



Research article

Impact of COVID-19 pandemic on a world-wide private ophthalmic practice

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ABSTRACT

Purpose: To assess the impact of the COVID-19 pandemic on a worldwide private ophthalmic practice.**Design:** In this retrospective study, we reviewed the 2020 monthly outpatient and surgical volume of refractive, cataract, and retinal disease in Aier Eye clinics/hospitals of different regions, including the United States, Germany, Spain, Italy, and six major cities in China (Wuhan, Beijing, Shanghai, Shenyang, Urumqi and Yili). All of these data were compared to those of the same period of 2019.**Results:** Overall, during the early stage (2020 January to 2020 April) of COVID-19 outbreak, the outpatient and surgical volume of three main type ocular diseases (refractive, cataract and retinal surgery) showed an obvious reduction and reached the bottom in February in China. The data from the United States, Germany, Spain and Italy revealed the same trend, but the visit count nadir occurred until April, which is consistent with the spread trend of COVID-19 disease around the world. The average change rates of surgery volume (refractive, cataract and retinal surgery) in Chinese centers are 5.59%, -26.38%, 11.76%. The change rates of refractive (REF) and cataract volumes (CAT) in the United States are -8.62% and -10.58%, in Germany are -13.71% and -20.49%, in Spain are 15.35% and 27.97%, in Italy are 30.43% and -22.64%. In addition, the optometry outpatient volumes keep going up since May, with an average increasing rate of 21.18%, ranging from 7.43% to 49.51%.**Conclusion:** In conclusion, in this global chain of eye care units, the visit volumes of cataract, retinal and refractive changed significantly with the spread of COVID-19 pandemic. Among them, cataract surgery was the most affected sub-specialty, and refractive surgery and optometry volumes showed a potential growth in the near future. Therefore, medical institutions should make corresponding adjustments to the disease diagnosis and treatment strategies.**Abbreviations:** coronavirus disease 2019, (COVID-19); refractive, (REF); cataract, (CAT); Ocular Emergency Department, (OED); World Health Organization, (WHO); Academy of Ophthalmology, (AAO); Medicare and Medicaid Services, (CMS); retinal detachment, (RD).

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1. Introduction

The COVID-19 disease, first detected in early December 2019 in Wuhan, rapidly became a pandemic in early 2020 [1]. Detailed analyses about the biological aspects of the virus, its transmission, diagnosis, therapies and vaccines have been worked out within a shining example of global collaboration. However, recurring lockdowns coupled with the general fear of contagion has delayed necessary medical office visits for non-Covid disease, resulting in potentially irreversible damage to target organs [2,3]. Data from the National Patient and Procedure Volume Tracker™ review of 2020 records a decline in volume of patients among most specialties, with ophthalmology reported a 21.9% loss in patient volume compared to 2019 [4]. The cessation of hospital visits could bring about a large surgical backlog and even social and economic pressure [5,6]. Hence, figuring out the effect of COVID-19 pandemic on ophthalmic practice is of great importance to post-pandemic recovery and will be helpful to prepare ophthalmologists to reopen and adjust to the “new normal” of this pandemic [7].

A recent study has shown that during the national lockdown in Italy, the number of total visits to Ocular Emergency Department (OED) has decreased 59% while the proportion of diagnosis considered emergent has increased [8]. Another study analyzing the ophthalmic emergency services in a tertiary hospital in Spain reveals the same trend as Italy in the first period that the total number of consultations reduced and the majority of cases were severe and urgent. While in the second period when the isolation measures were less strict, they noted an opposite trend: the volume tripled and many cases were considered trivial [9], which indicated an irrational use of medical resources and thereby the urgent need for popularization of health education. Besides, several other studies had revealed the great changes in hospital visits volumes before and after the lockdown period [10,11]. However, most previous researches analyzing the impact of COVID-19 pandemic on ocular practice focused on the early effects within a local region. Aier Eye hospital group, as a global chain of eye hospitals, provide medical services worldwide and would serve as an excellent basis for analysis, given the uniformity of assessment within its worldwide centers. In this study, we aimed to assess the effect of the COVID-19 pandemic on a worldwide private ophthalmic practice, and propose feasible solutions to alleviate the medical pressure after the COVID-19 outbreak. To our knowledge, this is the first comprehensive global multi-subspecialty study to explore the correlation between COVID-19 pandemic and ophthalmic practice. Although most national COVID-19 quarantine policies have been lifted, this retrospective analysis can provide a reference for the management of ocular practice in special situation that may arise in the future.

2. Methods

In this retrospective study, we collected the monthly outpatient and surgical volumes of three ophthalmic sub-specialties: refractive, cataract and retinal, within Aier Eye Hospitals in five countries: China, the United States of America (USA), Germany, Spain and Italy, during January 2019 to December 2020. A total of 10 hospitals participated in this study. These included: Aier Eye Hospitals in Wuhan, Beijing, Shanghai, Shenyang, Urumqi, Yili, (China); Nashville, (USA); Frankfurt, (Germany); Madrid, (Spain); and Milan, (Italy). All of the six Aier Eye Hospitals in China cover the entire medical care of ophthalmology and Wuhan, Beijing, Shenyang accepted emergency patients and the spectrum is the same as in outpatient department. The other four Aier Eye Hospitals/clinics provide entire ocular care without emergency service. All the data were collected by financial department of managing and the department of medical records via Aier Eye Hospital Group, Aier Global Vision Care Management Co (C.M.C, C.S.).

Besides, for any particular province/city/country wherein our centers were based, the newly confirmed COVID-19 cases were obtained through the public data released by the World Health Organization (WHO) and for six Chinese centers, the data were obtained from the Chinese National Health Commission and Province Health Commission. And the country or province confirmed numbers were collected to depict the COVID-19 spread trend of the corresponding city. The monthly outpatient and surgical volumes during 2020 and 2019 were recorded and analyzed. In addition, we defined four quarters of the year as four study periods (Q1 refers to January–March, Q2 refers to April–June, Q3 refers to July–September, Q4 refers to October–December) to allow for comparisons between 2020 and 2019, and the rate of change over the four periods of 2020 and 2019 was calculated by the formula: $(\text{the surgical volume of 2019 (Vol2019)} - \text{the surgical volume of 2020 (Vol2020)}) / \text{Vol2019}$. Since Yili Aier Eye Hospital haven't opened until April 2019, thus the number in Yili during SP1 is incomparable. A Student Test was conducted to analyze the significance of the volume differences between 2020 and 2019. All statistics were performed using Graph Pad Prism 6.0 software for Windows (GraphPad Software, La Jolla California USA) and SPSS 22.0 (IBM, Chicago, IL, USA).

Review and/or approval by an ethics committee was not needed for this study because the study was a retrospective study and did not involve any human participants, personal identifiable information or animal experiments.

2.1. Patient and public involvement statement

In our study, there has been no patient or public involvement.

3. Results

The monthly outpatient numbers noted in refractive, cataract and retinal subspecialties in Wuhan, Beijing, Shanghai, Shenyang, Yili, Urumqi, China within 2019 and 2020 are shown in Fig. 1 and surgery numbers in Fig. 2, displayed against the changing trend of newly confirmed COVID-19 cases.

There is an obvious decline in the number of patients attending to hospital in SP1 among six cities. As expected, a rise in COVID-19

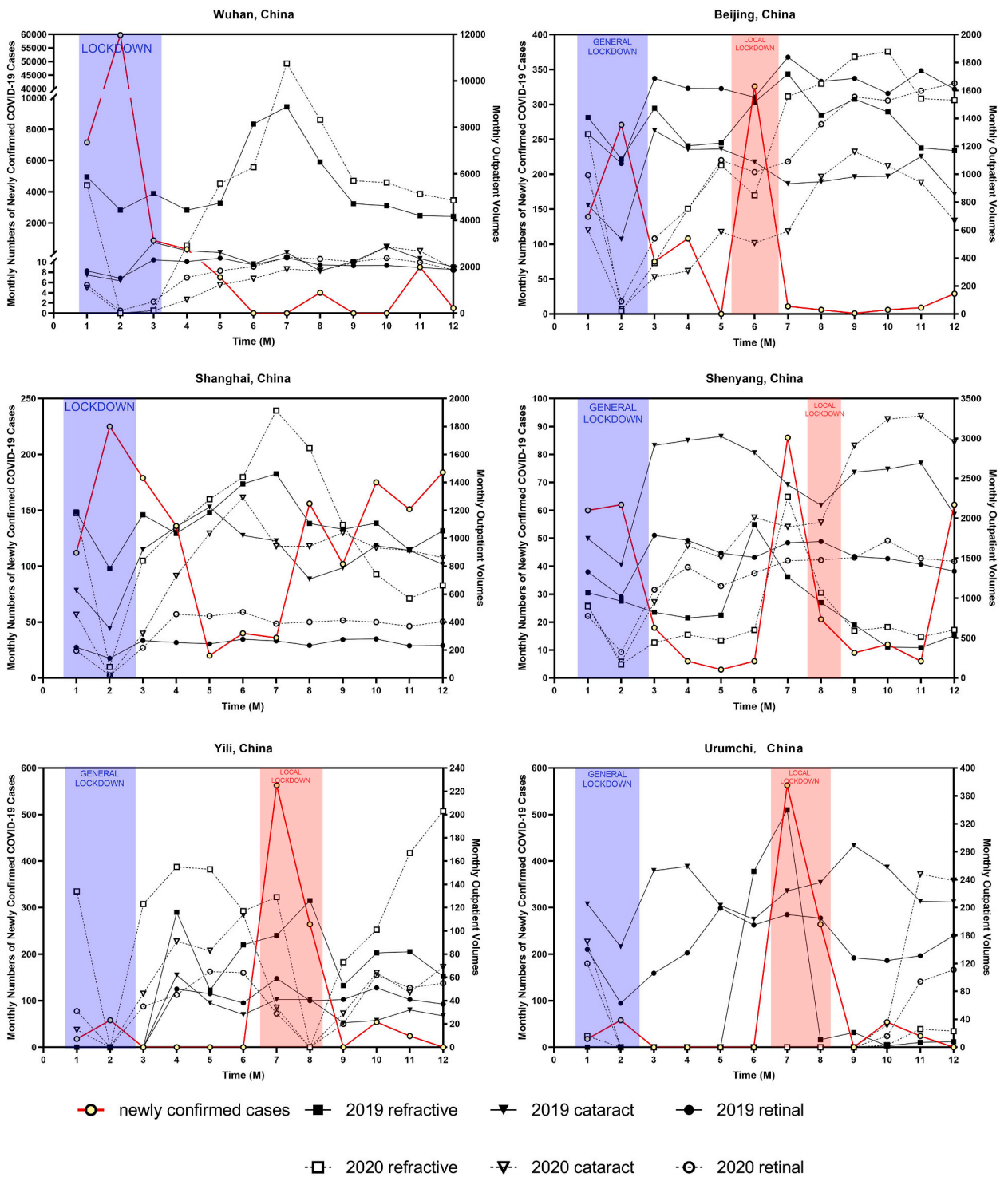


Fig. 1. Outpatient volumes of refractive, cataract and retinal from January 2019 to December 2020 in Wuhan, Beijing, Shanghai, Shenyang, Yili, Urumqi, China.

The blue box refers to the COVID-19 related national lockdown period, and the pink box refers to a local lockdown period. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

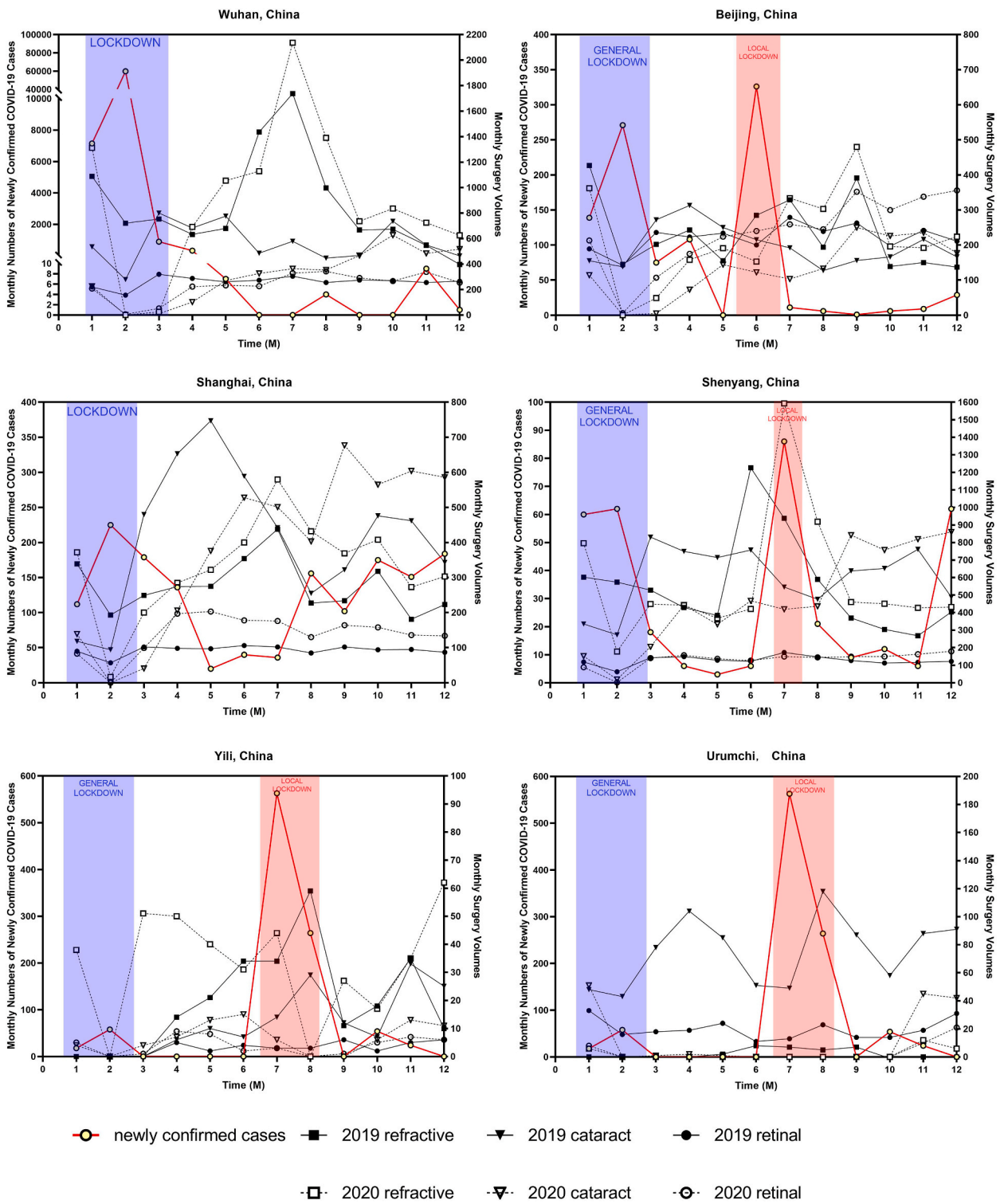


Fig. 2. Surgery volumes of refractive, cataract and retinal from January 2019 to December 2020 in Wuhan, Beijing, Shanghai, Shenyang, Yili, Urumqi, China.

The blue box refers to the COVID-19 related national lockdown period, and the pink box refers to a local lockdown period. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

cases corresponded with a decrease in outpatient attendance and a corresponding decrease in surgical numbers. Specifically, refractive surgery changed by -16.55% to -47.77% compared to 2019, cataract surgery changed by -73.87% to -85.43% , retinal surgery changed by -26.91% to -61.78% . Among these Chinese cities, Wuhan is the most affected. After the announcement of a stringent lockdown in Wuhan (23rd January 2020), which represented the start of a national-wide lockdown in China, we observed the volume of both outpatient and surgery reached its nadir (nearly to zero) in February.

After the COVID-19 pandemic lockdown was lifted, the surgical numbers in these three sub-specialties show a gradual increase. Besides, Beijing, Shenyang, Yili and Urumqi experienced another local outbreak, and a local lockdown was implemented over again. At this time, the outpatient and surgery number in Beijing experienced a slightly decrease; while in Shenyang, the outpatient and surgery number showed no significant decline and even a distinct increase in refractive number, with a 56.66% increase in refractive surgery; in Yili, both outpatient and surgery number experienced another dip in August (Figs. 1 and 2); and due to the pandemic and the hospital management policy, Urumqi Aier Eye Hospital temporarily suspended operations from February to October.

Generally speaking, apart from the lockdown period, the outpatient and surgery number mainly change in line with the number of 2019. Compared with 2019, the number of refractive surgery in Wuhan, Beijing, Shanghai, Shenyang, Yili and Urumqi changed by 3.25%, -5.57% , 19.85%, 4.83%, 67.52% and -18.64% ; and cataract surgery number changed by -44.95% , -33.09% , -7.13% , -20.33% , -26.38% and -44.76% ; retinal surgery number changed by -11.83% , 6.03%, 48.70%, 4.13%, 30.56% and -83.40% (Table 1).

The monthly surgical numbers noted in the refractive and cataract subspecialties in Nashville, (USA); Frankfurt, (Germany); Madrid, (Spain); and Milan, (Italy) within 2020 and 2019 were displayed in Fig. 3, displayed against the changing trend of newly

Table 1
The surgery volumes' change rates of 2020, compared with 2019.

	Q 1	Q 2	Q 3	Q 4	Overall
Wuhan, China					
refractive	-47.77%	4.62%	25.33%	35.26%	3.25%
cataract	$-85.43\%^*$	$-64.08\%^*$	-20.72%	-7.03%	$-44.95\%^*$
retinal	-61.78%	$-16.73\%^*$	15.38%	8.61%	-11.83%
Beijing, China					
refractive	-46.83%	-26.61%	22.23%	43.43%*	-5.57%
cataract	$-78.76\%^*$	$-56.43\%^*$	2.32%	16.42%	$-33.09\%^*$
retinal	-42.50%	-2.74%	9.60%	52.92%*	6.03%
Shanghai, China					
refractive	-24.66%	11.52%	53.76%	36.22%	19.85%
cataract	-73.99%	$-44.19\%^*$	55.15%	37.00%	-7.13%
retinal	-26.91%	92.03%*	62.63%*	55.07%*	48.70%*
Shenyang, China					
refractive	-16.55%	-39.60%	56.66%	34.27%*	4.83%
cataract	-73.87%	$-44.01\%^*$	2.23%	28.14%	-20.33%
retinal	-28.62%	4.99%	-0.89%	39.77%*	4.13%
Average of the four cities above					
refractive	-33.95%	-12.52%	39.50%	37.30%*	5.59%
cataract	-78.01%	$-52.18\%^*$	9.74%	18.63%	-26.38%
retinal	-39.95%	19.39%	21.68%*	39.09%*	11.76%
Yili, China					
refractive	–	75.36%	-31.73%	81.60%	67.52%
cataract	–	52.17%	$-89.09\%^*$	-53.85%	-44.76%
retinal	–	72.73%	-66.67%	38.46%	30.56%
Urumqi, China					
refractive	–	-100.00%	$-100.00\%^*$	170.00%	-18.64%
cataract	-69.23%	$-98.75\%^*$	$-100.00\%^*$	$-63.29\%^*$	$-84.22\%^*$
retinal	$-88.06\%^*$	$-100.00\%^*$	$-100.00\%^*$	-51.56%	$-83.40\%^*$
Nashville, America					
refractive	13.78%	-15.55%	37.67%	102.19%*	30.43%
cataract	$-26.56\%^*$	-33.33%	-9.18%	-20.31%	$-22.64\%^*$
Frankfurt, Germany					
refractive	28.84%	-19.15%	27.22%	25.05%	15.35%
cataract	37.50%	-14.58%	25.00%	53.13%	27.97%
Madrid, Spain					
refractive	-8.79%	-46.24%	19.09%	3.78%	-8.62%
cataract	-13.59%	-51.60%	17.24%	11.45%	-10.58%
Milan, Italy					
refractive	-21.32%	-15.63%	34.88%	-30.95%	-13.71%
cataract	-38.29%	-40.10%	-0.45%	12.26%	-20.49%

Note: We define four quarters of the year as four study periods (Q1 refers to January–March, Q2 refers to April–June, Q3 refers to July–September, Q4 refers to October–December) to allow for comparisons between 2020 and 2019, and the rate of change over the four periods of 2020 and 2019 was calculated by the formula: (the surgical volume of 2019 (Vol2019) - the surgical volume of 2020 (Vol2020))/Vol2019. Besides, Yili Aier Eye Hospital haven't opened until April 2019, thus the number in Yili during SP1 is incomparable.

*means significant difference was found between the surgery volumes between 2020 and 2019.

confirmed COVID-19 cases.

Obviously, in Nashville, America, there is a slightly decline of the refractive and cataract surgery volume in March, with a 26.56% decrease of cataract surgery in SP1. After the American Academy of Ophthalmology (AAO) suggesting that all ophthalmologists cease providing any treatment other than urgent or emergent care in 18th March 2020 [12], we observed the smallest surgery volume in April, with a 15.55% decrease in refractive surgery and 33.33% decrease in cataract surgery. And with the re-opening recommendations issued by the Centers for Medicare and Medicaid Services (CMS) in 19th April, some hospitals set about resuming their routine procedures gradually. Corresponding to that, the cataract and refractive volumes of Nashville begun to climb in May and reach its peak in June.

In Frankfurt, Germany, the refractive and cataract surgery numbers display a sharp decrease in April, with a 19.15% decrease of refractive surgery, and a 14.58% decrease of cataract surgery in SP2. After that, the surgical number gradually resume to normal and surpass that of 2019.

In Madrid, Spain, it is not difficult to discover that the refractive and cataract surgery volumes reach the nadir in April, with a 46.24% decrease of refractive surgery, and a 51.6% decrease of cataract surgery in SP2, and then gradual climb to almost the same volume of 2019, which is immune to the increase of COVID-19 numbers.

In Milan, Italy, with the Italian government issued an order that imposed severely confinement on population mobility on 9th March 2020 [13], a reduction of cataract and refractive surgery volumes was displayed in March, with a 21.32% decrease of refractive surgery, and a 38.29% decrease of cataract surgery in SP1. After the lockdown, the surgical volumes of 2020 begun to change in line with that in 2019.

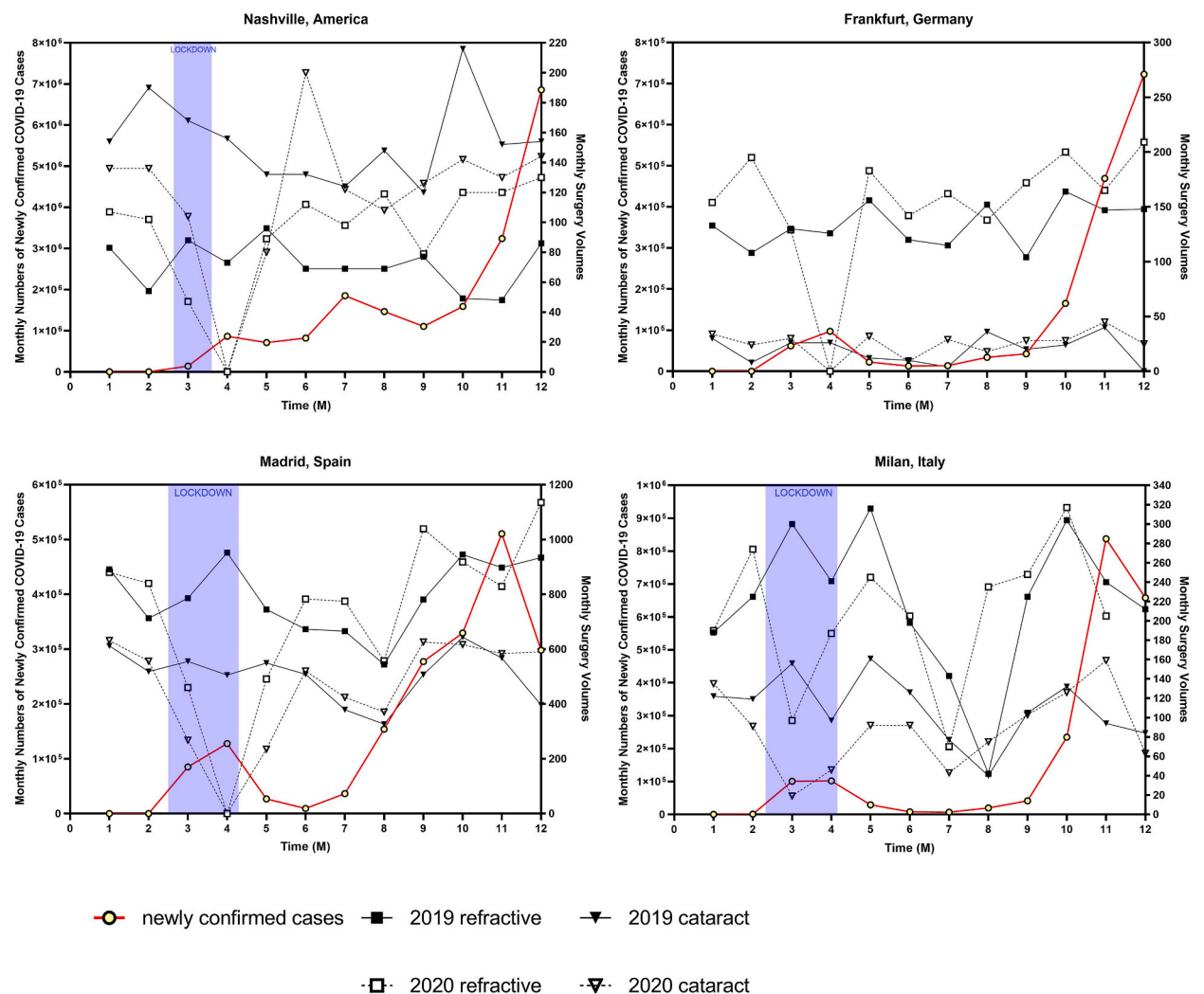


Fig. 3. Surgery volumes of refractive and cataract from January 2019 to December 2020 in Nashville, (USA); Frankfurt, (Germany); Madrid, (Spain); and Milan, (Italy). The blue box refers to the COVID-19 related lockdown period. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Overall, compared with 2019, the number of refractive surgery in Nashville, (USA); Frankfurt, (Germany); Madrid, (Spain); and Milan, (Italy) respectively changed by 30.43%, 15.35%,-8.62% and -13.71%; and cataract surgery number changed by -22.64%, 27.97%, -10.58%, -20.49%.

In addition, we have gathered the optometry and glass matching statistics from five hospitals in China (Wuhan, Beijing, Shanghai, Shenyang, Yili), and depict a stacked histogram (Fig. 4/5). It is observed that the optometry outpatient volumes showed a negative change (floated from -12% to -95%) from January to April and a positive change (floated from +7% to +50%) since May (Fig. 4). While the glasses matching volumes present a negative change (floated from -5% to 95%) from January to August and a positive change (floated from 3% to 27%) since September (Fig. 4).

4. Discussion

Since the outbreak of COVID-19 pandemic, proper diagnosis and treatment of many diseases have faced serious challenges [3,14]. In trying to figure out the effect of the pandemic on ophthalmology clinical activities, we depict the changing trends of refractive, cataract and retinal outpatient and surgery volumes presenting to ten Aier Eye Hospitals during COVID-19 pandemic, and compare the monthly volumes during 2020 with the corresponding volumes of the previous year. Which is the first comprehensive global multi-subspecialty study up to now.

Encountered the first attack of COVID-19 pandemic, the ocular practice around the world were badly affected. An Italian tertiary

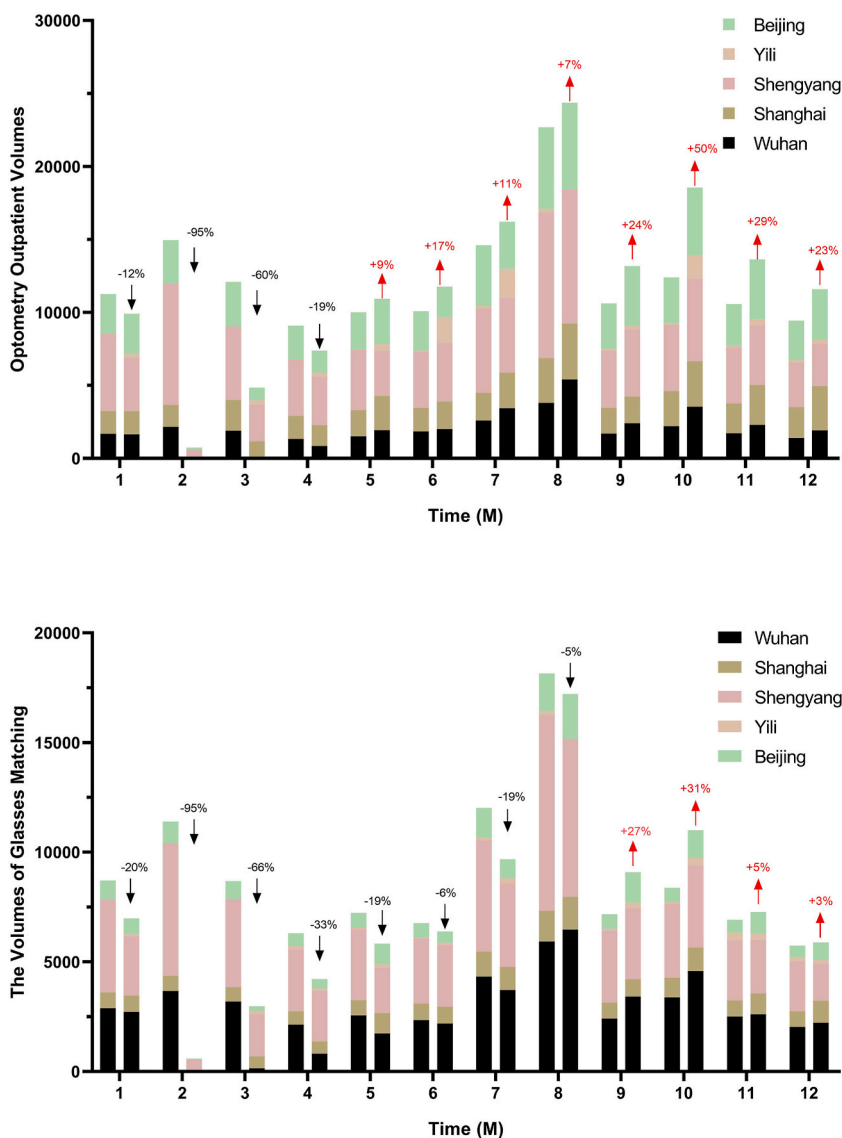


Fig. 4. The monthly variation of optometry outpatient volumes and glasses matching volumes between 2020 and 2019 among five cities in China.

eye center reviewed their OED during their national lockdown period (from March 9th to May 3rd, 2020) and found that the ocular visits followed an inversely proportional trend if compared with newly confirmed COVID-19 cases. A 59% drop of OED visits was reported and accompanied by an increase in urgency and severity of diagnosed disease [8]. Our research confirms this change on a larger scale: the refractive, cataract and retinal visit numbers present a decline trend since the beginning of 2020 year and reach its nadir in February in six Chinese hospitals. While in America, Germany, Spain, and Italy, the nadir was appeared in April, which was in step with the spread trends of COVID-19. We propose possible reasons explaining for these decreases. For one thing, for the fear of contracting the COVID-19 infection, it seems less likely for people to present to hospital when contagion reached its maximum spread. Besides, the government policy, like transport restriction, home isolation measures and series campaigns to raise public awareness may also account for the decrease, since we observed sharp declines after governments' lockdown policy.

After the national lockdown period, though there still showed signs of endemicity and surges in the number of newly confirmed COVID-19 cases, the ocular visit numbers were relatively stable. Interestingly, during an outbreak in Shenyang in July, a decrease in cataract and retinal volumes were observed while an increase in refractive volume was noticed. It is possible that the delay in the conduction of the College Entrance Examination (generally carried out in June, but delay beyond July 2020) partly accounted for this increase, as the population subgroup that generally opts for these procedures was rendered free consequent to the delayed exam. Besides, unlike the earlier lockdowns, there was no restriction on transport in Shenyang during the localized outbreak. A Polish study focus on the impact of three waves of the COVID-19 on cataract surgery and found that the cataract surgery volume has been steadily increasing since the first wave and the second and third waves did not cause an obvious decline in comparison to the inter-wave periods [15]. This may be related to an increased vaccination coverage and the consequent reduction of COVID-19 fear [16]. Given the better knowledge of the COVID-19 disease and the release of series guidelines directing at pandemic prevention and control, ocular practice gradually recover and step into a "new normal".

1 COVID-19 AND CATARACT SURGERY

It is not difficult to see that cataract is the sub-specialty that has been most affected by COVID-19 pandemic. The cause of the decrease in the number of cataract surgeries may be complex. One factor that potentially limit patient's visits was obligatory COVID-19 test performed before admission and followed by a prolonged visits. Besides the legally bound restrictions, patients' attitudes towards cataract surgery also accounts for this decrease. The cataract patients are primarily older population and face a higher COVID-19-related mortality[17]. They probably preferred staying at home rather than attending hospitals wherein they would have been at high risk of contracting the infection [18]. Additionally, vision loss due to cataracts usually progresses slowly, unlike the sharp vision decline caused by some retinal disease like retinal detachment. Hence, cataract patients probably adjusted to their gradually diminishing vision and did not timely seek medical help.

However, attention needs to be paid to the decreased number of performed cataract surgeries. Visual impairment due to cataracts can result in increased risk of hip fractures due to falls, and higher risk of depression and dementia [19–21]. Up to now, numerous recommendations have been provided in order to safely resume elective services and tackle the COVID-19 cataract backlog [22,23], and many clinical centers provide a safe model for the resumption of elective cataract surgery in a COVID-19 era [24,25]. The recommended changes included reducing the visit number through optimizing the procedures with the introduction of the same-day preoperative assessment and testing and reduction of postoperative follow-up. Another recommendation is encouraging simultaneous bilateral cataract surgeries, which is more applicable than ever in the pandemic era [26]. It effectively reduces COVID-19 infection exposure risk and provides faster binocular recovery of vision and higher cost efficiency for patients [27].

2 COVID-19 AND RETINAL SURGERY

During the COVID-19 lockdown period, we observed a 39.95% (range from 26.91% to –61.78%) drop in the retinal surgery volumes within four Chinese hospitals. Several studies reported an approximately 53%–66% decrease in retinal detachment (RD) patients presenting to ophthalmology clinics [10,28–30]. Likewise, a drop of 56%–62% in RD repair surgeries was observed. Besides, the decrease in medical visits seems accompanied with an increased severity of the disease, since the proportion of patients with macula-on RD and proliferative vitreoretinopathy are higher than before. Since the progression of the disease is mainly irreversible and at high risk of blinding, it is of great significance to reorganize ophthalmology practice patterns and provide appropriate medical support under such a special circumstance. Sommer et al. proved that telemedicine can be useful for diagnosing, screening and management of anterior segment problems, glaucoma and retinal disease [31]. Since the fear of contracting COVID-19 disease and the implementation of lockdown policy during the COVID-19 pandemic period seems to be the main reason for patients' unwillingness to attending hospitals, tele-ophthalmology can play a significant role in managing many ocular conditions, especially ocular emergencies. Telemedicine could identify at-high-risk patients and encourage them to attend hospital, which not only decreases unnecessary visits but also reduces delayed presentations. Moreover, phacovitrectomy instead of vitrectomy is encouraged to be performed as the treatment for many posterior segment disorders during such a special period. For one thing, nuclear sclerotic cataract formation is one of the most common complications of vitrectomy [32]. The vision loss caused by post-vitrectomy cataract formation and the prolonged duration of COVID-19 pandemic, even non-emergent cataract surgeries may be inevitable to maintain the quality of life. Hence, some scholars think it reasonable to perform joint operations instead of vitrectomy alone whenever possible to reduce the number of visits and the use of personal protective equipment [33,34].

3 COVID-19 AND REFRACTIVE SURGERY

We noted a slightly raise in refractive surgery volumes among five countries during the whole year. The average data collected from the EUROCOVCAT Group also reveals an obvious growth of around 25% in the volume of patients presenting for refractive surgery [35]. As regards the reasons for this increase, there are several hypotheses. First of all, unlike cataract and retinal disease patients, people who wanna to undergo a refractive surgery are usually younger and less afraid of the SARS-COV-2 virus. Thus, their surgical schedule may not be seriously affected by the pandemic. Secondly, with wearing masks has become one of the most important measures for COVID-19 pandemic prevention and control [36], new problems began to emerge in those wearing spectacles - that is fogging glasses [37,38]. And as wearing masks gradually become a daily necessity, it is likely to continue to drive the demand for refractive surgery due to glass fogging at least in the near future. Besides, contact lens are also a mainstream way of vision correction in addition to spectacles [39]. Although there is no definite relationship between contact lens use and COVID-19 infection [40], concerns still existed due to the fact that SARS-COV-2 has been isolated in tears and conjunctival secretions and also that the virus can be transferred through direct or indirect contact [41,42], and thus may be transferred to contact lens during their application and removal. This could be a reasonable argument for the permanent correction of refractive errors with surgery. Finally, owing to the "down time" people had from work and travelling restrictions during the lockdown period, they might choose to spend their unoccupied time and money on their eyesight instead. Hence, it is imperative to increase personnel and material input to cope with the potential demand of refractive surgery and more attention needs to be paid to the management of postoperative patients and contact lens wearers to avoid infection.

4 COVID-19 AND MYOPIA MANAGEMENT

From the optometry data gathered in five Chinese hospitals, a positive change in optometry outpatient numbers and glasses matching volumes can be observed, through which we can preliminarily conclude that the COVID-19 pandemic might have a potential stimulative effect on refractive error. Several studies with definitive clinical evidence also observed an accelerated progress in myopia onset and development [43,44]. As increased outdoor activities proved effective on the control of myopia onset and myopia shift in recent years [45,46], the limited outdoor time and prolonged near work (such as online courses) during COVID-19 lockdown period could partly account for the accelerated myopic onset and progression [47]. Yet household quarantining and school closures against the pandemic will not last forever, the increasing adoption and reliance on digital devices, as well as behavioural changes resulting from extended home confinement, may have long-lasting effects on myopia progression in the population. To mitigate the consequences of home confinement, the government, community, school and parents need to be cautious of the downside of the situation and take effective measures, such as establishing active communication patterns and assisting children in developing self-discipline skills [48].

As for the limits of our study, several points should be noted. First, restricted to the difference of patients' volume of each hospital, the ten hospitals/clinics enrolled in this study may not be representative enough of the local situation. But the strength is that they are parts of the same global chain of eye hospitals, which share uniform assessment principals, and self-controls were used to reduce the influence of other confounding factors. Besides, when analyzing the effect of COVID-19 pandemic on cataract surgery, we haven't taken the uneven CRS levels between different regions into consideration. As for refractive surgery, we haven't thought over the impact of the proportion of patients with goggles in different regions as well as the previous surgery volumes in recent few years. In regard to retinal surgery, we didn't subdivided it into specific disease like diabetic retinopathy, macular disease, retinal detachment, etc due to the study design (audit rather than casesheets analysis). Last, due to the retrospective nature of the study, the study is inevitable affected by the problem of incomplete data, like the severity of the eye disease and the general condition, thus some relevant factors cannot be explored in depth.

5. Conclusion

In conclusion, in this global chain of eye care units, the visit volumes of three ophthalmic sub-specialties changed significantly with the spread and subside of COVID-19 pandemic. Among them, cataract surgery was the most affected sub-specialty, retinal surgery was the earliest to show a trend towards normal volume, while refractive surgery demonstrated the greatest potential for continuing growth in the near future. Besides, there was an upward trend in optometry outpatient attendance, which indicates an accelerated myopic progression during the COVID-19 lockdown period. Increasing the personnel and material input into refractive and optometry clinics to cope with the increased demand is necessary. Furthermore, myopia screening work is needed to be launched and myopic progression should be considered and managed when a lockdown is imposed in the future.

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Data availability statement

The data associated with this study are not publicly available due to privacy or ethical restrictions, but they are available from the corresponding author upon reasonable request.

CRediT authorship contribution statement

Suowang Zhou: Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Chloe Mengdi Chen:** Resources, Investigation, Formal analysis, Data curation. **Chong Shen:** Investigation, Formal analysis, Data curation. **Hui Liu:** Investigation, Data curation. **Jianheng Liang:** Software, Formal analysis, Data curation. **Lijing Zhou:** Software, Data curation. **Haokun Qu:** Investigation, Data curation. **Xu Chen:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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