Original Article

Effective multidimensional approach for practical management of the emergency department in a COVID-19 designated children's hospital in east China during the Omicron pandemic: a cross-sectional study

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Background: Characterized by rapid transmission but lower severity, the new Omicron wave brought about an acute increase in local corona virus disease 2019 (COVID-19) cases in Shanghai, followed by stricter infection prevention and control strategies. Inevitably, more time was required for emergency consultation and treatment of children with critical illnesses. Therefore, a multidimensional approach was designed to streamline the emergency service and reduce the incidence of nosocomial infection of sever acute respiratory syndrome coronavirus 2 (SARS-CoV-2) during the Omicron wave for the emergency department (ED) at the Children's Hospital of Fudan University (CHFU).

Methods: A multidimensional approach was implemented in the ED to help achieve a balance between the demand for emergency services and pandemic control, consisting of ED layout adjustment; electronic screening (E-screening) measures; standard management processes for patients, medical staff, and goods transfer; reliable disinfection measures; and a surveillance system for infection prevention and control. To evaluate the effect of the management strategy, the data on nosocomial infection cases and occupational exposure episodes among staff in the ED were collected. The demographic and clinical characteristics of level I/II children by the five-level pediatric triage tool and their mean duration of stay in the resuscitation room were collected.

Results: There were 12,114 ED visitors from March 1 to May 31 in 2022, among which 53.24% were medical emergencies (6,449/12,114) and 46.76% were surgical emergencies (5,665/12,114). Twenty-nine patients were sent to the buffer zone, four of whom were transferred to the pediatric intensive care unit (PICU) because of the critical situation. Six patients tested positive for COVID-19 after entering ED, including three in the buffer zone and three in the ED clinic, causing a temporary closure of the ED for disinfection. There were no reports on medical care delays, unintended deaths, staff with COVID-19 infection, or occupational exposures to COVID-19.

Conclusions: Our findings highlight the effectiveness of the multidimensional approach, which can simultaneously meet the emergency care needs of patients as well as pandemic prevention and control.

However, the results were obtained against the proportional decrease in clinic visitors due to the Shanghai lockdown. Dynamic assessment and further optimization may be adopted to cope with the pre-pandemic visit volume.

Keywords: Corona virus disease 2019 (COVID-19); Omicron; pediatric; emergency health service

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Introduction

As of late May 2022, the corona virus disease 2019 (COVID-19) pandemic had resulted in approximately 520 million cases and more than 6.2 million confirmed deaths (1). Omicron was a new variant of sever acute respiratory syndrome coronavirus 2 (SARS-CoV-2), first reported to the World Health Organization (WHO) on 24 November, 2021 (2-4). Since the first local Omicron case on 1 March 2022 in Shanghai, there have been more than 40,000 pediatric Omicron cases. The Omicron variant is more transmissible and has a higher risk of reinfection (5); its possible transmission pathways may include droplets, aerosols, physical contacts, and the digestive tract (6). An exponential increase in COVID-19 cases and a sharp rise in pediatric hospitalizations were observed (7,8). Though some children infected with Omicron developed severe conditions (requiring invasive ventilation, vasopressors, or extracorporeal membrane oxygenation) or death (9), the strain was less virulent than previous ones in terms of the ratio of severe cases to the total number of infected children (10,11). Besides COVID-19, children were always susceptible to other microbial infections at the same time due to their immature immune systems, which may also lead to severe symptoms.

Since the outbreak of COVID-19, multiple in-hospital infection control measures have been reported in response to the pandemic in China and abroad. In China, a two-wing model was devised in a designated hospital to address both the needs for COVID-19 treatment and emergency service, including a safe treatment environment for patients, an on-duty/on-standby workflow for medical staff, and a reliable surveillance system (12). In the United States, an ordering pathway to facilitate COVID-19 testing of caregivers of patients from the pediatric emergency department (ED) was implemented for infection prevention and bed management decisions at a tertiary children's hospital (13). A temperature and symptom screening process was established for staff and visitors in a pediatric ED to guarantee their safety during the pandemic while minimizing unintended consequences (14). In France, respiratory panel-based testing was implemented for the rapid differentiation between SARS-CoV-2 and other viral infections when children attended the ED (15).

The above strategies were put in place either for resolving single issues in a children's hospital or applying multidimensional approaches in a comprehensive hospital for both children and adults. However, experience in applying a multidimensional approach specialized for managing the pediatric ED is limited. Considering this, the Children's Hospital of Fudan University (CHFU) developed and implemented a multidimensional approach for all individuals entering our ED. Our goal was to guarantee normal emergency service conditions and the safety of patients and staff by minimizing unintended

Highlight box

Key findings

- A multidimensional approach might provide a balance between pediatric emergency care and pandemic prevention and control measures for Omicron.

What is known and what is new?

- Since the outbreak of COVID-19, multiple in-hospital infection control measures have been proven effective. The Omicron variant is more transmissible and re-infectable but less virulent. Children are susceptible to other microbial infections, which may also cause emergent and critical conditions.
- The proportions of critical pediatric patients did not change notably in the ED during Omicron. A multidimensional approach was shown to be effective in guaranteeing regular emergency service and conforming to nosocomial infection control at the same time.

What is the implication, and what should change now?

- Children with critical conditions have the priority to receive prompt treatment. Adjusting the layout and optimizing the approaches of management in pediatric ED are positive responses.

consequences such as extended waiting times, occupational exposures, and nosocomial infections associated with COVID-19. We present the following article in accordance with the STROBE reporting checklist (available at https://tp.amegroups.com/article/view/10.21037/tp-22-314/rc).

Methods

Study setting, design, and participants

The CHFU, a large tertiary children's hospital and a National Children's Medical Center in China, is the only designated hospital in Shanghai to treat children with infectious diseases, including the new-onset major ones. There were 31,867 ED visitors and nearly 85 emergency staff from March to May 2021. Efforts to implement the multidimensional approach for all visitors and staff in ED began on March 1, 2022. A cross-sectional study was conducted to evaluate the effect of the approach between March 1, 2022, and May 31, 2022. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). According to the guidelines set by CHFU Institutional Review Board, this is an observational study in response to a major pandemic, which is not required for the ethical review and inform consent.

Multidimensional approach for ED management (Figure 1)

Applying E-screening measures

In response to the pandemic, digital sentinels and infrared thermometers were assembled at the entrance of the hospital and all of its buildings. By scanning the health code, the digital sentinel, a hardware device, obtains real-time data from the big data center to verify visitors' health status information, including the latest nucleic acid test result and the health code color. The scanning result will be displayed on its screen, with voice reminders. The infrared thermometer, a non-contact infrared body thermometer, converts radiant power to an electrical signal via an infrared detector and then transmits the signal to a color display. The fever alarm alert may be triggered when the temperature is measured greater than or equal to 37.3 ℃.

The health code is a three-color QR code used as an e-passport reporting a person's health condition during the COVID-19 pandemic in China. All citizens in Shanghai can apply for it through Suishenban application (APP) authorized by the Shanghai Municipal Government. Five categories of people could be assigned a red code, including (I) those who tested positive in the preliminary polymerase chain reaction (PCR) screening and pooled sample testing, (II) confirmed COVID-19 cases, asymptomatic cases, and suspected cases, (III) close contacts, (IV) all people entering China through Shanghai (excluding those from Macao), and (V) all travelers to Shanghai from high-risk regions. Four categories of people will be assigned the yellow code, including (I) close contacts undergoing health monitoring after being lifted from isolation for medical observation, (II) secondary contacts, (III) all travelers to Shanghai from medium-risk regions, and (IV) those should have been tested (16-18).

All visitors and staff were required to have their health code and temperature checked by the digital sentry and infrared thermometer, respectively, when they entered the hospital and other sites at the hospital. Children with a red code were sent to the COVID-19 clinics; children with fever (greater than or equal to 37.3 ℃) and a green/yellow health code were referred to the fever clinic; non-febrile children with a green/yellow health code were triaged to the ED or outpatient clinic based on their conditions.

Redesigning the ED layout

The ED initially consisted of an emergency clinic, a preview area, a waiting area, resuscitation rooms, a debridement room, three observation rooms, an emergency ward, two personnel living rooms, two offices, and two warehouses. In response to the pandemic, the original ED was newly equipped with an emergency buffer zone, which was a separate area for children without a PCR test report but in need of emergency treatment (19), personal protective equipment (PPE) donning and doffing rooms, and a second ED, which was an independent standby area be utilized when the main ED was closed due to unpredicted COVID-19 cases. Independent from the main ED, the second ED, comprising a separate ventilation system, emergency clinics, resuscitation units, and an observation area, was set up as a backup emergency area. The second ED would be used if the main ED had to be temporarily closed for disinfection due to identified COVID-19 cases. Different colors were used to mark area divisions (20), with red denoting contaminated areas and pathways, yellow representing potentially contaminated areas, and green signifying clean areas and pathways.

The clean areas referred to personnel living rooms, offices, warehouses, and PPE-donning rooms. The potentially contaminated areas were set between the contaminated and clean areas, including PPE-doffing rooms

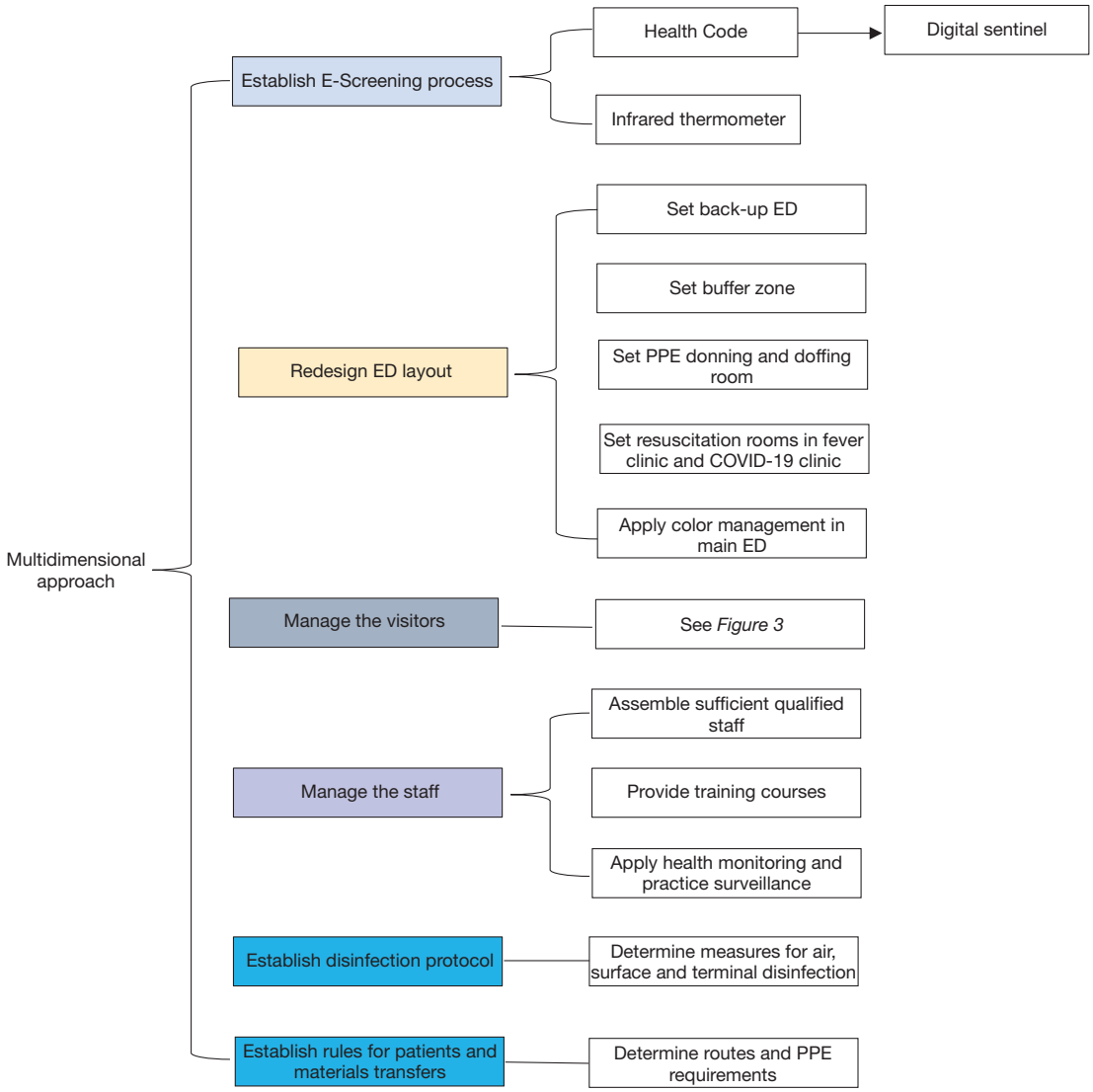

Figure 1 Multidimensional approach for the management of the pediatric ED in east China. The measures consisted of an ED layout adjustment; electronic screening (E-screening) measures; standard management processes for patients, medical staff, and goods transfer; reliable disinfection measures; and a surveillance system for infection prevention and control. ED, emergency department; E-screening, electronic screening; PCR, polymerase chain reaction; PPE, personal protective equipment; COVID-19, coronavirus disease 2019.

1 and 2. Staff who intended to remove PPE entered room 1 from the contaminated areas and left the doffing areas from room 2. The contaminated areas included the emergency buffer zone, emergency triage area, waiting area, emergency clinic, resuscitation room, debridement room, observation room, and emergency ward. The clean pathways were used for ED staff and clean materials deliveries, while the contaminated areas were for ED visitors and contaminated materials deliveries (*Figure 2*).

At the beginning of the COVID-19 pandemic in December 2019, there were only one outpatient clinic and one ED in the hospital. Subsequently, the fever and COVID-19 clinics were established. A resuscitation room was set up in both of these clinics, considering that emergency patients might be triaged to either of them. A rapid response team comprising anesthetists, nurses, and doctors with emergency and critical care experience was established to ensure the safety of our patients.

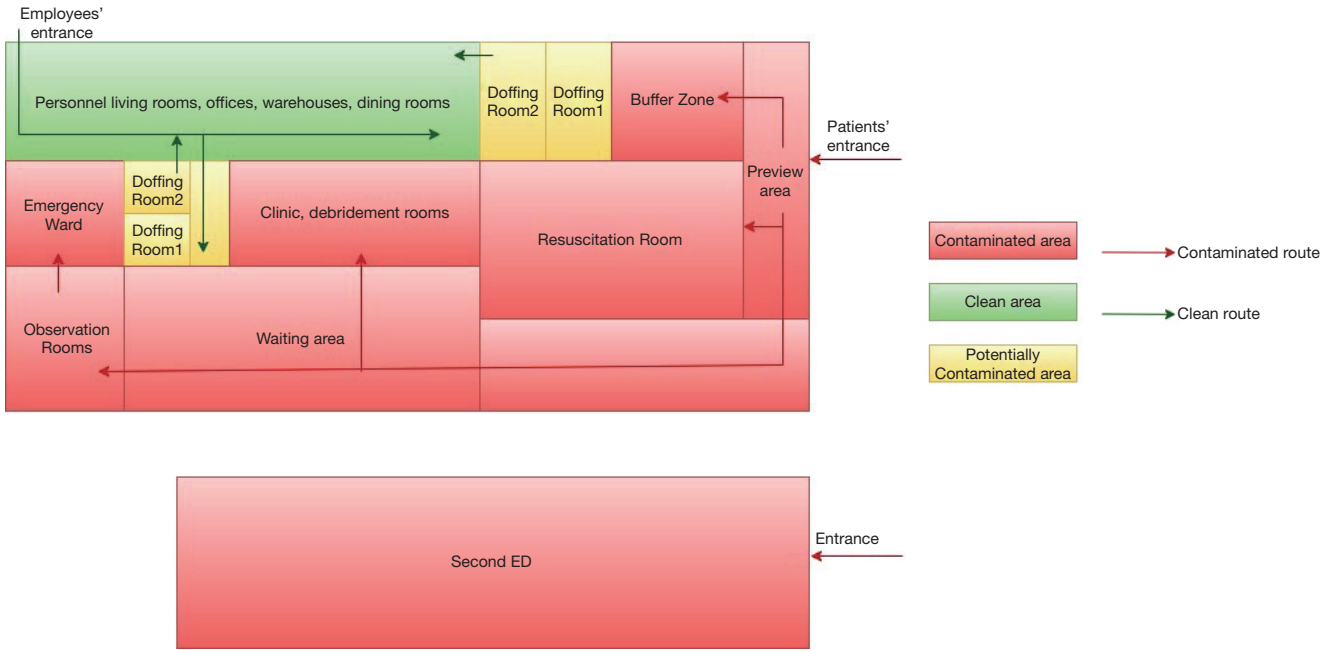

Figure 2 Plan of the ED layout. Different colors were used to mark area divisions, with red denoting contaminated areas and pathways, yellow denoting potentially contaminated areas, and green denoting clean areas and pathways. ED, emergency department.

Management of ED visitors

During the Omicron variant pandemic, our patients were either from the community or isolation sites (including cabin hospitals, quarantine hotels, and fever clinics of other hospitals). Children from isolation sites were transferred to our hospital via a negative-pressure ambulance and were seen in our hospital's COVID-19 clinic. Children from the community (>28 days) were checked by E-screening measures at the hospital entrance. Neonatal patients were separately previewed and treated. After being triaged to the ED, children were required to accept a second E-screening at the ED entrance and complete an epidemiological investigation, then they were previewed and triaged by nurses using the five-level pediatric triage tool (21).

For level I/II children according to the tool, those with 48-hour negative PCR tests were directly sent to the resuscitation room. After rapid assessment and treatment, a quick PCR test was given to decide their destination [the COVID-19 ward, the COVID-19 intensive care unit (ICU), the general ward, or the ICU]; those without 48-hour negative PCR tests were sent to the emergency buffer zone and underwent the same subsequent interventions as above. For level III to V children, if no 48-hour negative PCR tests were reported, pre-consultation antigen testing was performed at the ED entrance, and those with negative antigen test reports were sent to the ED waiting area. During the consultation, the patient would be prescribed a PCR test, and the subsequent triage was performed according to the result and the individual clinical condition (*Figure 3*).

When there was a confirmed case in the main ED (excluding the buffer zone), the second ED was immediately activated to continue to deal with new visitors. The main ED was temporarily closed, and the staff from the nosocomial infection control department arrived instantly to track the involved people and sites, collect samples for testing and perform terminal disinfection. Based on the results of the epidemiological investigations and the clinical condition, children originally in the main ED would be arranged to a specific isolation room under observation or discharged home.

Children directly transferred to the COVID-19 clinic, or the fever clinic were also previewed and triaged by nurses using the five-level pediatric triage tool. Level I/II children were immediately sent to the resuscitation room for rapid assessment and treatment.

Management of ED staff

Sufficient qualified staff including doctors, nurses, and other personnel were assembled, and training courses were

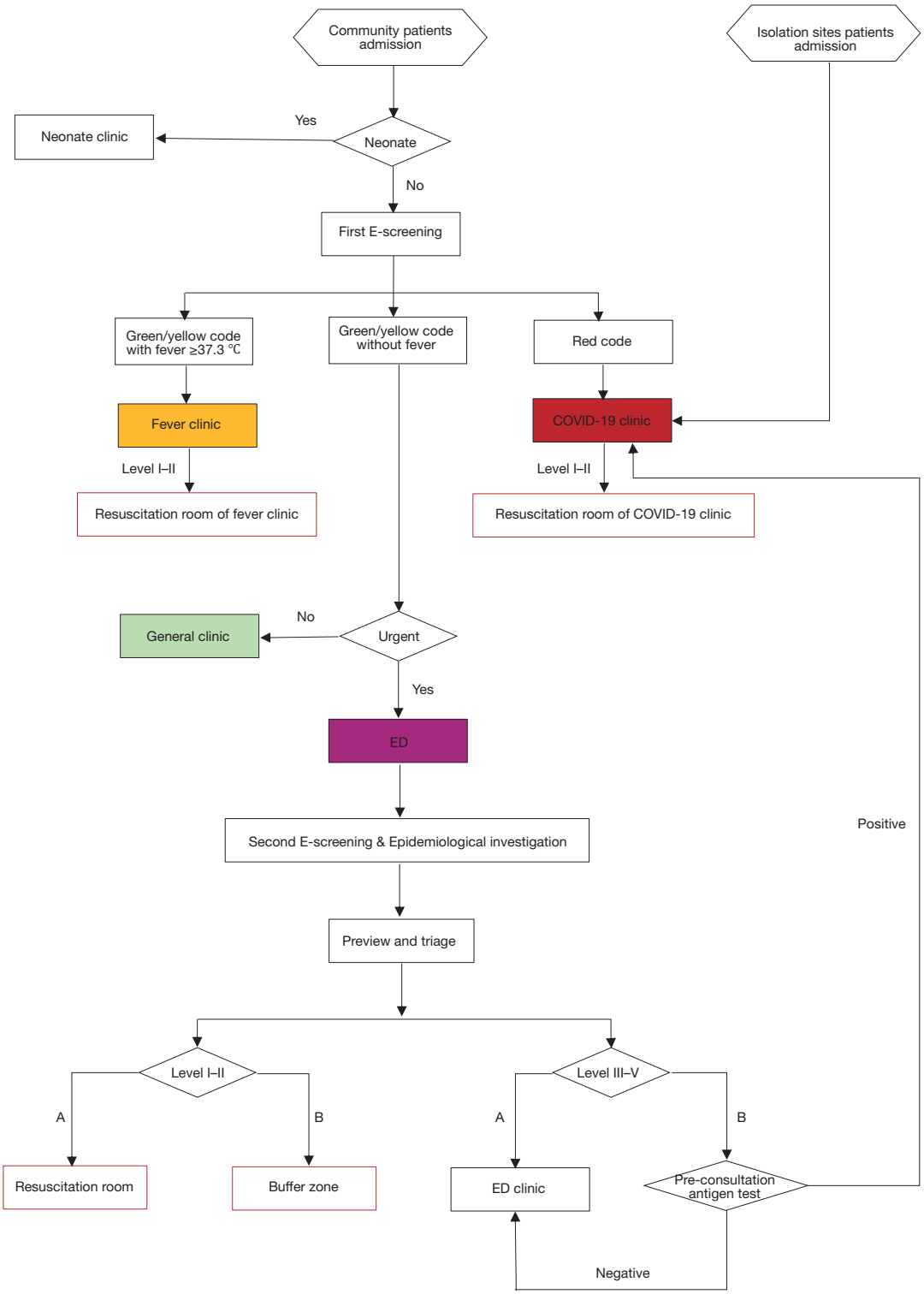

Figure 3 Flowchart for the screening, preview, and triage of the patients. A: patients with 48-hour negative PCR test report; B: patients without 48-hour negative PCR test report. ED, emergency department; E-screening, electronic screening; PCR, polymerase chain reaction; COVID-19, coronavirus disease 2019.

Table 1 PPE for different protection levels

PPE	Level I protection						Level II protection	Level III protection
	(0)	(1)	(+1)	(+2)	(+3)	(+4)		
Overall		√	√	√	√	√	√	√
Medical masks								
Surgical masks		√	√	√	√			
N95 respirators						√	√	√
Medical hats		√	√	√	√	√	√	√
Goggles/face shields					√	√	√	
Full facepiece elastomeric respirators/powered air-purifying respirators								√
Fluid-resistant gowns				√	√	√		
Protective suits							√	√
Shoe covers						√	√	√
Medical gloves			√	√	√	√	√	√

PPE, personal protective equipment.

prepared. The course contents were tailored to the staff's responsibilities, which entailed the standard operating procedures (SOPs) of intra-hospital infection prevention and control, the emergency response to COVID-19 confirmed cases in the ED, the transfer of goods and patients, and the self-monitoring of abnormal health conditions reported by the department of nosocomial infection control. All staff in ED were required to complete the training and pass the associated examination before being qualified to work. To ensure the safety of staff working in the ED, PPEs of level II protection were provided for the buffer zone, level I+4 protection for other workplaces, and level III protection for performing high-risk practices such as trachea intubation or central venous catheterization (*Table 1*).

All ED staff needed to collect and report the health information of themselves and their family members daily to the nosocomial infection control department via the Dingding APP before work. The required information included temperature, respiratory symptoms, and travel history. A designated nurse was assigned to test the temperature of every staff member using a touchless handheld thermometer before every shift and recorded the results in a structured table sheet. All on-duty staff were required to accept daily PCR tests and were not allowed to leave the ED before negative results were reported. Staff with fever or respiratory symptoms had to stay at home or attend an adult hospital, and medical observation or further treatment was administered according to the doctor's orders there. All information was then promptly reported to the department of nosocomial infection control. Those who did not have COVID-19 symptoms were allowed to return to work. Staff who were judged as a close contact or secondary contact at work were placed under medical observation. If a staff member became a suspected or confirmed case of COVID-19 at work, he or she would be transferred to a designated adult hospital.

Adequate electronic monitors were installed in the ED to supervise the staff's daily practices such as hand hygiene, PPE donning and doffing, and environment disinfection. A spy nurse in the ED and two staff from the department of nosocomial infection control cooperated to supervise the daily practices through the assembled monitor every day and on-site twice a week.

Management of ED disinfection

All emergency areas were routinely disinfected three times daily. For air disinfection, the resuscitation room and buff zone were disinfected by hypochlorous acid atomization, and the other areas were disinfected by man-machine coexistence ultraviolet-C (UV-C) disinfection panel lights. The equipment, facilities, and floor surfaces were wiped or mopped with disposable wipes or towels soaked with 1,000 mg/L chlorine disinfectant. The toilet was sprayed with chlorine disinfectant of the same concentration.

For areas where COVID-19 exposure was found, terminal disinfection was performed in the entire area. The air was disinfected using an intelligent disinfection robot that automatically walked around the clinic area spraying hydrogen peroxide at an action concentration of 8–12 g/m^3. Floor disinfection was performed by spraying with 2,000 mg/L chlorine disinfectant for 30 minutes before cleaning. Other surfaces of equipment and facilities were disinfected with disposable hydrogen peroxide wipes. Following terminal disinfection, sampling was carried out to assess environmental safety. The main ED reopened after negative PCR tests were reported for all staff, visitors, and the environment.

Transfers of high-risk patients

A negative pressure stretcher was used to transfer confirmed or highly suspected patients through a specialized route. The staff in charge of the transfer wore level II protection PPEs.

Transfers of materials

All supplies (PPEs, antiseptic solutions, gauze pads, stickers, dressings, syringes, etc.) and specimens were all sealed in plastic boxes. A designated logistical worker with level I+4 PPEs protection delivered them on a cart. Specialized routes were respectively designed for clean materials and waste or contaminated ones.

Data collection and measurements

The data on nosocomial infection cases and occupational exposure episodes among staff were collected to evaluate the management strategy's effect. The demographic and clinical characteristics of level I/II children according to the five-level pediatric triage tool and their mean resuscitation room length of stay in the ED were also extracted from March 1 to May 31, 2022. All data were obtained from the Hospital Information System (HIS).

Statistical analysis

Data management and statistical analysis were performed with the hospital information system. The categorical variables were expressed as frequencies.

Results

Clinical manifestations of the ED visitors

There were 12,114 ED visitors during the observation period, among which 53.24% were medical emergencies (6,449/12,114) and 46.76% were surgical emergencies (5,665/12,114). Level I–V patients initially previewed and triaged by the nurse accounted for 0.12% (15/12,114), 2.56% (310/12,114), 72.05% (8,728/12,114), 21.17% (2,564/12,114), and 4.10% (497/12,114), respectively. Level V patients were arranged to the outpatient clinic. In total, 29 patients were sent to the buffer zone, two of whom received resuscitation. Four patients were transferred to the pediatric intensive care unit (PICU) due to a critical situation. Six patients tested positive for COVID-19 after entering the ED, with three of these cases resulting in a temporary closure of the ED for disinfection (*Table 2*). There were no medical care delays or unintended deaths.

Among these six children, case 1, who had a 48-hour negative PCR test report, was diagnosed with acute gastroenteritis and was seen in the emergency surgery clinic but later tested positive during consultation. Case 2 was diagnosed with acute appendicitis, a level II emergency condition, and was directly sent to the emergency buffer zone for treatment without a 48-hour negative PCR test report; during the consultation, the PCR test was reported as positive. Cases 3 and 4 were siblings with fever from the community under quarantine and had suspected positive reports screened in the community. They were temporarily placed in the emergency buffer zone as the COVID-19 clinic had exceeded its capacity. Cases 5 and 6 were diagnosed with bacterial enteritis and acute respiratory infections respectively, and neither had a 48-hour negative PCR test report. Antigen tests were performed before they arrived at the emergency hall and the reports were all negative. Due to the requirement to stay in the clinic, a PCR test was administered during the consultation and was reported as positive. Cases 1, 5, and 6 resulted in a temporary ED closure.

Clinical manifestations of the visitors in the COVID-19 clinic and fever clinic with emergency conditions

A total of 8,328 visitors were seen in the fever clinic from March 1, 2022, to May 31, 2022. The corresponding figure was 12,594 during the same period in 2021. Among them, there were 20 level I/II patients in 2022 and 43 in 2011. A total of 432 patients were referred to the COVID-19 clinic in the same period of 2022, three of whom were level I/II patients. There were no medical care delays or unintended deaths at both sites.

Table 2 Overview of the confirmed COVID-19 cases in the ED

Case	Diagnosis	Epidemiology history	48-hour PCR test on admission	Antigen test on admission	Area	Temporary closure of the emergency area for decontamination
1	Acute gastroenteritis	From the community under quarantine	Negative	Not provided	Emergency clinic	Yes
2	Acute appendicitis	From the community under quarantine	Not provided	Not provided	Emergency buffer zone	No
3	Infectious fever	From the community under quarantine, tested positive during a routine screening	Not provided	Not provided	Emergency buffer zone	No
4	Infectious fever	From the community under quarantine, tested positive during a routine screening	Not provided	Not provided	Emergency buffer zone	No
5	Bacterial enteritis	From the community under quarantine	Not provided	Negative	Emergency clinic	Yes
6	Acute respiratory infections	From the community under quarantine	Not provided	Negative	Emergency clinic	Yes

ED, emergency department; PCR, polymerase chain reaction.

Nosocomial infection and occupational exposure in the ED

There were 77 staff working in the ED, including 36 doctors, 38 nurses, and three sanitation workers from March 1, 2022, to May 31, 2022. Their daily PCR test reports were all negative. The PCR test reports of staff who had close contact with the six COVID-19 patients were negative. There were no reports of any staff infected with COVID-19 and no episodes of occupational exposure to COVID-19.

Mean length of stay in the ED resuscitation room

From March 1, 2022, to May 31, 2022, a total of 704 were sent to the resuscitation room for rapid assessment and treatment, and the mean length of stay was 40 minutes. In contrast, there were 1,364 patients with 64 minutes on average during the same period in 2021.

Discussion

For children in emergency conditions, prompt treatment and management are crucial to reducing mortality and improving prognosis. The E-screening measures enacted in our hospital during the pandemic resulted in an unobstructed entrance, and visitors were triaged quickly to the destination. The five-level pediatric triage tool was used to differentiate pediatric emergency conditions so that patients could be promptly sent to receive required treatments. The emergency buffer zone was set up to ensure the timely and effective rescue of children classified as level I–II during the pandemic, which successfully avoided the possible contamination of the ED. As seen from the results, 29 patients with emergency conditions who were sent to the buffer zone accepted effective treatment without delay, 25 of which were stable after treatment, and four of which were then transferred to the PICU after rapid assessment and treatment in the buffer zone. Among the six COVID-19 cases confirmed in the ED, three were placed in the buffer zone. However, a potential risk still existed. Children classified as level III–V without a negative 48-hour PCR test report were required to undergo an antigen test before entering the emergency hall and wait in a fixed area for a negative result. The entire antigen test process took 15 minutes, meeting the waiting time required for level III–V children. Evidence from early reports showed that the sensitivity of the novel coronavirus antigen test was 78.4% and the specificity was 99.4% (22), while the sensitivity and specificity of a PCR test were 67.35% and 100%, respectively (23). Our study also showed that one child with a 48-hour negative PCR test report and two children with on-site negative antigen reports had positive reports after receiving PCR testing during consultation in the ED. A temporary closure was immediately activated to

the main ED due to the potential transmission risk. The second ED was simultaneously opened, effectively ensuring that the patient consultation would not be halted. Multiple transmission routes of the Omicron variant put tremendous pressure on the pandemic control in the ED. By adjusting the ED layout, setting tiered protection measures according to the workplaces, and using a color system to clarify the different areas, staff and patients were well managed to travel via the designated routes. Two entrances were set in the ED, one for patient entry and contaminated materials transportation, and the other for staff entry and clean materials transportation.

Our results indicated that the public health measures for pandemic prevention and control were likely to influence healthcare-seeking behavior, as the overall number of ED visitors declined (24). However, we also found that the proportions of level I/II patients did not change notably in the ED and fever clinic, implying that regular emergency healthcare service should be guaranteed.

Limitations of the study

The multidimensional approach was implemented in a national children's medical center in east China during a 2-month lockdown period where sufficient staff and materials were available and fewer patients were seen in the clinic (as compared to the pre-pandemic level. These factors both potentially limited extending the application of the results. Thus, continuous observation should be conducted to help adjust the details of the multidimensional approach measures.

Conclusions

This wave of the Omicron pandemic has presented a considerable challenge to Shanghai's public health system, especially the pediatric system. Adjusting the layout of the ED and optimizing the approaches of management in the ED are positive responses to it. Based on the strategic management, all patients with emergency conditions accepted immediate medical assessments and treatments, and the pandemic was well controlled. Only six patients were confirmed COVID-19 cases. In addition, neither nosocomial infection nor occupational exposure related to COVID-19 occurred.

However, the results were obtained in the context of a proportional decrease in clinic visitors due to the Shanghai lockdown. Dynamic assessment and further optimization may be adopted to cope with the pre-pandemic visit volume.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://tp.amegroups.com/article/view/10.21037/tp-22-314/rc

Data Sharing Statement: Available at https://tp.amegroups.com/article/view/10.21037/tp-22-314/dss

Peer Review File: Available at https://tp.amegroups.com/article/view/10.21037/tp-22-314/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tp.amegroups.com/article/view/10.21037/tp-22-314/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). According to the guidelines set by CHFU Institutional Review Board, this is an observational study in response to a major pandemic, which is not required for the ethical review inform consent.

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