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China's experience in COVID-19 prevention and control among children in its different regions

Q. LUO[1], L. YUAN[2], J. ZHANG[3], W. WEI[4], W. XIANG[4], J.-B. SHAO[5], L.-C. FAN[4], L. LI[4], X.-W. ZHAI[6], X.-B. ZHANG[6], A.-F. ZHOU[5], G.-Y. HUANG[6], S. GU[4]

[1]Department of Research Service, Hainan Women and Children's Medical Center, Haikou, China
[2]Hospital Office, Children's Hospital of Fudan University, Shanghai, China
[3]Medical Department, Wuhan Children's Hospital, Wuhan, China
[4]Department of Pediatrics, Hainan Women and Children's Medical Center, Haikou, China
[5]Hospital Office, Wuhan Children's Hospital, Wuhan, China
[6]Department of Pediatrics, Children's Hospital of Fudan University, Shanghai, China

Qing Luo, Lin Yuan, and Jie Zhang contributed equally to this work

Abstract. – OBJECTIVE: To summarize the experience of three Chinese cities (Wuhan, Shanghai and Haikou) and provide a reference for global efforts to combat COVID-19 spread among children.

MATERIALS AND METHODS: Through collecting the measures and outcomes of preventing and controlling COVID-19 in China's three hospitals, we compared the effect of different strategies.

RESULTS: From January to March 2020, the number of suspected and confirmed COVID-19 cases in Wuhan increased exponentially, and Wuhan Children's Hospital as a whole was transformed into a designated quarantine and treatment facility, which is the "Wuhan Model". Shanghai has more children's hospitals with better capabilities to tackle public health emergency. Besides, it is far away from Wuhan and had a small caseload. Children's Hospital of Fudan University, a facility in Shanghai to treat pediatric infectious diseases, is famous for its well-equipped building for infectious disease treatment and professional medical team, and therefore no major transformation was required. That is the "Shanghai Model". Haikou is located on an island. Amid the outbreak, large numbers of tourists and travelers from Hubei had already arrived in Haikou. Hainan Women and Children's Medical Center, as the only pediatric care hospital in Hainan Province, did not have a separate building for infectious disease treatment. After a citywide survey of the medical resources and facilities available, a temporarily idle hospital 3 kilometers away from Hainan Women and Children's Medical Center was requisitioned as the quarantine and treatment facility for pediatric cases. That is the "Hainan Model". The three models enabled the treatment of all suspected and confirmed cases and no fatality was reported.

CONCLUSIONS: The COVID-19 coping strategies for children should be designed according to the existing conditions of the local children's hospitals and the risk levels of the epidemic.

Key Words:
COVID-19, Pneumonia, Prevention and control, Children, China

Introduction

In December 2019, COVID-19 began to circulate in Wuhan City, Hubei Province. It was detected on January 7, 2020 as an acute respiratory infectious disease. It was included in the Class B infectious diseases stipulated in the Law of the People's Republic of China on the Prevention and Treatment of Infectious Diseases, but managed as a Class A infectious disease. With its transmission into many areas of China, infections among infants and children were also diagnosed. It was reported that among the pediatric cases, the youngest was a 30-hour old newborn, and the oldest was 17 years old[1]. On February 8, Wuhan Children's Hospital reported China's first severe pediatric COVID-19 case. Diagnosis and Treatment Program for Pneumonia Infected by the Novel Coronavirus (trial 5th Edition) issued in China made it clear that people of all age groups are susceptible to COVID-19. Children, as a

Corresponding Authors: Aifen Zhou, MD; e-mail: april1972@163.com
Guoying Huang, MD; e-mail: gyhuang@shmu.edu.cn
ShuoGu, MD; e-mail: gushuo007@163.com

special group, have different immune defense responses from adults, especially in the clinical manifestations and treatment responses[2]. As many non-COVID-19 pediatric patients also exhibit symptoms of fever and cough, greater challenges exist in every aspect of COVID-19 prevention and control among children. To better combat COVID-19, children's medical centers in different regions of China have worked out different strategies in accordance with the local severity and their own treatment capabilities. We chose three cities representing three regions in China: Wuhan (central region of China), Shanghai (eastern region of China) and Hainan (southern region of China), and their experience is summarized as follows.

Materials and Methods

Sources of Data

We collected the basic information from Wuhan Children's Hospital, Hainan Women and Children's Medical Center and Children's Hospital of Fudan University about their responses to COVID-19, including preparations, patient admission and treatment, and follow-ups, as well as the treatment outcomes.

Methods

Through collecting the different COVID-19 coping strategies from three Chinese cities (Wuhan, Shanghai and Haikou) with different outbreak severity and analyzing their outcomes, we summarized their experience.

Statistical Analysis

Based on the collected data, an analysis is made on the pediatric cases admitted in the above three hospitals, including the gender, average age and days of hospitalization of both the suspected and confirmed cases.

Results

Basic Facts of the Three Regions and Their Child Population

Wuhan is located in the central part of China with convenient land and water transport. It has a population smaller than Shanghai but much larger than Haikou. Shanghai is situated in the Yangtze River Delta, with a robust economy and the highest population density and GDP among the three. Haikou is the capital of Hainan Province with the smallest land size and GDP. Besides, Qiongzhou Strait on its north makes a natural isolation barrier from China's mainland (Table I).

Coping Strategies Adopted by Children's Hospitals in Different Regions

Wuhan was the epicenter of the pandemic, and Wuhan Children's Hospital was the only designated hospital for pediatric COVID-19 cases. During the outbreak, besides treating its own patients and delivering daily medical services, it actively joined the citywide efforts to control the spread of COVID-19 among children, and provided guidance to some quarantine facilities. Shanghai and Hainan, although located in different regions, mainly dealt with imported cases and local cluster cases, and the two hospitals had lighter tasks because of the smaller number of pediatric cases. In view of the local outbreak severity and their existing treatment capabilities, Wuhan Children's Hospital, Children's Hospital of Fudan University and Hainan Women and Children's Medical Center worked out different coping strategies (Table II).

Basic Facts

Wuhan Children's Hospital is the largest one, followed by Children's Hospital of Fudan University. Both have a separate building for the infection department and are locally the only designated hospital for pediatric COVID-19 cases.

Table I. Basic facts of the three regions and their child population.

Region	Total population (10,000)	Child population (n,%)	Regional area (sq. km)	GDP in 2019 (RMB 100 million)
Wuhan	853.65	132.29 (15.50)	8494	17157
Shanghai	1455.13	173.05 (11.89)	6340	38155
Haikou	230.23	38.61 (16.77)	2305	5309

Note: The statistics of the total population and child population are from 2018. And children in Wuhan and Shanghai are aged from 0-17 years old and 0-14 years old in Haikou.

Table II. Prevention and control strategies for children in different regions.

Measure	Wuhan Children's Hospital	Children's Hospital of Fudan University	Hainan Women and Children's Medical Center
Basic facts			
Total beds	1,588	800	500
Separate infection building	Yes	Yes	No
Designated facility for suspected cases	Yes	Yes	Yes
Designated facility for confirmed cases	Yes	Yes	No
Preparations			
Site transformation	10 wards, 262 beds	1 ward, 22 beds	1 ward, 34 beds
Staff preparation	555 doctors, 1023 nurses	25 doctors, 20 nurses	16 doctors, 37 nurses
Expert panel	Yes	Yes	Yes
Three-level echelon	Yes	Yes	Yes
PCR laboratory conditions			
Before transformation	No	Yes	No
After transformation	Yes	Yes	Yes
Admission and treatment			
Admission scope			
Suspected cases	Yes	Yes	Yes
Confirmed cases	Yes	Yes	No
National diagnosis and treatment plan	Yes	Yes	Yes
Quarantine in a single negative pressure room	No	Yes	No
Use of TCM	85%	100%	72.5%
Discharge and follow-up			
Quarantine and observation at a designated place	Yes	No	No
At-home quarantine	No	Yes	Yes
Telephone follow-up	Yes	Yes	Yes
Follow-up at the clinic	Yes	Yes	No

Hainan Women and Children's Medical Center, including its infection department, is housed in a single building and no quarantine and treatment conditions are available.

Preparations

Ward Preparation: Wuhan Children's Hospital and Children's Hospital of Fudan University transformed some of their non-infectious disease floors to meet the admission criteria for COVID-19 cases. Because Hainan Women and Children's Medical Center doesn't have a separate building for its infection department, with the coordination of the municipal government, an idle orthopedic hospital was requisitioned as the quarantine and treatment facility for suspected cases. Staff preparation: each of the three hospitals made staffing plans by building a pool of doctors and nurses from the respiratory, critical medicine and infection departments. A three-level echelon was formed, consisting of doctors and nurses currently working in the general internal medicine wards but with experience in the infection department and ICU. Meanwhile, a panel of senior experts from the infection, critical medicine, respiratory, radiology, nursing and lab testing departments was established. Laboratory test preparation: among the three hospitals, only Fudan University Children's Hospital has a standard P2 lab with the PCR test qualification and can directly carry out COVID-19 nucleic acid testing. The rest two hospitals had the testing capabilities only after the transformation.

Patient Admission and Treatment

Hainan Women and Children's Medical Center was the only designated medical facility to admit suspected pediatric cases, but if confirmed, they would be immediately transferred to a medical institution specializing in their treatment. Even though the other two hospitals served locally as the only facility to treat confirmed cases, they could also admit suspected cases. Several other local medical institutions also admitted suspected cases. However, if confirmed, they would be transferred to the two designated children's hospitals for treatment. As some pregnant women were infected in Wuhan, Wuhan Children's

Hospital also admitted suspected and confirmed newborn cases. All three hospitals followed the COVID-19 Diagnosis and Treatment Plan strictly. The patients were mostly given symptomatic treatment, and no special antiviral drugs but Traditional Chinese Medicine (TCM). Wuhan Children's Hospital and Hainan Women and Children's Hospital administered TCM to 85% and 72.5% of their patients respectively. However, Fudan University Children's Hospital administered TCM to 100% of their patients.

Hospital Discharge and Follow-Ups

Discharge criteria were standardized with reference to COVID-19 Diagnosis and Treatment Plan. However, a rehabilitation express system was set up in Wuhan, according to which, pediatric cases discharged were sent to a designated place for two-week quarantine by the healthcare workers of the district where they resided. In Shanghai, the discharged cases should spend two weeks in quarantine at home or a designated place, with a follow-up visit 14 days later. In Haikou, when the suspected cases were discharged, they should be quarantined at home, with regular follow-up phone calls in the next 3 months.

Admission Conditions in the Three Children's Hospitals

Wuhan, as the hardest-hit area, had the largest number of suspected and confirmed pediatric cases, mainly local ones. Besides, it was the only among the three cities to have severe and critical cases (12.6%). Shanghai and Haikou didn't have severe cases, and their suspected and confirmed cases were mainly imported from Wuhan or cluster cases through close contact with those imported cases. They had a smaller number of pediatric cases than Wuhan. On the whole, there was no gender difference between suspected cases and confirmed cases, and the average age was young. All the suspected and confirmed pediatric cases in the three hospitals were cured and discharged. The admission and treatment information of each hospital is broken down as follows (Table III).

Wuhan Children's Hospital

As of March 27, a total of 271 suspected COVID-19 pediatric cases were admitted, including 163 boys (60.15%) and 108 girls (39.85%). The oldest was 17 years old and the youngest 1 day old, averaging 3.19 years old. They were discharged from hospital after testing negative after 2 nucleic acid tests.

There were 500 confirmed pediatric cases, all local, including 297 boys (59.04%) and 203 girls (40.60%). The oldest was 17 years old, the youngest was one day old and their average age was 5.1 years. There were 437 common cases (87.40%), 46 severe cases (9.2%) and 17 critical cases (3.4%). All were cured and discharged from hospital.

Children's Hospital of Fudan University

As of March 13, a total of 63 suspected COVID-19 pediatric cases were admitted, including 35 boys (55.56%) and 28 girls (44.44%). The oldest and youngest were 13 years old and 6 months old respectively, and their average age was 4.51 years. There were 33 local cases (52.38%) and 30 imported cases (47.62%), all with

Table III. Admission conditions in the three children's hospitals.

Indicator	Wuhan Children's Hospital	Children's Hospital of Fudan University	Hainan Women and Children's Medical Center
Suspected cases	271	63	104
Male*	163	35	63
Female	108	25	41
Average age (y)	3.19	4.51	5.21
Average hospital stay (d)	10.79	3.35	2.57
Confirmed cases	500	11	1
Male*	297	6	1
Female	203	5	0
Average age (y)	5.10	5.77	0.53
Average hospital stay (d)	12.47	19.09	12
Maximum admissions a day	16	5	10
Maximum hospitalizations a day	262	14	22

* $p>0.05$.

a clear epidemic history such as traveling to the hotspots or having close contact with people from epidemic areas. The hospitalization lasted 3.35 days on average, and after they tested negative after 2 nucleic acid tests, they could be discharged from hospital.

11 pediatric cases were confirmed, including 6 boys (54.55%) and 5 girls (45.45%), among whom the oldest was 11 years and 6 months old, the youngest was 7 months and 9 days old, and their average age was 5.77 years. There were 8 local residents (72.73%) and 3 from Wuhan (27.27%). There were 6 mild cases (54.55%), 5 common cases (45.45%) and 0 severe case. All were cured and discharged from hospital. Their hospitalization lasted 19.09 days on average.

Hainan Women and Children's Medical Center

The quarantine wards were operational for 30 days, and a total of 104 suspected cases were admitted, including 63 boys (60.58%) and 41 girls (39.42%). There were 13 local cases (12.5%) and 91imported cases (87.5%). The oldest was 14 years old, the youngest was 3 years and 23 days old, and the average age was 5.21 years. The average hospitalization lasted 2.57 days. On average, 3 cases were admitted each day. However, over the 30 days, a maximum of 10 people was admitted in a single day.

The only one confirmed case, was a boy aged 6 months and 14 days. He was a mild case from local cluster infection, showing the symptoms of fever and cough. After being transferred to a designated hospital, he was given regular antiviral and symptomatic treatment. He was hospitalized for 12 days, discharged after meeting the criteria, and then quarantined for observation.

As of March 27, Wuhan Children's Hospital had been the main hospital for treating pediatric COVID-19 cases; Children's Hospital of Fudan University did not admit any new domestic cases and focused on treating imported cases from overseas; Hainan Women and Children's Medical Center pulled out of the designated facility for suspected cases on March 11.

Discussion

Since the outbreak of the COVID-19 pandemic, earlier reports have focused on middle-aged and elderly cases[3]. However, with the progression of the pandemic, an increasing number of pediatric cases were reported, including every age, even the newborn[4]. Besides, severe cases and fatalities were reported. As a result, pediatric cases have come under the spotlight. On March 3, 2020, China's National Health Commission issued COVID-19 Diagnosis and Treatment Plan (trial 7th Edition) in which the description of children's clinical manifestations became more detailed, for example, "the symptoms of some infected children and newborns could be atypical, like vomiting, diarrhea and other digestive tract symptoms or only mental weakness and shortness of breath". In the plan, severe adult and pediatric cases were defined separately. The standards for severe adult cases remained unchanged, but the standards for severe pediatric cases were added[5].

Wuhan Children's Hospital has recently reported a series of diseases caused by SARS-CoV-2 infection in children. Compared with infected adults, most infected children seemed to have a milder clinical process, and their asymptomatic infections were not uncommon. Determining the transmission potential of these asymptomatic patients was vital in formulating measures to control the pandemic[6]. Experts from Children's Hospital of Fudan University in Shanghai have found that the average incubation period of COVID-19 in children is longer than that in adults[7]. Children of all ages are sensitive to COVID-19, and no significant gender difference exists. Studies have shown that although the clinical manifestations of COVID-19 pediatric cases are not as serious as those in adult cases, young children, especially infants, are more vulnerable to COVID-19 infection[8].

From the above reports, we can see that the treatment of pediatric cases during the pandemic is complicated and should be given due attention. Based on its special nature, the treatment plans for children should have their own features in comparison with those for adults.

– The treatment plan for pediatric cases is in principle the same as that of adult cases. However, children's physical conditions should be taken into account: their immature autoimmune function, especially their relatively narrow trachea and bronchus and weak cough are more likely to cause airway obstruction, thus making the symptoms worsen. Therefore, medical observation, airway care and supportive treatment may be more important for pediatric cases. All these require professional pediatric care personnel and specific equipment;

– Young children need the company and attendance of their parents, and in this case a proper balance should be found between quarantine and parental care. Therefore, setting up designated hospitals for suspected and confirmed pediatric cases is a choice that local government and regional children's medical centers must make.

Children's hospitals in China have witnessed rapid development in recent years with government support, and infrastructure and facilities have improved markedly. However, specialized facilities and professional experience in infectious diseases prevention and control are still lacking on the whole. Some large hospitals in the first-tier cities may have improved after undergoing SARS and HFMD outbreaks, but most children's hospitals are not adequately prepared and need to take emergency prevention and control measures[9]. It is a grave challenge for them to quarantine and treat pediatric COVID-19 cases. They are confronted with several problems:

– Most children's hospitals do not have a separate building for infection diseases treatment, and they are basically operating at full capacity for regular patients. Therefore, how to achieve effective quarantine and control nosocomial infection is quite challenging;
– The layout of common wards in most hospitals does not meet the nosocomial infection control standards to admit infectious diseases patients, and need to be transformed. Basically, it is rare for children's hospitals to have surplus wards, and the existing wards need to be adjusted and merged to make room for transformation;
– At present, the newly built children's hospitals are mostly equipped with a central air-conditioning system, and therefore there are few special negative pressure wards. Even if there are any, the hospital's admission procedure often fails to meet the requirements of infectious disease control. Partial transformation can hardly meet the standard requirements of nosocomial infection control;
– If the whole children's hospital is cleared for transformation, the standards of nosocomial infection control may be met quickly, but this will disrupt the treatment for children with other diseases, and the service suspension for these patients will seriously threaten their lives.

During this COVID-19 pandemic, different regions of China have adopted different coping strategies. This paper selects three representative children's hospitals in three cities for analysis, and briefly calls them the Wuhan Model, Shanghai Model and Haikou Model. Wuhan was the hardest hit area and therefore a hotspot. In the face of a sharp increase in suspected and confirmed pediatric cases, Wuhan Children's Hospital took the most extreme measure, and transformed itself as a whole into a designated COVID-19 quarantine and treatment hospital. This is the Wuhan Model. Shanghai has more children's hospitals and relatively better capabilities for public health emergency response. Besides, it is far away from Wuhan and has a small caseload, so Children's Hospital of Fudan University was designated as the hospital for pediatric COVID-19 cases. Moreover, it has been the hospital in Shanghai to treat pediatric infectious diseases since its establishment. With a separate well-equipped building and a professional medical team, it could cope with more ease and no large-scale transformation was required. This is the Shanghai Model.

Compared with Shanghai, Haikou is located farther away from Wuhan, but when the outbreak occurred in the middle of the Spring Festival holiday, a large number of tourists and travelers from Hubei had already arrived. The Haikou-based Hainan Women and Children's Medical Center is the only children's hospital in Hainan Province. It has a fever clinic and four negative pressure wards, but no separate building for infection diseases treatment. On the whole, it is not properly equipped to admit pediatric COVID-19 cases. Therefore, considering the projected caseload and the existing number of other child patients in the hospital, under the guidance of Hainan provincial expert panel and with a citywide survey of the available medical resources and facilities, it took a unique emergency measure. A hospital which was 3 kilometers away and left idle temporarily was requisitioned as a quarantine and treatment facility for pediatric COVID-19 cases. This is the Hainan Model. Its implementation and outcome are presented earlier. The plan is executed in a rapid and effective fashion, ensuring the delivery of the daily service and meanwhile the treatment of pediatric COVID-19 cases in a designated facility. Judging from the current outcome of the above models, they played a decisive role in treating all the suspected and confirmed pediatric cases without any fatality.

The authors conclude that the coping strategies for pediatric COVID-19 cases need to be determined in light of the existing children's hospitals in different regions, and the pandemic trend needs to be scientifically analyzed. In high-risk areas with serious outbreaks, the Wuhan Model featuring the overall transformation of the children's hospital is a plan that has to be adopted in dealing with the crisis. However, in the low and middle-risk areas far from the epicenter, children's hospitals can act according to their own actual conditions. For instance, if they do not have a separate building for infection diseases treatment, they can rely on the administrative power of the local government to allocate medical resources, and the Hainan Model which requisitioned a temporarily idle hospital (small or medium-sized) in its proximity is worth consideration. In the long run, we strongly recommend the Shanghai Model under which a separate building within a provincial-level or relatively large children's hospital is available for children's public health response. This building can be used for treating common pediatric infectious diseases on a daily basis, while in the event of a serious epidemic outbreak, enough capacity can be provided for an influx of cases.

Conclusions

To sum up, during this COVID-19 outbreak, children's hospitals in different regions in China have adopted effective coping strategies which are distinct from one another. Despite the desirable results they have achieved, we should take a proactive approach and make early preparations for possible children-related public health emergency in the future.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Authors' Contribution

QL, LY, JZ and SG contributed to the literature search, data collection, data analysis, data interpretation, figures and writing of the article. WW, JBS, LCF, LL, XWZ and XBZ contributed to the data collection and data analysis. WX, SG, GYH and AFZ contributed to the study design and writing of the article. All authors read and approved the final draft.

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