

Ocular Manifestations and Clinical Characteristics of Children With Laboratory-Confirmed COVID-19 in Wuhan, China

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IMPORTANCE Ocular manifestations and outcomes in children with confirmed coronavirus disease 2019 (COVID-19), relevant affecting factors, and differences in ocular disease between children and adults have yet to be fully understood.

OBJECTIVE To investigate ocular manifestations and clinical characteristics of children with laboratory-confirmed COVID-19.

DESIGN, SETTING, AND PARTICIPANTS This cross-sectional study was conducted at Wuhan Children's Hospital in Wuhan, China. Children with COVID-19 confirmed by severe acute respiratory syndrome coronavirus disease 2 nucleic acid tests of upper respiratory tract specimens between January 26 and March 18, 2020, were included.

MAIN OUTCOMES AND MEASURES Onset clinical symptoms and duration, ocular symptoms, and needs for medication.

RESULTS A total of 216 pediatric patients were included, among whom 134 (62%) were boys, with a median (interquartile range) age of 7.25 (2.6-11.6) years. Based on the exposure history, 193 children (89.4%) had a confirmed (173 [80.1%]) or suspected (20 [9.3%]) family member with COVID-19 infection. The most common symptoms among symptomatic children were fever (81 [37.5%]) and cough (79 [36.6%]). Of 216 children, 93 (43.1%) had no systemic or respiratory symptoms. All children with mild (101 [46.8%]) or moderate (115 [53.2%]) symptoms recovered without reported death. Forty-nine children (22.7%) showed various ocular manifestations, of which 9 had ocular complaints being the initial manifestations of COVID-19. The common ocular manifestations were conjunctival discharge (27 [55.1%]), eye rubbing (19 [38.8%]), and conjunctival congestion (5 [10.2%]). Children with systemic symptoms (29.3% vs 14.0%; difference, 15.3%; 95% CI, 9.8%-20.7%; $P = .008$) or with cough (31.6% vs 17.5%; difference, 14.1%; 95% CI, 8.0%-20.3%; $P = .02$) were more likely to develop ocular symptoms. Ocular symptoms were typically mild, and children recovered or improved.

CONCLUSIONS AND RELEVANCE In this cross-sectional study, children hospitalized with COVID-19 in Wuhan, China, presented with a series of onset symptoms including fever, cough, and ocular manifestations, such as conjunctival discharge, eye rubbing, and conjunctival congestion. Patients' systemic clinical symptoms or cough were associated with ocular symptoms. Ocular symptoms recovered or improved eventually.

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Coronavirus disease 2019 (COVID-19) has spread rapidly and caused a global pandemic, as declared by World Health Organization on March 10, 2020.¹ The novel coronavirus, known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), belongs to β coronavirus.² It is an enveloped nonsegmented positive-sense RNA virus, which shows 82% genomic homology to the severe acute respiratory syndrome coronavirus (SARS-CoV) that caused an outbreak in early 2003.³ Because the virus is heavily present in respiratory secretions, respiratory droplets are considered the main transmission route. Aerosol transmission⁴ and transmission via conjunctival route have also been suggested but remain controversial.⁴⁻⁸ The common initial clinical manifestations of COVID-19 are fever, fatigue, and dry cough.⁹ However, some patients had conjunctivitis as the initial symptom.⁶

There have been reports of COVID-19 infections among medical staff, including ophthalmologists, presumably acquired during close contact with infected patients. Better understanding of the ocular manifestations of COVID-19 can help develop more effective prevention and mitigation strategies. Cases of patients with COVID-19 and ocular symptoms and potential conjunctival transmission route for SARS-CoV-2 have been reported.¹⁰⁻¹² However, nearly all reported cases were adults, and little is known about ocular manifestations in children with COVID-19. Compared with adults, COVID-19 in children could be very different in terms of exposure history, clinical characteristics, and ocular manifestations.¹³⁻¹⁸ Therefore, we performed a retrospective clinical study on the clinical and ocular characteristics of pediatric patients with COVID-19, all from Wuhan Children's Hospital in Wuhan, China.

Methods

Research Individuals

Laboratory-confirmed children with COVID-19 admitted from January 26 to March 18, 2020, to Wuhan Children's Hospital, which was the only designated hospital for treating children with COVID-19, were included in the study. All patients were confirmed by SARS-CoV-2 real-time reverse transcriptase-polymerase chain reaction (RT-PCR) of nasopharynx or oropharynx swabbing specimens collected at an isolation facility, fever clinic, or hospital unit designated for suspected cases pending confirmation. Diagnosis and classifications of COVID-19 were made according to the Novel Coronavirus Pneumonia Diagnosis and Treatment Guidelines, 7th edition, published by the National Health Commission of China.¹⁹ This study was approved by the Ethics Committees of Wuhan Children's Hospital. Informed consent was obtained by both electronic questionnaire and oral confirmation from the legal guardians of the children diagnosed with COVID-19. There was no financial compensation for the participation in the study.

Data Collection

The demographic information and clinical manifestations of patients were collected through medical record review, including name, sex, age, exposure history, past medical history, onset of symptoms, admission time, hospital stay, and laboratory test-

Key Points

Question What are the ocular manifestations and outcomes in children with confirmed coronavirus disease 2019 (COVID-19) and what factors contributed to ocular symptoms during the course of disease in children?

Findings In this cross-sectional study of 216 children hospitalized with COVID-19 in Wuhan, China, 49 (22.7%) had ocular manifestations, including conjunctival discharge, eye rubbing, and conjunctival congestion. Children with systemic symptoms or cough were more likely to develop ocular symptoms, which were mild, and recovered or improved with minimal eye drops or self-healing.

Meaning These data could help guide prevention and management of ocular disorders in children with COVID-19.

ing and imaging results. Meanwhile, electronic questionnaires were designed to obtain additional information on ocular involvements, including onset and duration of ocular symptoms, as well as topical medication if applicable. If the information provided was unclear or incomplete, a follow-up telephone call or face-to-face examination was conducted. All data were collected and independently reviewed by 2 research team members (N.M. and P.L.). Although some of the data on demographic and clinical characteristics were shared with the other studies,^{20,21} data on the ocular manifestations of the children with COVID-19 have not been reported anywhere else.

Diagnostic criteria of COVID-19 included epidemiology history, clinical manifestations, and etiologic evidence provided by RT-PCR testing. Definitive etiology evidence was required. Asymptomatic patients with COVID-19 were defined as such that the SARS-CoV-2 RT-PCR test was positive, but there had been no symptoms before the laboratory confirmation. The severity of the disease was classified according to 7th edition guideline for diagnosis and treatment of COVID-19.¹⁹

Laboratory Testing

Upper respiratory tract specimens (nasopharynx or oropharynx swabbing specimens) were obtained from patients. Subsequently, RNA was extracted and tested by real-time RT-PCR with SARS-CoV-2-specific primers and probes, developed by a local public health laboratory. Per testing procedure, if 2 specific viral targets (open reading frame 1A or 1B, nucleocapsid protein) were detected, the case was then considered to be laboratory confirmed. The cycle threshold value (Ct value) was crucial for the result interpretation. A Ct value of less than 37 was defined as positive for the specific target, and a Ct value of 40 or higher was defined as negative. A Ct value of 37 to 39 was considered indeterminate, requiring test repeat. If the repeat Ct value was less than 37 or the repeat Ct value was 37 to 40 but with an obvious amplification peak, the retest was then interpreted as positive.

Statistical Analysis

All statistical analyses were performed with SPSS software, version 18.0 (SPSS Inc). Continuous variables were expressed as medians and interquartile ranges, which were compared by *t* test or Mann-Whitney test depending on whether the data were normally distributed or not. Categorical variables were summarized as counts and percentages. Percentiles were rounded to 1 decimal

place. χ^2 Test or Fisher exact test were used for comparison of categorical data as appropriate. Of all the statistical analysis, differences, 95% CIs, and *P* values were calculated, while a 2-sided *P* < .05 was considered statistically significant.

Results

Demographic and Clinical Characteristics

Details of demographic and clinical characteristics of children with confirmed COVID-19 are shown in **Table 1**. A total of 216 children were included, of which 49 participants (22.7%) reported ocular symptoms. The overall median (interquartile range) age was 7.25 (2.6-11.6) years, while that of the patients

with ocular symptoms was 4.1 (1.1-10.2) years. A total of 134 patients (62.0%) were boys. Among the cohort, 193 children (89.4%) had a confirmed (173 [80.1%]) or suspected (20 [9.3%]) family member with COVID-19. Presumably, the remaining 23 children (10.6%) had infections associated with undefined sources, such as public transportation, school, restaurants, or supermarkets. Among 49 patients with ocular manifestations, 83.7% (*n* = 41) had contact with confirmed family exposure, and 12.2% (*n* = 6) had contact with suspected family exposure. Regarding previous medical history, the most common was rhinitis (25 [11.6%]), followed by urticaria (6 [2.8%]), respiratory diseases (6 [2.8%]), cardiovascular diseases (4 [1.9%]), previous surgery (3 [1.4%]), endocrine disease (2 [0.9%]), and other (8 [3.7%]).

Table 1. Demographic and Clinical Characteristics of Children With Confirmed COVID-19 in Wuhan Children's Hospital

	No (%)				
Characteristic	Total (N = 216)	Ocular symptoms		Difference (95% CI)	P value
		With (n = 49)	Without (n = 167)		
Age, median (IQR), y	7.25 (2.6 to 11.6)	4.1 (1.1 to 10.2)	7.4 (3.2 to 11.8)	1.43 (−0.89 to 2.95) ^a	.07 ^b
Age group, y					
<1	32 (14.8)	12 (24.5)	20 (12.0)	12.5 (5.9 to 19.2) ^c	.11 ^d
1 to <5	50 (23.2)	13 (26.5)	37 (22.2)	4.4 (−2.7 to 11.5) ^c	
5 to <10	69 (31.9)	12 (24.5)	57 (34.1)	−9.6 (−16.8 to −2.5) ^c	
10 to ≤16	65 (30.1)	12 (24.5)	53 (31.7)	−7.2 (−14.4 to −0.1) ^c	
Male	134 (62.0)	35 (71.4)	99 (59.3)	12.1 (4.7 to 19.6) ^c	.12 ^d
Exposure history					
Confirmed family members	173 (80.1)	41 (83.7)	132 (79.0)	4.6 (−1.5 to 10.8) ^c	.19 ^d
Suspected family members	20 (9.3)	6 (12.2)	14 (8.4)	3.9 (−1.3 to 9.0) ^c	
Undefined exposure history	23 (10.6)	2 (4.1)	21 (12.6)	−8.5 (−19.0 to 2.0) ^e	
Previous history					
Any	54 (25.0)	16 (32.7)	38 (22.8)	9.9 (2.5 to 17.3) ^c	.16 ^d
Rhinitis	25 (11.6)	7 (14.3)	18 (10.8)	3.5 (−2.0 to 9.1) ^c	.50 ^d
Urticaria	6 (2.8)	3 (6.1)	3 (1.8)	4.3 (−1.7 to 10.4) ^e	.13 ^f
Respiratory system diseases	6 (2.8)	0	6 (3.6)	−3.6 (−9.6 to 2.4) ^e	.34 ^f
Endocrine diseases	2 (0.9)	0	2 (1.2)	−1.2 (−5.1 to 2.7) ^e	>.99 ^f
Cardiovascular diseases	4 (1.9)	2 (4.1)	2 (1.2)	2.9 (−2.0 to 7.8) ^e	.22 ^f
Previous surgery history	3 (1.4)	0	3 (1.8)	−1.8 (−6.3 to 2.7) ^e	>.99 ^f
Other	12 (5.6)	5 (10.2)	7 (4.2)	6.0 (1.4 to 10.6) ^c	.11 ^f
Initial symptoms					
Asymptomatic	93 (43.1)	13 (26.5)	80 (47.9)	−21.4 (−28.8 to −14.0) ^c	.008 ^d
Fever	81 (37.5)	23 (46.9)	58 (34.7)	12.2 (4.2 to 20.2) ^c	.12 ^d
Cough	79 (36.6)	25 (51.0)	54 (32.3)	18.7 (10.7 to 26.7) ^c	.02 ^d
Diarrhea	11 (5.1)	5 (10.2)	6 (3.6)	6.6 (2.1 to 11.2) ^c	.13 ^f
Fatigue	10 (4.6)	3 (6.1)	7 (4.2)	1.9 (−5.6 to 9.4) ^e	.70 ^f
Nasal discharge	7 (3.2)	1 (2.0)	6 (3.6)	−1.6 (−7.7 to 4.6) ^e	>.99 ^f
Nasal congestion	6 (2.8)	2 (4.1)	4 (2.4)	1.7 (−4.2 to 7.5) ^e	.62 ^f
Sore throat	3 (1.4)	2 (4.1)	1 (0.6)	3.5 (−0.9 to 7.8) ^e	.13 ^f
Nausea or vomiting	7 (3.2)	2 (4.1)	5 (3.0)	1.1 (−5.2 to 7.4) ^e	.66 ^f
Sneeze	4 (1.9)	1 (2.0)	3 (1.8)	0.2 (−4.6 to 5.1) ^e	>.99 ^f
Myalgia or arthralgia	4 (1.9)	1 (2.0)	3 (1.8)	0.2 (−4.6 to 5.1) ^e	>.99 ^f
Abdominal pain	3 (1.4)	1 (2.0)	2 (1.2)	0.8 (−3.4 to 5.1) ^e	>.54 ^f
Ocular symptoms	9 (4.2)	9 (18.4)	0	18.4 (9.7 to 27.1) ^e	<.001 ^d
Conjunctival discharge	5 (2.3)	5 (10.2)	0	10.2 (4.0 to 16.4) ^e	
Conjunctival congestion	4 (1.9)	4 (8.2)	0	8.2 (2.7 to 13.6) ^e	
Eye rubbing	2 (0.9)	2 (4.1)	0	4.1 (0.4 to 7.8) ^e	

(continued)

Table 1. Demographic and Clinical Characteristics of Children With Confirmed COVID-19 in Wuhan Children's Hospital (continued)

Characteristic	No (%)		Difference (95% CI)	P value
	Total (N = 216)	Ocular symptoms With (n = 49) Without (n = 167)		
Chest CT				
Normal	101 (46.8)	17 (34.7)	84 (50.3)	-15.6 (-23.4 to -7.8) ^c
Unilateral abnormality	68 (31.5)	18 (36.7)	50 (29.9)	6.8 (-1.0 to 14.5) ^c
Bilateral abnormality	47 (21.8)	14 (28.6)	33 (19.8)	8.8 (1.7 to 16.0) ^c
Interval from onset of symptom to hospitalization, median (IQR), d	5 (3 to 8)	6.5 (2 to 9.5)	5 (3 to 8)	-0.86 (-3.16 to 1.45) ^a
Duration of hospitalization, median (IQR), d	11 (8 to 15)	11 (9 to 14.5)	11 (8 to 16)	0.03 (-1.66 to 1.71) ^a
Severity of COVID-19				
Mild	101 (46.8)	17 (34.7)	84 (50.3)	-15.6 (-23.4 to -7.8) ^c
Moderate	115 (53.2)	32 (65.3)	83 (49.7)	15.6 (7.8 to 23.4) ^c

Abbreviations: COVID-19, coronavirus disease 2019; CT, computed tomography; IQR, interquartile range.

^a Independent t test.

^b Mann-Whitney U test.

^c Approximate normal distribution method.

^d χ^2 Test.

^e Newcombe-Wilson method.

^f Fisher exact probability test.

The initial symptoms were predominantly fever (81 [37.5%]) and cough (79 [36.6%]). Other symptoms included diarrhea (11 [5.1%]), fatigue (10 [4.6%]), nasal discharge (7 [3.2%]), nasal congestion (6 [2.8%]), conjunctival discharge (5 [2.3%]), and conjunctival congestion (4 [1.9%]). However, 93 of 216 children (43.1%) were asymptomatic. In the 93 asymptomatic children (without systemic and nonocular symptoms), 13 children (14.0%) had ocular symptoms and 80 children (86.0%) did not. All patients were arranged to have lung computed tomography examination. The computed tomographic imaging study revealed unilateral lung abnormality in 68 patients (31.5%) and bilateral lung abnormality in 47 (21.8%). The remaining 101 patients (46.8%) had normal lung computed tomography results. According to COVID-19 diagnostic criteria, 101 (46.8%) and 115 (53.2%) were determined to have mild and moderate disease, respectively. Furthermore, the median (interquartile range) interval from onset of symptom to hospitalization was 5 (3-8) days, and the median (interquartile range) duration of hospitalization was 11 (8-15) days. All patients recovered and were discharged without any major complication.

Ocular Characteristics

Ocular characteristics in children with confirmed COVID-19 are summarized in Table 2. Overall, 49 patients (22.7%) had various ocular symptoms during COVID-19 infection. Among those with ocular symptoms, 27 patients (55.1%) presented with increased conjunctival discharge, including white mucoid (9 [18.4%]), thin watery (7 [14.3%]) and yellow-green purulent (11 [22.4%]) discharge, and with conjunctival congestion (5 [10.2%]). Other ocular manifestations contained eye rubbing (19 [38.8%]), ocular pain (4 [8.2%]), tearing (2 [4.1%]), and eyelid swelling (4 [8.2%]). Regarding ocular history, 2 patients (4.1%) had allergic conjunctivitis before the COVID-19 pandemic. Treatment for the 49 patients with ocular symptoms included observation without treatment (self-healing in 23 participants [46.9%]), antibacterial eye drops, antiviral eye

Table 2. Ocular Manifestations in Children With Confirmed Coronavirus Disease 2019 in Wuhan Children's Hospital

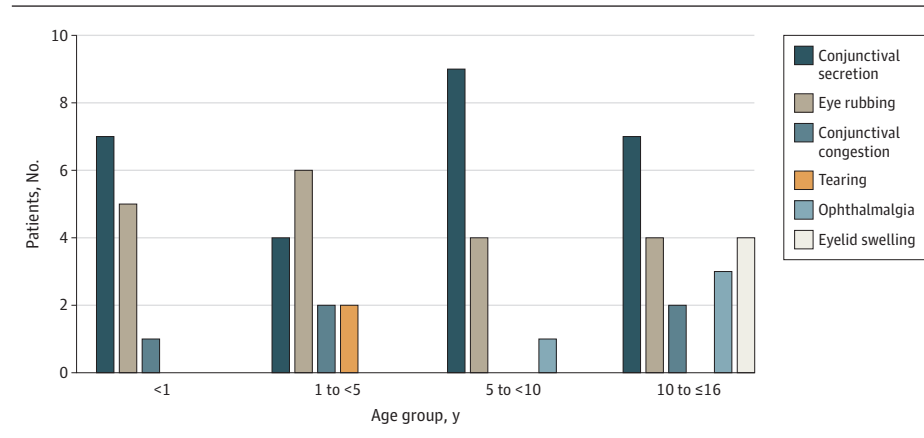
Ocular characteristics	No. (%)
No.	49
Symptoms	
Conjunctival discharge	27 (55.1)
White mucoid	9 (18.4)
Thin watery	7 (14.3)
Yellow-green purulent	11 (22.4)
Eye rubbing	19 (38.8)
Conjunctival congestion	5 (10.2)
Ocular pain	4 (8.2)
Tearing	2 (4.1)
Eyelid swelling	4 (8.2)
Previous ocular disease	
Allergic conjunctivitis	2 (4.1)
Medication	
No medication	31 (63.3)
Ofloxacin eye drop	14 (28.6)
Tobramycin eye drop	1 (2.0)
Ganciclovir ophthalmic gel	1 (2.0)
Azelastine eye drop	2 (4.1)
Tobramycin/dexamethasone eye drop	1 (2.0)
Duration of ocular symptoms, median (IQR), d	7 (3-10)
Prognosis	
Recovered	41 (83.7)
Improved	8 (16.3)

Abbreviation: IQR, interquartile range.

drops, and antiallergic eye drops. Except for 8 children who had persistent eye rubbing, the other 41 children recovered completely. The median (interquartile range) duration of ocular symptoms was 7 (3-10) days.

The age distribution among those with ocular symptoms is summarized in Figure 1. Eye rubbing and conjunctival dis-

Figure 1. Ocular Symptoms in Different Age Groups



charge were present across all age groups, whereas tearing was only recorded in children aged 1 to 5 years and eyelid swelling only occurred in children aged 10 to 16 years.

Figure 2 shows information of 27 children with conjunctival discharge, including date of symptom onset, date of hospitalization, date of discharge, and results of SARS-CoV-2 RT-PCR testing. The median (interquartile range) duration of all conjunctival discharge was 4 (4-8) days. Five patients experienced conjunctival discharge at the initial presentation (patients 5, 8, 16, 21, and 25), and among them, 3 patients had conjunctival discharge as the only manifesting symptom of COVID-19 (patients 16, 21, and 25).

Comparison Between Children With and Without Ocular Symptoms

As shown in Table 1, the percentage of asymptomatic (no fever and/or cough) children was lower in participants with ocular symptoms (13 [26.5%]) compared with those without ocular symptoms (80 [47.9%]) (difference, -21.4%; 95% CI, -28.8% to -14.0%; $P = .008$). Meanwhile, of 93 initially asymptomatic children, 13 children (14.0%) had ocular symptoms, while among 123 children with systemic symptoms, 36 children (29.3%) had ocular symptoms. The difference between the 2 incidences had statistical significance (difference, 15.3%; 95% CI, 9.8%-20.7%; $P = .008$). As for the specific symptoms, the incidence of cough (difference, 18.7%; 95% CI, 10.7%-26.7%; $P = .02$) was higher in those with ocular symptoms (25 [51.0%]), compared with those without ocular symptoms (54 [32.3%]). Meanwhile, of 79 children with cough as initial symptom, 25 children (31.6%) had ocular symptoms, while among the 137 children without cough, 24 (17.5%) had ocular symptoms (difference, 14.1%; 95% CI, 8.0%-20.3%, $P = .02$). However, no difference was found between the 2 groups for other systemic symptoms.

Discussion

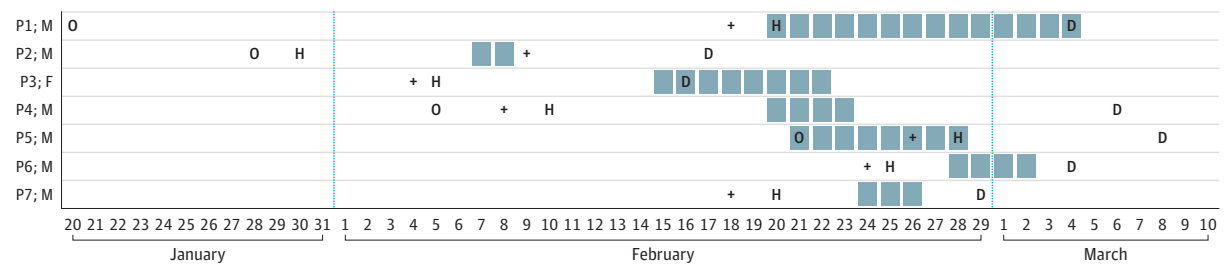
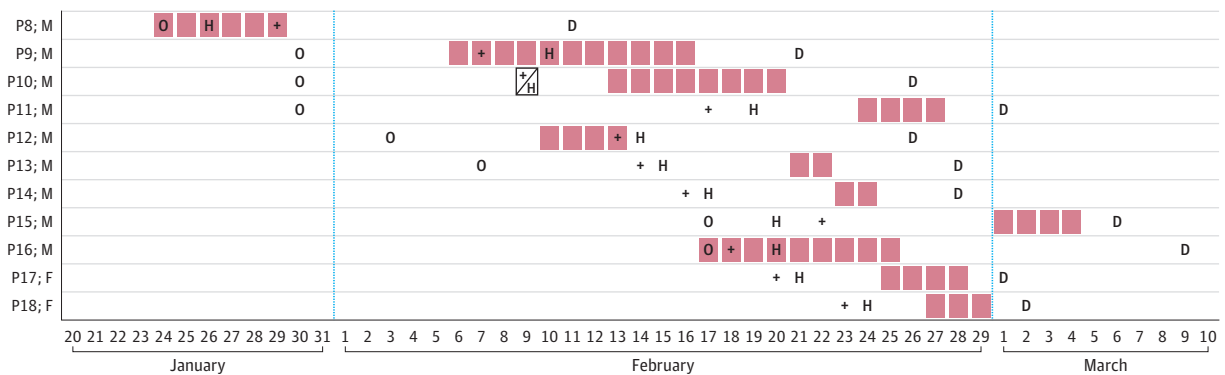
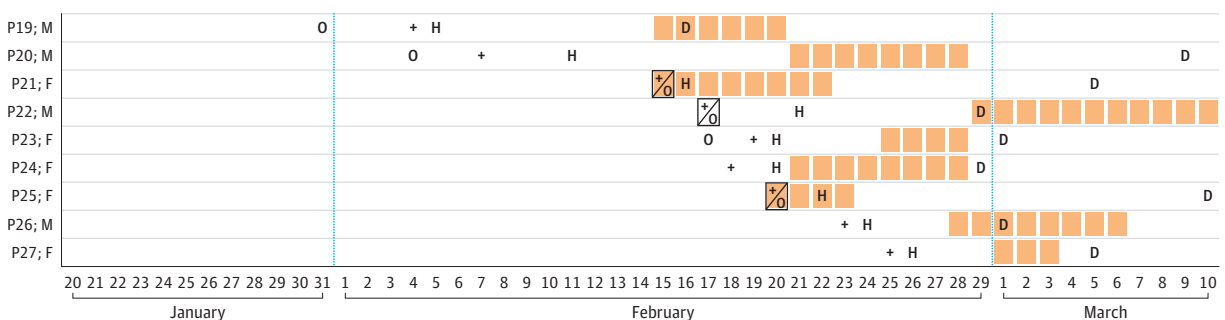
We studied 216 children with COVID-19 from Wuhan Children's Hospital, the only designated hospital to treat COVID-19-infected children in Wuhan in early 2020. About

90% children had family members with suspected or confirmed COVID-19. About 43% of COVID-19-infected children were asymptomatic before laboratory confirmation. Several studies have indicated that asymptomatic SARS-CoV-2 infections are not uncommon,²²⁻²⁵ and about 60% of newly infected people may be asymptomatic or only mildly symptomatic.²⁶ This finding reminds us of the risk of cross infection with asymptomatic SARS-CoV-2-infected children. The common initial symptoms in the children were fever and cough, which were consistent with that observed in adult patients.⁹ However, different from adults, all the infected children had mild or moderate symptoms, and some investigators explained the difference by the distribution of angiotensin-converting enzyme 2 receptors and activated innate immune system.²⁷⁻²⁹

To our knowledge, large case series of ocular manifestations of COVID-19 in children have not been reported. This study included the largest sample size on ocular manifestations in children with COVID-19, to our knowledge. Among 216 participants, 49 (22.7%) experienced ocular symptoms. Although several studies reported the ocular findings in COVID-19, the correlation between ocular symptoms and COVID-19 remain controversial, regardless of ocular detection of SARS-CoV-2.^{5-8,11,12,30,31} Could SARS-CoV-2 really cause viral conjunctivitis?^{7,31} Anatomically, the ocular surface (including cornea, conjunctiva, and tear film) communicates with air just like the nasal mucosa. Furthermore, the nasolacrimal duct links the conjunctival sac with the nasal meatus, which could provide the opportunity for the viruses to travel from the respiratory tract to the ocular surfaces. Histologically, angiotensin-converting enzyme 2,³² which is necessary when SARS-CoV-2 infects host cells by the receptor-binding motif,³³ was found to be present in ocular tissues.^{32,34,35} Whether the ocular disease was directly caused by SARS-CoV-2 remains unknown, and more studies are needed.

However, children with systemic symptoms (eg, fever, cough) appeared more likely to have ocular symptoms. It is plausible that cough can lead to ocular infection through inevitable hand-eye contact in children and/or that the force of cough could push nasopharyngeal secretions from the nasolacrimal duct into the conjunctival sac.

Figure 2. Clinical Course of 27 Patients With Conjunctival Discharge

A Thin watery secretions**B** Yellow-green purulent secretions**C** White mucoid secretions

Patients were numbered as P1 to P27, followed by sex, shown as M for male or F for female. They were further divided into 3 groups by the different properties of conjunctival discharge, namely thin watery secretions (A), yellow-green purulent secretions (B), and white mucoid secretions (C). Reverse transcriptase–polymerase chain reaction test was completed for severe acute respiratory syndrome coronavirus 2 on nasopharyngeal or oropharyngeal swabbing specimens. + Indicates positive reverse transcriptase–polymerase chain reaction test result; D, date of discharge; H, date of hospitalization; O, date of onset.

Of 216 children with COVID-19, conjunctival discharge, conjunctival congestion, and eye rubbing were the initial manifestations of SARS-CoV-2 infection in 9 children (4.2%). Five children (2.3%) presented with conjunctival congestion. This incidence was higher than that in a case series of 1099 patients (9 [0.8%]),⁹ which enrolled mostly adult patients. The higher incidence of conjunctival congestion in pediatric patients than in adult patients might be attributed to the likely frequent hand-eye contact in children.³⁰ Among 49 children with ocular symptoms, 27 children (55.1%) presented with conjunctival discharge during the course of COVID-19. It is well known that conjunctival congestion and discharge are common symptoms of conjunctivitis, which can also be noted in

children at pediatric fever clinics.³⁶⁻³⁸ When young children had fever and cough, most of them naturally resisted examination and treatment by crying and fidgeting and with body movements, which increased the risk of unsanitary hand-eye contact and conjunctivitis. Among the different types of conjunctival discharge, purulent secretions are more likely to be bacterial conjunctivitis, watery secretions be viral conjunctivitis, mucoid secretions be allergic conjunctivitis.³⁹ This study did not determine the etiology of the conjunctivitis, although allergic history was equally present in those with and without ocular findings.

There is still no specific medical treatment for COVID-19-related ocular disorders. However, as shown in this study,

ocular disorders in children with COVID-19 are typically very mild, children recover rather quickly, and these disorders are not associated with any long-term complications. Most individuals with ocular symptoms recover spontaneously without any treatment. Therefore, we recommend only close observation for COVID-19-related ocular manifestations in children.

Limitations

There are several limitations in our study. First, we could not acquire the pathogenic evidence of ocular disorders in children. We considered swabbing the conjunctival sac and collecting tear samples for additional analysis but did not receive consent from guardians of the children. Second, the descriptions of ocular symptoms can be subjective to a certain extent, especially in young children who were unable to express or describe the discomfort. The face-to-face examinations by ophthalmologists were performed in a COVID-19 isolation unit, which was not equipped with eye examination instruments.

Third, children with COVID-19 in the present study came from the city of Wuhan only, and therefore the findings may not be generalizable to children in other regions. Nevertheless, it was clinically important to analyze the ocular manifestations in children with confirmed COVID-19. This study describes the ocular involvements, the clinical course, and the outcome, which will help guide the prevention and management of ocular disorders in children with COVID-19.

Conclusions

In conclusion, of 216 children with laboratory confirmed COVID-19, 49 (22.7%) had ocular manifestations. The common ocular manifestations were conjunctival discharge, eye rubbing, and conjunctival congestion. COVID-19 in children was typically not severe, and all ocular symptoms were mild and could recover or improve eventually.

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Author Contributions: Drs Jiang and S. Li had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Drs Ma, P. Li, Wang, and Yu contributed equally to the manuscript as joint first authors.

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Critical revision of the manuscript for important intellectual content: All authors.

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