



# Coronavirus Disease 2019– Related Health Disparities in Ophthalmology with a Retrospective Analysis at a Large Academic Public Hospital



Y. Grace Chung, BS<sup>a</sup>, Christie M. Person, OD<sup>b</sup>,  
Jacquelyn O'Banion, MD, MSc<sup>c,d</sup>, Susan A. Primo, OD, MPH<sup>c,d,\*</sup>

<sup>a</sup>Emory University School of Medicine, 201 Dowman Drive, Atlanta, GA 30322, USA; <sup>b</sup>Grady Health System, Eye Clinic, 80 Jesse Hill Jr Drive, SE, Atlanta, GA 30303, USA; <sup>c</sup>Emory Eye Center, 1365B Clifton Road, NE Suite B1100, Atlanta, GA 30322, USA; <sup>d</sup>Department of Ophthalmology, Emory University School of Medicine

## Keywords

• COVID-19 • Ophthalmic findings • Public U.S. hospital • Health care disparities

## Key points

- Coronavirus disease 2019 has disproportionately affected racial and ethnic minorities in the United States, in particular Black, Latinx, and Native American populations.
- Significant health care disparities within ophthalmology owing to coronavirus disease 2019 also have been discovered.
- Ophthalmic manifestations of coronavirus disease 2019 are prevalent; common findings include dryness, redness, and increased discharge, and may be the initial symptoms of a coronavirus disease 2019 infection.
- There is a lack of data of ophthalmic findings from coronavirus disease 2019 specifically in underrepresented minorities, and public hospitals have a unique opportunity to research presentation of disease in these populations.
- Ocular findings in patients with coronavirus disease 2019 potentially will support health care providers in managing these cases.

\*Corresponding author. Emory Eye Center, 1365B Clifton Road, NE Suite B1100, Atlanta, GA 30322. *E-mail address:* sprimo@emory.edu

## INTRODUCTION

Initially detected and identified in Wuhan, China in late 2019, severe acute respiratory syndrome coronavirus 2 has rapidly progressed to the coronavirus disease 2019 (COVID-19) pandemic, officially declared on March 22, 2020 [1]. The severity of this disease has had devastating fatality rates globally [2] and has had an extensive range of presentations, not solely limited to the respiratory system [3]. Asymptomatic transmission of the virus was discovered early on, with ophthalmic care being limited in most practices across the world to primarily emergency services, particularly owing to the close physical proximity needed to properly conduct a diagnostic eye examination [4–6]. Ultimately, ocular manifestations were found to be prevalent among patients with COVID-19, most commonly dry eye or foreign body sensation, redness, tearing, itching, eye pain, and discharge [7]. These manifestations may be the initial symptoms of a COVID-19 infection; a greater understanding of COVID-19–related ocular signs may lead to earlier diagnosis and improved ophthalmic care [8].

COVID-19 has disproportionately affected racial and ethnic minority groups, specifically resulting in much higher rates of death from disease in Black, Latinx, and Native American communities [9]. Alongside the impact of COVID-19 on patients, the pandemic has drastically impacted health care delivery, particularly at the beginning of the pandemic, with an increase in the use of telemedicine and a large decrease in outpatient visits [10–12]. Although access to telemedicine had been shown to alleviate the disruptions in outpatient care [13,14], racial and socioeconomic disparities have been prevalent in patient engagement to telemedicine and in outpatient visits, disproportionately affecting Black, Latinx, and Native American ethnic groups and patients with fewer socioeconomic resources [15–19]. These disparities in access to telemedicine have also been studied specifically within ophthalmology [20]. In 1 study, Black patients were less likely to be seen in a retina clinic, despite no increase in telemedicine visits [21].

Even with the disproportionate impact on Black, Latinx, and Native American populations of COVID-19, the ophthalmic manifestations of this virus have not specifically been studied in these communities. Large public hospitals may serve as a unique opportunity to study COVID-19 ocular disease presentation in underrepresented minorities. To further elucidate the effects of COVID-19 on patient demographics and health disparities in ophthalmology, the authors performed an analysis of patient demographics and ocular findings among COVID-19 positive patients at a public academic tertiary health care center primarily serving underserved populations during the height of the first wave of the COVID-19 pandemic. A retrospective chart review of ambulatory ophthalmology outpatient visits, as well as inpatient consultations, during this initial surge of the virus was undertaken because there is a dearth of research of COVID-19–related ocular manifestations in underserved populations to better define its impact on currently present health disparities.

## **SIGNIFICANCE**

### COVID-19 disproportionate impact

COVID-19 has disproportionately impacted all minority racial and ethnic groups, including Black, Latinx, Asian, Native Hawaiian and Pacific Islanders, and American Indian and Alaska Native communities in both infection and mortality rates [22]. A systematic review found that Black and Latinx individuals also have disproportionately higher rates of hospitalization with moderate to high-strength evidence [23]. Most studies attribute poverty, low household income, housing insecurity, education level, and language barriers as risk factors for higher rates of infection, death, and hospitalization [23]. With multivariable analyses, the excess burden of COVID-19 infections is not fully explained by other variables, such as underlying comorbidities and socioeconomic factors [24]. Other studies also have identified higher rates of infection for Black and Latinx patients compared with White patients; however, once hospitalized, lower rates of critical illness and death, indicating the presence of previously known existing structural barriers in accessing care [25]. These disparities are compounded by racial and ethnic minority communities also experiencing lower vaccination rates; Black and Latinx vaccination rates were shown to be approximately 2.1 and 2.9 times lower, respectively, compared with non-Hispanic White population across the United States [26]. Lower vaccination rates are not fully attributable to vaccine hesitancy from mistrust resulting from systemic injustices, but rather underlying structural inequities and vaccine accessibility are major contributing factors [27]. Moreover, Black and Latinx populations are underrepresented in vaccine clinical trials and for COVID-19 treatment trials [28,29].

### COVID-19-related health care disparities in ophthalmology

Barriers to care exist for underserved patients and racial and ethnic minorities, particularly around the constructs of social determinants of health. Factors like cost, transportation, language, and health literacy, to name a few, remain as barriers in normal times, only to be magnified during times of medical crisis, like the COVID-19 pandemic. Eye care delivery is no exception, and, although alternative methods of evaluation have been attempted, such as telemedicine, missed clinic visits have dramatically increased among elderly and non-White patients [12], particularly in the first wave of the pandemic. Timely interventions for ophthalmic diseases like diabetic retinopathy and macular degeneration can stave off preventable vision loss, whereas glaucoma requires continuous monitoring in most cases. Generally speaking, deviation and delay in eye care can be both tragic and insurmountable when urgent ocular diseases either are not identified or when chronic ones miss periodic and appropriate follow-up.

Many medical disciplines have been able to pivot to telemedicine through incorporating virtual, video, and/or phone visits into their daily practices [30]. Innovative hybrid care has allowed for medication check-ins, follow-ups, and even diagnostic capabilities, in many instances leading to improved

compliance and continuity of care. Those specialties that are technology driven have been able to order tests, scans, images, and so on, allowing patients to undergo a procedure and then have a consultation with their provider regarding the results and management. In many cases, patients can defer in-person care, particularly if anxious about physically visiting health care facilities.

For ophthalmologic care, although it is technology driven in many instances, a face-to-face in-person visit is needed to accurately measure and monitor things like vision and eye pressure, although innovative solutions have been proposed and implemented, even circumventing the need for the traditional delivery model [31]. However, treatment for retinal diseases such as diabetic retinopathy and age-related macular degeneration rely on periodic intravitreal injections with the significant potential for vision loss if delayed [32]. Retina and glaucoma also require the use of specialized equipment that limit telemedicine use. A study found that, during COVID-19, cataracts saw a more than 60% decrease in visits, with only approximately 1% telemedicine use; glaucoma saw a more than 50% decrease in visits with only approximately 3% telemedicine use [30]. Telemedicine remains a less prevalent form of delivering eye care in most facilities, unlike other areas of medicine, and has significant limitations. Sudden painful or painless loss of vision, especially in monocular patients, new cases of retinal tumors or cancers, retinopathy of prematurity, recent surgical patients, and more all require physical examination of the eye [33]. Ophthalmic disparities will prevail when barriers to care from social determinants of health exist.

### COVID-19–related ophthalmic manifestations

The ocular findings associated with COVID-19 are varied and have affected both the anterior and posterior structures of the eye. A meta-analysis of 38 studies found that the most common diagnoses from December 2019 through August 2020 were foreign body sensation, redness, tearing, itching, eye pain, and discharge [7]. Another meta-analysis of 20 studies determined that one of the earliest ocular symptoms associated with COVID-19 is viral conjunctivitis and is associated with more severe disease, requiring hospitalization [34]. Microvascular alterations were also noted in the SERPICO-19 study, which cited findings of retinal hemorrhages, cotton wool spots, dilated veins, and tortuous vessels in patients with COVID-19 [35]. Cranial nerve abnormalities also have been noted in a few cases, specifically with oculomotor, trochlear, and abducens nerve palsies in patients with COVID-19. Other neuro-ophthalmic findings include Guillain Barre syndrome and Miller Fisher syndrome, with cases that improved with intravenous immunoglobulin treatment. Optic neuritis and intracranial hypertension have been observed in patients with COVID-19 as well, with angiotensin-converting enzyme 2 receptor cells postulated as the method of entry; they are present in the aqueous humor, retina, retinal pigment epithelium, choroid, and conjunctival epithelium [36,37].

The authors performed a retrospective, cross-sectional, observational study at a large public hospital serving primarily underrepresented minorities seen during the first surge of the COVID-19. A total of 7022 ambulatory patients

seen in the ophthalmology clinic were identified between March 1 and November 30, 2020. Of these patients, 192 ambulatory patients had COVID-19-positive tests within this time frame, with a prevalence rate of 2.73%. An additional 10 inpatient ophthalmology consults also were identified. Of the ambulatory patients included in this study, 116 patients had a positive COVID-19 test before or within 1 week of their ambulatory visit. The average time to visit—the length of time from a positive COVID-19 test to the patient's next ambulatory visit—was  $85.0 \pm 39.6$  days.

The demographics of ambulatory and inpatient consultation patients were examined (Table 1). The mean age of ambulatory and inpatients was  $56.4 \pm 12.5$  and  $51.0 \pm 17.2$  years, respectively. The majority of patients in both settings were female (65.6% for ambulatory patients, 70.0% for inpatient consultations). Black or African American and Latinx patients constituted the predominant ethnicity in both settings (78.6% Black or African American and 16.1% Hispanic ambulatory patients, 60% Black or African American and 20% Latinx inpatients), which is consistent with the overall patient population within the large, urban, academic hospital from which this subset was taken.

All 10 inpatients had at least 2 comorbidities, with hypertension (70%) and tobacco use (30%) being the most common. No inpatients had ocular symptoms directly related to COVID-19. Comorbidities were analyzed for all 192 ambulatory patients. The average number of comorbidities for all ambulatory patients was  $3.4 \pm 2.1$ , and 157 of 192 (81.8%) patients had at least 2 comorbidities. The most common comorbidities were tobacco use (70.8%), hypertension (70.3%), diabetes mellitus (47.4%), dyslipidemia (40.6%), and overweight and obesity (34.9%).

The most common *International Classification of Diseases*, 10th edition, diagnosis for ambulatory and inpatients were examined (Tables 2 and 3) with age-related nuclear cataracts, presbyopia, and type 2 diabetes mellitus with ophthalmic complications being the most common for ambulatory patients and viral pneumonia, severe sepsis, and mixed disorder of acid–base balance being the most common for inpatients. Two ambulatory patients had ocular manifestations of COVID-19, including dry eye and conjunctivitis.

Within the ambulatory patient population who tested positive from March 1, 2020, to November 30, 2020, 63.8% were diagnosed with age-related nuclear cataracts, 63.8% with presbyopia, and 52.6% with diabetic-related ophthalmic complications. Diabetic ophthalmic complications included retinal hemorrhage, vitreous hemorrhage, retinal vein occlusion, and nonproliferative and proliferative diabetic retinopathy. These findings were the top 4 diagnoses prevalent within our patient population during this 8-month time period and are consistent with ocular conditions that presented in our clinic before the pandemic. Retinal vaso-occlusion, often in the form of a central retinal vein occlusion, is an ophthalmic COVID-19 finding, which may occur as a result of immune-mediated pathogenesis after infection [38,39]. COVID-19 should be suspected in any patient who presents with retinal vaso-occlusion, but without

**Table 1**  
Ambulatory and inpatient patient demographics

	Ambulatory	Inpatient
Total number	116	10
Age, years		
Mean	55.1 ± 13.2	51.0 ± 17.2
Median (range)	56.5 (26–87)	50.0 (20–72)
Sex, proportion (%)		
Female	76/116 (65.5)	7/10 (70.0)
Male	40/116 (34.5)	3/10 (30.0)
Ethnicity, no. (%)		
Asian	2/116 (1.7)	0/10 (0.0)
Black	88/116 (75.9)	6/10 (60.0)
Hispanic	21/116 (18.1)	2/10 (20.0)
White	4/116 (3.4)	1/10 (10.0)
Other	1/116 (0.9)	1/10 (10.0)

known vascular disease risk factors; vasculitis in patients with COVID-19 has been identified in the lung, liver, kidney, and skin [40].

A study done in a medical center with similar demographics during the same time period revealed that patients who tested positive for COVID-19 had

**Table 2**  
Ambulatory most common ICD-10 codes

ICD-10 Code	Description	Frequency, proportion (%)
H25.1	Age-related nuclear cataract	74/116 (63.8)
H52.4	Presbyopia	74/116 (63.8)
E11.3	Type 2 diabetes mellitus with ophthalmic complications	61/116 (52.6)
H52.2	Astigmatism	60/116 (51.7)
H40.0	Glaucoma suspect	43/116 (37.1)
H52.1	Myopia	38/116 (32.8)
H04.1	Other disorders of lacrimal gland	37/116 (31.9)
Z96.1	Presence of intraocular lens	37/116 (31.9)
E11.9	Type 2 diabetes mellitus without complications	33/116 (28.4)
I10	Essential (primary) hypertension	32/116 (27.6)
Z79.8	Other long term (current) drug therapy	32/116 (27.6)
H25.8	Other age-related cataract	25/116 (21.6)
H52.0	Hypermetropia	23/116 (19.8)
Z79.4	Long term (current) use of insulin	21/116 (18.1)
H40.1	Open-angle glaucoma	20/116 (17.2)
Z98.4	Cataract extraction status	19/116 (16.3)
Z48.8	Encounter for other specified postprocedural aftercare	17/116 (14.7)
E78.5	Hyperlipidemia, unspecified	15/116 (12.9)
H2.8	Other specified disorders of eyelid	14/116 (12.1)

Abbreviations: ICD-10, *International Classification of Diseases*, 10th edition.

outcomes comparable with their White counterparts when controlled for age, sex, and comorbidities [41]. A more recent study found that Black inpatients had a higher mortality rate than White patients, which was due to the different hospitals where each group of patients was admitted. This study adjusted for age, sex, income, and comorbidities. It also included a much larger and more diverse patient sample of 44,217 compared with 5902 in the earlier study [42]. When reviewing hospitalized patients within our patient population, the 2 most prevalent in-patient diagnoses include viral pneumonia (60%) and severe sepsis (50%). A similar study at Oschner Health in New Orleans from March to April 2020 reported that a diagnosis of pneumonia along with a coinfection of hypoxic respiratory failure were more commonly observed [43]. The patient demographics were comparable with those of our inpatient population with 70.4% of the COVID-19 positive patients in the study identifying as Black non-Hispanic.

The most common comorbidities identified in this study were tobacco use, hypertension, diabetes mellitus, dyslipidemia, and overweight and obesity. Hypertension and diabetes reflect the most common comorbidities found in meta-analysis pertaining to COVID-19; however, the prevalence found in this demographic was much higher than found in the literature [44]. The high rate of comorbidities found is especially important to take note in this population, in which the majority of the demographic are minorities disproportionately impacted by COVID-19, because comorbidities have been associated with higher rates of mortality owing to COVID-19 [45].

Although an estimated 1 in 10 patients with COVID-19 had at least 1 ocular manifestation [7], only 2 of 116 ambulatory patients with positive COVID-19 tests had ocular complaints directly related to COVID-19. The 2 symptoms seen in this study were dry eye and conjunctivitis, 2 of the most common eye concerns related to COVID-19, as discussed elsewhere in this article. The low prevalence of COVID-19 ocular manifestations in comparison with previously described meta-analyses may be a result of several factors, including hospital restrictions for ambulatory visits for patients with a positive COVID-19 tests, symptoms not correctly identified as related to COVID-19, or ocular symptoms overlooked owing to other COVID-19 symptoms. This finding highlights the importance of an awareness of COVID-19 ocular symptoms, because the prevalence of COVID-19-related ocular symptoms identified may be low, even in large institutions.

Our findings present the ocular diagnoses observed during the onset of the COVID-19 pandemic and one of a few studies with patients from an urban, academic hospital. There are limitations to our study, including a relatively small sample size. Additionally, COVID-19 tests included in the study were only those performed at our institution; patients with positive COVID-19 tests performed elsewhere may exist who were not included in our analysis. Another limitation to consider is that the COVID-19 vaccine was not approved during the study time period; therefore, the observed diagnoses may differ from those in breakthrough cases among vaccinated patients. A point-prevalence survey of

**Table 3**  
Inpatient most common ICD-10 codes

ICD-10 Code	Description	Frequency, proportion (%)
J12.8	Other viral pneumonia	6/10 (60.0)
R65.2	Severe sepsis	5/10 (50.0)
E87.4	Mixed disorder of acid-base balance	4/10 (40.0)
G93.4	Other and unspecified encephalopathy	4/10 (40.0)
J80	Acute respiratory distress syndrome	4/10 (40.0)
D68.8	Other specified coagulation defects	3/10 (30.0)
J95.8	Other intraoperative and postprocedural complications and disorders of respiratory system, not elsewhere classified	3/10 (30.0)
D62	Acute posthemorrhagic anemia	3/10 (30.0)
I10	Essential (primary) hypertension	3/10 (30.0)
A41.5	Sepsis owing to other gram-negative organisms	3/10 (30.0)

Abbreviations: ICD-10, *International Classification of Diseases*, 10th edition.

100,000 people in England and a randomized trial of the Moderna vaccine both found that fully vaccinated individuals were two-thirds less likely to be asymptomatic COVID-19 carriers than the unvaccinated [46]. There is little in the literature documenting ocular symptoms in these breakthrough cases. It would be beneficial to compare the ocular findings in COVID-19–positive patients before vaccinations were available with those of COVID-19–positive breakthrough cases. This work may provide insight on the effectiveness of the current messenger RNA vaccines in preventing ocular symptoms in patients who test positive for COVID-19. Our retrospective study in an academic setting also was limited by the need to rely on the accuracy of the data entered in the electronic medical record.

## RELEVANCE AND FUTURE AVENUES

Ophthalmic practice requires close physical contact with patients along with proper understanding of potential ocular findings from COVID-19 within various settings and among different populations. COVID-19–related ocular manifestations may not be seen as commonly in an outpatient setting, further underscoring the importance of identifying ocular findings from this virus. The information from our study underscores the importance of local demographic evaluation, particularly from large, urban settings with a predominance of underrepresented minorities who have been disproportionately affected by COVID-19.

The disparities in COVID-19–related diagnoses are due to numerous factors, including socioeconomic status, increased incidence of comorbidities, and a lack of access to quality health care, all resulting in poor outcomes [47,48]. Black and Latinx patients are more likely to work in jobs requiring frontline exposure to COVID-19; however, the positions often provide inadequate or no health insurance. These individuals also are more likely to live in

crowded housing, thus putting them at risk of COVID-19 infection [47,48]. Reduced access to quality care was examined in a recent study involving telemedicine practices during the early phase of the pandemic. Older non-White patients were less likely to access care, largely owing to a preference for in-person visits as opposed to video visits or phone calls. Non-White patients also were less likely to have access to internet service to facilitate a video visit [21]. As a result, ophthalmic and other COVID-19-related findings may not be detected at the same rate as White patients or are diagnosed at later stages of the viral process, with little to no correlation between the findings and the patient's COVID-19 testing status.

Future research directions should concentrate efforts at both further elucidating the impact of COVID-19 on racial and ethnic disparities and interventions for eliminating systemic barriers, both broadly and specifically within ophthalmology. Our study observed the average time for follow-up for patients during the initial surge of COVID-19 at an academic center; the impact of COVID-19 on access to ophthalmic care should continue to be studied. Several studies have identified the changes in ophthalmic care, from decreases in the number of in-person visits to increases in telemedicine use, and the impact on vision [32,49,50]. One retrospective analysis of medical retina patients in Australia found an average delay of 8 weeks or more in 40% of patients, with patients with neovascular macular degeneration experiencing the greatest vision loss from treatment delay [32]. Another study in Brazil found a decrease in the mean number of visits and medications for glaucoma patients before and during the pandemic [51]. There remains a lack of research on follow-up delay owing to COVID-19 in the United States and racial and ethnic disparities in regards to follow-up care in ophthalmology during COVID-19. Because the pandemic continues and telemedicine remains as a greater part of patient care, ensuring adequate follow-up care to prevent vision loss must be a priority. The burden of canceled visits remains on patients, whether the patient or the provider cancels [52], and racial and ethnic minorities may be disproportionately affected in follow-up care as seen with other disparities related to COVID-19. Current systemic reviews of racial and ethnic health disparities primarily identify these disparities; however, other articles expand on strategies for addressing them. Such strategies involve multipronged policy approaches, including accessible testing, contact tracing, and vaccination [48,53,54]. Evaluating the intersectionality between racial and ethnic health disparities with socioeconomic, environmental, and disability status is crucial for developing effective interventions for equitable access to care.

## CONCLUSION

Studies that present findings from large public hospitals and large urban medical centers are integral in examining gaps in health care for Black and Latinx patients and ensure that future management and treatment options during the pandemic will be focused on identifying areas for improvement during ophthalmic examination. Eye care professionals and providers from all

disciplines should be aware of the common ocular diagnoses found in all patient populations, particularly minority patients, when working in similar settings as the one in our study. Our study serves to inform assessing ocular findings for patients with COVID-19–positive tests, expanding on and adding to our current body of literature to date and perhaps for future variants or pandemics.

The question remains as to how this information can be applied during ophthalmic examinations. The common diagnoses of age-related nuclear cataracts and diabetes-related ophthalmic complications are found in many patients and may not prompt much concern for possible COVID-19 infection. Diabetes-related ophthalmic findings should however cause us to further examine the likelihood that these findings may be due to COVID-19, especially if the patient has a known recent positive test result. The vaso-occlusive retinal findings discussed in other studies supports the necessity of comprehensive examinations with a careful history focused on a positive COVID-19 diagnosis in the past. The history should include questioning patients on any recent dry eye or conjunctivitis-related symptoms around the time of COVID-19 diagnosis. Breakthrough cases also must be studied more closely to determine if ophthalmic findings are present in these patients at the same or lower rates. Some patients may be asymptomatic and present to their eye examination with symptoms that prompt COVID-19 testing, further contributing to the identification of these individuals who otherwise would have no awareness of their status.

## SUMMARY

Opportunities exist in both eye care delivery and implementation of observational studies with intervention-based strategies to examine and evaluate the past, current, and ongoing effects COVID-19 has on our patients. In particular, investigational research in underserved populations should remain a cornerstone for reducing health disparities and improving access to care for those patients most vulnerable. Public hospitals and urban academic medicals must seize this opportunity and are uniquely positioned to do so.

## Disclosure

The authors declare there are no conflicts or competing interests.

## References

- [1] Khalili M, Karamouzian M, Nasiri N, et al. Epidemiological characteristics of COVID-19: a systematic review and meta-analysis. *Epidemiol Infect* 2020;148:e130.
- [2] Matta S, Chopra KK, Arora VK. Morbidity and mortality trends of Covid 19 in top 10 countries. *Indian J Tuberc* 2020;67(4):S167–72.
- [3] Mahajan R, Paul G, Mahajan R, et al. Systemic manifestations of COVID-19. *J Anaesthesiol Clin Pharmacol* 2020;36(4):435.
- [4] Nair A, Gandhi R, Natarajan S. Effect of COVID-19 related lockdown on ophthalmic practice and patient care in India: results of a survey. *Indian J Ophthalmol* 2020;68(5):725.

- [5] Wan KH, Huang SS, Young AL, et al. Precautionary measures needed for ophthalmologists during pandemic of the coronavirus disease 2019 (COVID-19). *Acta Ophthalmol* 2020;98(3):221–2.
- [6] Lai TH, Tang EWH, Chau SKY, et al. Stepping up infection control measures in ophthalmology during the novel coronavirus outbreak: an experience from Hong Kong. *Graefes Arch Clin Exp Ophthalmol* 2020;258(5):1049–55.
- [7] 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(1):103–12.
- [8] Zhong Y, Wang K, Zhu Y, et al. Ocular manifestations in COVID-19 patients: a systematic review and meta-analysis. *Trav Med Infect Dis* 2021;44:102191.
- [9] Tai DBG, Shah A, Doubeni CA, et al. The disproportionate impact of COVID-19 on racial and ethnic minorities in the United States. *Clin Infect Dis* 2021;72(4):703–6.
- [10] Chatterji P, Li Y. Effects of the COVID-19 pandemic on outpatient providers in the United States. *Med Care* 2021;59(1):58–61.
- [11] Ohannessian R, Duong TA, Odone A. Global telemedicine implementation and integration within health systems to fight the COVID-19 pandemic: a call to action. *JMIR Public Heal Surveill* 2020;6(2):e18810.
- [12] Brant AR, Pershing S, Hess O, et al. The impact of COVID-19 on missed ophthalmology clinic visits. *Clin Ophthalmol* 2021;15:4645–57.
- [13] Patel SY, Mehrotra A, Huskamp HA, et al. Trends in outpatient care delivery and telemedicine during the COVID-19 pandemic in the US. *JAMA Intern Med* 2021;181(3):388.
- [14] Koonin LM, Hoots B, Tsang CA, et al. Trends in the use of telehealth during the emergence of the COVID-19 pandemic — United States, January–March 2020. *MMWR Morb Mortal Wkly Rep* 2020;69(43):1595–9.
- [15] Yang J, Landrum MB, Zhou L, et al. Disparities in outpatient visits for mental health and/or substance use disorders during the COVID surge and partial reopening in Massachusetts. *Gen Hosp Psychiatry* 2020;67:100–6.
- [16] Eberly LA, Kallan MJ, Julien HM, et al. Patient characteristics associated with telemedicine access for primary and specialty ambulatory care during the COVID-19 pandemic. *JAMA Netw Open* 2020;3(12):e2031640.
- [17] Differences in the use of telephone and video telemedicine visits during the COVID-19 pandemic. *Am J Manag Care* 2021;27(1):21–6.
- [18] Ye S, Kronish I, Fleck E, et al. Telemedicine expansion during the COVID-19 pandemic and the potential for technology-driven disparities. *J Gen Intern Med* 2021;36(1):256–8.
- [19] Cao YJ, Chen D, Liu Y, et al. Disparities in the use of in-person and telehealth outpatient visits among Medicare beneficiaries in an accountable care organization during COVID-19. *Health Serv Res* 2021;56(S2):5.
- [20] Aziz K, Moon JY, Parikh R, et al. Association of patient characteristics with delivery of ophthalmic telemedicine during the COVID-19 pandemic. *JAMA Ophthalmol* 2021;139(11):1174.
- [21] Elam AR, Sidhom D, Ugoh P, et al. Disparities in eye care utilization during the COVID-19 pandemic. *Am J Ophthalmol* 2022;233:163–70.
- [22] Boserup B, McKenney M, Elkbuli A. Disproportionate impact of COVID-19 pandemic on racial and ethnic minorities. *Am Surg* 2020;86(12):1615–22.
- [23] Mackey K, Ayers CK, Kondo KK, et al. Racial and ethnic disparities in COVID-19-related infections, hospitalizations, and deaths. *Ann Intern Med* 2021;174(3):362–73.
- [24] Rentsch CT, Kidwai-Khan F, Tate JP, et al. Patterns of COVID-19 testing and mortality by race and ethnicity among United States veterans: a nationwide cohort study. In: Zelnor J, editor. *PLoS Med* 2020;17(9):e1003379.
- [25] Ogedegbe G, Ravenell J, Adhikari S, et al. Assessment of racial/ethnic disparities in hospitalization and mortality in patients with COVID-19 in New York City. *JAMA Netw Open* 2020;3(12):e2026881.

- [26] Disparities in COVID-19 vaccination rates across racial and ethnic minority groups in the United States. *ASPE Off Sci Data Policy*; 2021 (Issue Brief). Available at: <https://aspe.hhs.gov/reports/disparities-covid-19-vaccination-rates-across-racial-ethnic-minority-groups-united-states>. Accessed May 18, 2022.
- [27] Nguyen LH, Joshi AD, Drew DA, et al. Self-reported COVID-19 vaccine hesitancy and uptake among participants from different racial and ethnic groups in the United States and United Kingdom. *Nat Commun* 2022;13(1):636.
- [28] Flores LE, Frontera WR, Andrasik MP, et al. Assessment of the inclusion of racial/ethnic minority, female, and older individuals in vaccine clinical trials. *JAMA Netw Open* 2021;4(2):e2037640.
- [29] Chastain DB, Osae SP, Henao-Martínez AF, et al. Racial disproportionality in Covid clinical trials. *N Engl J Med* 2020;383(9):e59.
- [30] Patel SY, Mehrotra A, Huskamp HA, et al. Variation in telemedicine use and outpatient care during the COVID-19 Pandemic in the United States. *Health Aff* 2021;40(2):349–58.
- [31] Parikh D, Armstrong G, Liou V, et al. Advances in telemedicine in ophthalmology. *Semin Ophthalmol* 2020;35(4):210–5.
- [32] Stone LG, Grinton ME, Talks JS. Delayed follow-up of medical retina patients due to COVID-19: impact on disease activity and visual acuity. *Graefes Arch Clin Exp Ophthalmol* 2021;259(7):1773–80.
- [33] Gelnick S, Akanda M, Lieberman R. Retina in the age of COVID-19. *Adv Ophthalmol Optom* 2021;6:187–200.
- [34] Al-Namaeh M. COVID-19 and conjunctivitis: a meta-analysis. *Ther Adv Ophthalmol* 2021;13:251584142110033.
- [35] Invernizzi A, Torre A, Parrulli S, et al. Retinal findings in patients with COVID-19: results from the SERPICO-19 study. *EClinicalMedicine* 2020;27:100550.
- [36] Betsch D, Freund PR. Neuro-ophthalmologic manifestations of novel coronavirus. *Adv Ophthalmol Optom* 2021;6:275–88.
- [37] Bypareddy R, Rathod BS, Shilpa Y, et al. Fundus evaluation in COVID-19 positives with non-severe disease. *Indian J Ophthalmol* 2021;69(5):1271.
- [38] Venkatesh R, Reddy NG, Agrawal S, et al. COVID-19-associated central retinal vein occlusion treated with oral aspirin. *BMJ Case Rep* 2021;14(5):e242987.
- [39] Walinikar J, Makhija S, Sharma H, et al. Central retinal vein occlusion with COVID-19 infection as the presumptive etiology. *Indian J Ophthalmol* 2020;68(11):2572.
- [40] Sheth J, Narayanan R, Goyal J, et al. Retinal vein occlusion in COVID-19: a novel entity. *Indian J Ophthalmol* 2020;68(10):2291.
- [41] Kabarriti R, Brodin NP, Maron MI, et al. Association of race and ethnicity with comorbidities and survival among patients with COVID-19 at an urban medical center in New York. *JAMA Netw Open* 2020;3(9):e2019795.
- [42] Asch DA, Islam MN, Sheils NE, et al. Patient and hospital factors associated with differences in mortality rates among Black and White US Medicare beneficiaries hospitalized with COVID-19 Infection. *JAMA Netw Open* 2021;4(6):e2112842.
- [43] Price-Haywood EG, Burton J, Fort D, et al. Hospitalization and mortality among black patients and white patients with Covid-19. *N Engl J Med* 2020;382(26):2534–43.
- [44] Paudel S. A meta-analysis of 2019 novel corona virus patient clinical characteristics and comorbidities. *Res Sq* 2020; <https://doi.org/10.21203/rs.3.rs-21831/v1>.
- [45] Ejaz H, Alsrhani A, Zafar A, et al. COVID-19 and comorbidities: deleterious impact on infected patients. *J Infect Public Health* 2020;13(12):1833–9.
- [46] Klompas M. Understanding breakthrough infections following mRNA SARS-CoV-2 vaccination. *JAMA* 2021;326(20):2018.
- [47] Dalsania AK, Fastiggi MJ, Kahlam A, et al. The relationship between social determinants of health and racial disparities in COVID-19 mortality. *J Racial Ethn Heal Disparities* 2022;9(1):288–95.

- [48] Lopez L, Hart LH, Katz MH. Racial and ethnic health disparities related to COVID-19. *JAMA* 2021;325(8):719.
- [49] Subathra G, Rajendrababu S, Senthilkumar V, et al. Impact of COVID-19 on follow-up and medication adherence in patients with glaucoma in a tertiary eye care centre in south India. *Indian J Ophthalmol* 2021;69(5):1264.
- [50] Valentim CCS, Muste JC, Iyer AI, et al. Characterization of ophthalmology virtual visits during the COVID-19 pandemic. *Eye* 2022; <https://doi.org/10.1038/s41433-022-01938-2>.
- [51] Ayub G, Vasconcellos JPC de, Costa VP. The impact of Covid-19 in the follow-up of glaucoma patients in a tertiary center: a comparison between pre-pandemic and pandemic periods. *Clin Ophthalmol* 2021;15:4381–7.
- [52] Morse AR. The Importance of patients' perspectives in providing ophthalmic care—lessons from the COVID-19 pandemic. *JAMA Ophthalmol* 2021;139(5):516.
- [53] White A, Liburd LC, Coronado F. Addressing racial and ethnic disparities in COVID-19 among school-aged children: are we doing enough? *Prev Chronic Dis* 2021;18:210084.
- [54] Wen LS, Sadeghi NB. Addressing Racial Health Disparities In The COVID-19 Pandemic: Immediate And Long-Term Policy Solutions. *Health Aff Forefront* 2020; <https://doi.org/10.1377/forefront.20200716.620294>.