijo.IJO_3770_20.

64. Sanjay S, Gowda PB, Rao B, et al. ‘Old wine in a new bottle’ – post COVID-19 infection, central serous chorioretinopathy and the steroids. J Ophthalmic Inflamm Infect 2021; 11: 14. DOI: 10.1186/s12348-021-00244-4.

65. Goyal M, Murthy SI and Annum S. Retinal manifestations in patients following COVID-19 infection: a consecutive case series. Indian J Ophthalmol 2021; 69: 1275–1282. DOI: 10.4103/ijo.IJO_403_21.

66. Ortiz-Seller A, Martínez Costa L, Hernández-Pons A, et al. Ophthalmic and neuro-ophthalmic manifestations of coronavirus disease 2019 (COVID-19). Ocul Immunol Inflamm 2020; 28: 1285–1289. DOI: 10.1080/09273948.2020.1817497.

67. Huber M, Rogozinski S, Puppe W, et al. Postinfectious onset of myasthenia gravis in a COVID-19 patient. Front Neurol 2020; 11: 576153. DOI: 10.3389/fneur.2020.576153.

68. Vasanthapuram VH and Badakere A. Intraocular ophthalmoplegia as a presenting feature in a COVID-19-positive patient. BMJ Case Rep 2021; 14: e241873. DOI: 10.1136/ber-2021-241873.

69. Lindner AK, Pandit SA and Lazzaro DR. An adult with COVID-19 Kawasaki-like syndrome and ocular manifestations. Am J Ophthalmol Case Rep 2020; 20: 100875. DOI: 10.1016/j.ajo.2020.100875.

70. Avula A, Gill A, Nassar R, et al. Locked-in with COVID-19. J Clin Neurosci 2020; 79: 80–83. DOI: 10.1016/j.jocn.2020.07.014.

71. Foucard C, San-Galli A, Tarrano C, et al. Acute cerebellar ataxia and myoclonus with or without opsoclonus: a parainfectious syndrome associated with COVID-19. Eur J Neurol 2021; 28: 3533–3536. DOI: 10.1111/ene.14726.

72. Colavita F, Lapa D, Carletti F, et al. SARS-CoV-2 isolation from ocular secretions of a patient with COVID-19 in Italy with prolonged viral RNA detection. Ann Intern Med 2020; 173: 242–243.

73. Zhang L, Peres TG, Silva MVF, et al. What we know so far about coronavirus disease 2019 in children: a meta-analysis of 551 laboratory-confirmed cases. Pediatr Pulmonol 2020; 55: 2115–2127. DOI: 10.1002/ppul.24869.

74. Ma N, Li P, Wang X, et al. Ocular manifestations and clinical characteristics of children with laboratory-confirmed COVID-19 in Wuhan, China. JAMA Ophthalmol 2020; 138: 1079–1086. DOI: 10.1001/jamaophthalmol.2020.3690.

75. Pérez-Chimal LG, Cuevas GG, Di-Luciano A, et al. Ophthalmic manifestations associated with SARS-CoV-2 in newborn infants: a preliminary report. JAAPOS 2021; 25: 102–104. DOI: 10.1016/j.jaapos.2020.11.007.

76. Walinjak JA, Makhija SC, Sharma HR, et al. Central retinal vein occlusion with COVID-19 infection as the presumptive etiology. Indian J Ophthalmol 2020; 68: 2572–2574. DOI: 10.4103/ijo.IJO_2575_20.

77. Valente P, Iarossi G, Federici M, et al. Ocular manifestations and viral shedding in tears of pediatric patients with coronavirus disease 2019: a preliminary report. JAAPOS 2020; 24: 212–215. DOI: 10.1016/j.jaapos.2020.05.002.

78. Pirraglia MP, Coccarelli G, Cerini A, et al. Retinal involvement and ocular findings in COVID-19 pneumonia patients. Sci Rep 2020; 10: 17419.

79. Abrishami M, Tohidinezhad F, Daneshvar R, et al. Ocular manifestations of hospitalized patients with COVID-19 in Northeast of Iran. Ocul Immunol Inflamm 2020; 28: 2115–2127. DOI: 10.1080/09273948.2020.1817497.

80. Meduri A, Oliverio GW, Mancuso G, et al. Ocular surface manifestation of COVID-19 and tear film analysis. Sci Rep 2020; 10: 20178.

81. Bostanci Ceran B and Ozates S. Ocular manifestations of coronavirus disease 2019. Graefes Arch Clin Exp Ophthalmol 2020; 258: 1959–1963. DOI: 10.1007/s00417-020-04777-7.

82. Leyland LA, Bremner FD, Mahmood R, et al. Visual tests predict dementia risk in Parkinson disease. Neurol Clin Pract 2020; 10: 29–39. DOI: 10.1212/CPS.000000000000719.
83. Zimmermann P and Curtis N. Coronavirus infections in children including COVID-19: an overview of the epidemiology, clinical features, diagnosis, treatment and prevention options in children. *Pediatr Infect Dis J* 2020; 39: 355–368. DOI: 10.1097/INF.0000000000002660.

84. Kiappe OP, Santos da, Cruz NF, Rosa PAC, et al. Ocular assessments of a series of newborns gestationally exposed to maternal COVID-19 infection. *JAMA Ophthalmol* 2021; 139: 777–780. DOI: 10.1001/jamaophthalmol.2021.1088.

85. Öztürk C, Yüce Sezen A, Savaş Şen Z, et al. Bilateral acute anterior uveitis and corneal punctate epitheliopathy in children diagnosed with multisystem inflammatory syndrome secondary to COVID-19. *Ocul Immunol Inflamm* 2021; 29: 700–704. DOI: 10.1080/09273948.2021.1909070.

86. Maniaci A, Iannella G, Vicini C, et al. A case of COVID-19 with late-onset rash and transient loss of taste and smell in a 15-year-old boy. *Am J Case Rep* 2020; 21: e925813. DOI: 10.12659/ajcr.925813.

87. She J, Liu L and Liu W. COVID-19 epidemic: disease characteristics in children. *J Med Virol* 2020; 92: 747–754. DOI: 10.1002/jmv.25807.