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Tackling COVID-19: Insights from the Qinghai Province plague prevention and control (PPC) model

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A B S T R A C T

Plague, caused by Yersinia pestis, is a natural focus infectious disease. In China, plague is classified as category A, with the highest risk and hazard among the infectious diseases. Qinghai used to be considered as one of the most serious areas of plague in China. In recent years, thank to the measures in eight aspects summarized as the “Qinghai model” which were adopted to prevent and control the human plague in Qinghai, Qinghai has not experienced any plague case reported for eight years. In early 2020, coronavirus disease 2019 (COVID-19) outbreaked in China. The Qinghai model on plague was employed to deal with the COVID-19 emergency in Qinghai Province. The Qinghai Center for Disease Control and Prevention (Qinghai CDC) and hospitals, along with the departments of public security, animal husbandry and other departments, quickly tracked and treated the patients with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and started surveillance programs on close contacts timely. At present, the cure rate of patients has reached 100%, and close contacts have been effectively quarantined and tested to avoid the spread of COVID-19. The findings from the study suggest that the prevention and control measures undertaken in Qinghai Province might be effective in dealing with the category A infectious diseases such as COVID-19 and other diseases.

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1. Introduction

Plague is an infectious disease caused by Yersinia pestis (Y. pestis) with acute onset, short duration and high mortality [1]. There are three main forms of plague in humans: bubonic plague, septicemic plague, and pneumonic plague [1]. In China, plague is classified as category A and with the highest risk among all the infectious diseases. World Health Organization (WHO) lists it as a quarantinable infectious disease as well [2]. Qinghai Province has suffered the most serious plague infections in China, with the area of confirmed plague foci being 200,000 km². The Y. pestis strain carried by Marmota himalayana (M. himalayana or marmot) in the Qinghai-Tibet Plateau (QTP) is strongly virulent. Without timely treatment, the infected patients will rapidly develop into severe secondary septicemic or pneumonic stages which would be leading to death. Patients in these phases can transmit the disease among human beings, even causing epidemics to occur. Human cases were reported every year from 1958 to 2010, with exception of 1972, 1984, 1999, 2000, 2002, 2007, 2008 and 2010 in Qinghai [3]. Since 2010, the governments and health departments at all levels in Qinghai Province have made considerable efforts on PPC, and by formulating feasible prevention and control countermeasures, they have achieved good results.

In December 2019, coronavirus disease 2019 (COVID-19) [4,5] caused by SARS-CoV-2 [6], a novel coronavirus, was reported in Wuhan, Hubei province, in China. COVID-19 is characterized by its extremely infectious nature and its general susceptibility to the virus within a population. The National Health Commission (NHC) of the China has classified COVID-19 as a category B infectious disease, but has implemented the prevention and control measures used normally for category A infectious diseases [7]. Provinces and cities have also launched first-level responses to this public health emergency one after another to control infection sources quickly and break the transmission routes. It is imperative to prevent and control infections with SARS-CoV-2 to prevent its occurrence, ensure public health and safety, and to safeguard economic and social development. For this reason, Qinghai Province has effectively applied the prevention and control experience of human plague, which has not occurred for 8 years in a row [8], to the disposal of this epidemic situation with satisfactory effect. Accordingly, the present study is focused on assessing and summarizing the measures and strategies used for PPC in Qinghai Province, and it

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explores the potential preventative and control strategies for novel COVID-19 infections and other dangerous infectious diseases.

2. Characteristics of the plague epidemic situation in Qinghai province

There are 12 known natural plague foci in China, covering more than 15% of the country. Qinghai is one of the provinces that have experienced the most severe plague epidemics in China. The natural focus of this epidemic centers on *M. himalayana*, which mainly inhabited alpine grassland in the eastern Qaidam basin, surrounding the Qinghai Lake region, the southern foot of the Qilian Mountains, the Huangnan region, and Yushu region in Qinghai [9]. More than 97% of *Y. pestis* strains isolated in Qinghai are virulent, as characterized by having strong virulence, high invasiveness and high mortality. Since 1958, 192 outbreaks of human plague have occurred in Qinghai, involving 479 patients and 242 deaths [10]. Among them, 14 patients were involved in an outbreak of pneumonic plague in Nangqian County in 2004, of whom six died [11]. In 2009, a pneumonic plague outbreak in Xinghai County involved 12 people, of whom three died [12]. The *M. himalayana* is the main source of human plague infections in Qinghai natural epidemic focus. Of the 192 outbreaks, 72.92% of the human plague outbreaks are associated with the marmots, only 15.63% with non-rodent sources of infection [13]. As shown in Table 1, 58.22% of the first plague cases were related to behavior of eating wild marmots, followed by eating Tibetan sheep (15.19%), and from flea bites (8.86%). As shown in Fig. 1, the maximum number of outbreaks from 1960 to 1969 was around 90. Since 2011, the Qinghai model of PPC has been promoted and carried out province-wide. As a result, only one plague outbreak was documented between 2010 and 2019, confirming the effectiveness of the Qinghai model.

3. The strategy used for prevention and control of plague in Qinghai province

Considering the difficulties involved in PPC in Qinghai province and the continuous occurrence of human plague, the plague surveillance and control team from the Qinghai Institute for Endemic Disease Prevention and Control (QIEDPC) conducted yearly first-line investigations to obtain a large dataset from *M. himalayana* which was determined to be the main host for plague transmission [12-14]. The following three PPC models were examined: the Huangyuan model, which focuses on strengthening investigations of migrant workers; the Menyuan model, which standardizes the construction of fixed plague monitoring points and plague health quarantine stations; and the Wulan model, an initiative based on human-protective marmot killing, which has achieved good prevention and control effects. Based on these models, we have summarized eight aspects of the measures for plague prevention and control in Qinghai, named “Qinghai model”. They allowed us to achieve a zero incidence rate for human plague across eight consecutive years.

### 3.1. Strengthening organization and leadership and specifying accountabilities

Currently, Qinghai is the only Chinese province to retain a leadership group for the prevention and control of endemic disease, and their office is located in the Health Commission of Qinghai Province (HCQP). The deputy secretary of the Committee of the Qinghai Provincial Communist Party of China is also the head of the leadership group for endemic disease in the provincial party committee, and the officer-in-charge is the deputy head of the group. Concurrently, the city and county have also established leadership groups for PPC, with the aim of strengthening leadership in the PPC organizations so as to ensure an organized, coordinated, supervised and effective implementation of the various prevention and control measures.

### 3.2. Strengthening epidemic risk assessment and monitoring, and implementing better forecasting and early warning systems

There are four national monitoring locations and nine general monitoring locations in Qinghai. In May each year, in accordance with the requirements of the National Plague Surveillance Program and the Qinghai Plague Surveillance Program, more than 30 different levels of plague emergency response and monitoring teams that are affiliated with HCQP, are sent out to monitor marmot density and plague outbreaks among wild animals. Important traffic arteries, large development and construction areas, and tourist attractions are also listed as key monitoring areas. By employing unmanned aerial vehicles and a marmot information collection system, these teams have been able to collect samples widely across the province and analyze them to determine the potential epidemic situation for plague locally. This has allowed timely estimates of the epidemic situation among animals to be generated, enabling disease forecasting and early warning systems to operate, and preventing epidemics from spreading to human beings. Thus, a 24-h on-duty system and plague reporting system have been implemented to strengthen the direct reporting system in the network, from which an epidemic duty telephone number is made available to the public in a timely manner. These events trigger the release of the emergency materials reserve, with emergency exercises and training initiated in various forms to implement in-field dispositions immediately after an outbreak.

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**Table 1**

First infections in human plague epidemics in Qinghai Province from 1975 to 2019.

| Cause of infection                  | Number of infections at the start of the epidemic | Percentage |
|------------------------------------|--------------------------------------------------|------------|
| Eating marmot (*Marmota himalayana*) | 46                                               | 58.22%     |
| Eating Tibetan sheep (*Ovis aries*) | 12                                               | 15.19%     |
| Eating Mongolian gazelle (*Procapra picticaudata*) | 2 | 2.53% |
| Contact with dog (*Canis familiaris*) | 3                                               | 3.79%      |
| Peeled skin from dead lynx (*Lynx lynx*) | 1 | 1.27% |
| Peeled skin from desert cat (*Felis bieti*) | 1 | 1.27% |
| Contact with plateau pika (*Ochotona curzoniae*) | 1 | 1.27% |
| Contact with hare (*Lepus oioostolus*) | 1 | 1.27% |
| Flea bite (*Oropsylla silumintei* and *Callopsylla dolabra*) | 7 | 8.86% |
| Peeled skin from fox (*Vulpes corsac*) | 1 | 1.27% |
| Unknown                           | 4                                               | 5.06%      |
3.3. Applying laws and regulations to optimize cooperative investigations on plague

Close coordination among the departments for public security, transportation, agriculture, animal husbandry, forestry, industry and commerce, civil aviation, and railways was encouraged to strengthen communication about PPC. This enabled prompt investigation and remedial action to be taken for illegal hunting, marmot trafficking and marmot selling, thereby strictly preventing the occurrence and long-distance spread of plague. In accordance with the regulations on the prevention and control of endemic diseases in Qinghai Province and the regulations on Traffic Health and Quarantine of Plague in Qinghai Province, the HCQP strengthened plague coordination and cooperation within the various departments. It also continues to carry out joint investigations on the illegal hunting and trafficking of marmots, with the aim that, through highway inspections, traffic (highway, railway and civil aviation), passenger and freight inspections, and market inspections, the timely detection of marmot trafficking will eliminate plague transmission and its potential epidemic risk.

3.4. Strengthening access to information and education at the grassroots level in the community

Since 2012, the HCQP has organized experts to compile and issue a series of books, including Knowledge of Plague Prevention and Control for Clinical Medical Workers, the Manual of Plague Prevention and Control for Migrant Workers in Qinghai Province, and the Guide to Plague Prevention and Control for Civil Servants, which were distributed to various cities and counties as PPC handbooks. All kinds of backpacks, shopping handbags, hats, and tea cups with slogans such as *We prevent plague together. Plague can be prevented and cured*, and *Say no to plague* have been distributed to inhabitants in towns and villages to remind people of the potential danger. Internet, television and the WeChat App have been used to promote PPC knowledge courses among primary and secondary school students, and to distribute publicity and educational materials on PPC to the mass population [15,16]. All of this work has aimed at enhancing public knowledge about epidemic prevention to achieve an awareness rate exceeding 85%.

3.5. Importance of the initial-diagnosis doctor and appropriate training for all medical staff

In order to detect, isolate, and treat plague cases efficiently and as possible, a series of rules and regulations were formulated and issued by the medical legislation since 2010. These laws and regulations require doctors at all levels of medical institutions to have the ability to initially diagnose suspected cases of plague. The initial-diagnosis doctor was required to be responsible for his/her patients with plague through the course of the treatment. The institutions have been tasked with prohibiting prevaricating, derailing, delaying treatment, or doing anything that might contribute to epidemic spread. Additionally, to improve knowledge about PPC among clinicians at all levels in Qinghai province, for many years provincial, state, and county health departments have held annual training courses for clinicians at all levels to conduct full staff training for all clinicians, and to increase funding and personnel investment for fever clinics in medical institutions. Concurrently, the *Book of Knowledge of Plague Prevention and Control for Clinical Medical Staff*, which was compiled and issued by the HCQP and QIEDPC, has greatly improved the PPC ability of clinical medical and nursing staff at all levels in Qinghai province.

3.6. Assessing risk and supervising the implementation of anti-plague measures

The leader group for the prevention and control of endemic diseases has organized one or two risk investigations each year to assess the risks associated with PPC in the counties and cities under its jurisdiction. These investigations have mainly included the implementation of PPC measures by governments and departments at all levels. The way this is done is that the Transportation department assists the HCQP in carrying out traffic quarantine, and inspects the carriage and transportation of animals potentially infected with plague (e.g., marmots and their products) at bus stations, toll stations and overload checking stations. The Administration for Industry and Commerce is tasked with investigating and dealing with the units and individuals who operate, sell, and process plague-infected animals and their products, and the Railway and Civil Aviation departments have formulated departmental emergency plans for PPC and developed a traffic quarantine system for plague [17]. The Agriculture and Animal Husbandry departments have been tasked with assisting the HCQP in carrying out the monitoring and health supervision of livestock and animal plague. The Forestry departments have been tasked with timely reporting to the administrative departments of HCQP and the disease control departments on any abnormal deaths and abnormal changes in wild animals (e.g., marmots), and the inspection of plague-infected animals (e.g., marmots and their products), and implementing publicity and education for students about PPC. This has involved the Radio and Television departments in actively publicizing and providing education on PPC laws and regulations and knowledge about PPC via radio, television, and other mass media, as well as arranging, allocating, and supervising PPC funds in financial departments. This has also involved the implementation of ethnic and religious work related to PPC in ethnic and religious-affairs departments, formulating emergency plans for PPC in tourism departments, and promoting publicity and education about PPC to tourists.

3.7. Key areas relating to marmot control

Monitoring marmots is one of the key measures against plague in Qinghai Province because frequent outbreaks occur among these animals. Active human intervention can reduce the density of marmots, thereby reducing the epidemic intensity of animal plague, so as to prevent the spread of this type of plague to humans [18,19]. For areas with a custom of hunting and selling marmots, a targeted responsibility system was implemented in various counties, townships (towns), villages and households, with responsibilities being specified at the personal level. A series of reward and punishment systems have been formulated and implemented, and people are discouraged from hunting wild animals.

3.8. Making full use of plague research to apply scientific knowledge to the prevention and control of highly pathogenic human diseases

The HCQP and QIEDPC have always adhered to the guiding principles of the government-led, prevention-oriented, scientific prevention and control. The biosafety level-3 laboratories and key laboratories in the NHC are situated in Qinghai Province, thereby providing a better research platform for PPC in this location and strong hardware and software to effectively manage the inspection and detection platform for highly pathogenic human diseases.

4. The role of the Qinghai model in the COVID-19 epidemic in Qinghai

Eighteen confirmed cases of COVID-19 have been reported in Qinghai since Feb. 5, 2020, from which, most were imported. Among them, two cases developed severe clinical signs and symptoms. Altogether, 437 close contacts with COVID-19 cases were identified and segregated. By Feb. 21, 2020, the COVID-19 epidemic was placed under control in Qinghai, and 18 cases had completely recovered. At the same time, new cases, suspected cases, cases of infection in medical staff, and patient deaths were not continuously reported. This is fully attributed to the model and experience of PPC in Qinghai. When the outbreak occurred, the government immediately started the highest level of response to the public health emergency to deal with the COVID-19 epidemic, based on the Qinghai model for PPC in Qinghai province. Under the unified command of the leading team for COVID-19 prevention and control, the departments involved in controlling the spread of COVID-19, including the departments for health, public security, transportation, industry and commerce, railway, civil aviation, finance, agriculture, animal husbandry, education, and radio and
television, were quickly organized to perform their respective duties (Fig. 2). To halt the spread of the virus, quarantine stations were rapidly established on the main roads entering Qinghai Province. Since the 18 new patients with COVID-19 were initially identified, medical clinics at all levels throughout Qinghai also rigorously implemented the system “Qinghai provincial health department implements the responsibility of doctors for the first diagnosis of plague patients in medical institutions”, which aims to identify, isolate and treat residents as early as possible. Given that PPC was a successful operation in Qinghai, we have sufficient reserves for epidemic prevention, and through the timely and reasonable deployment of various epidemic prevention and treatment units, our efforts aimed to guarantee the safety of front-line medical care staff and personnel involved in disinfection and epidemic prevention. The Qinghai CDC have undertaken accurate epidemiological investigations for confirmed cases by coordinating with other departments so as to ensure the isolation of close contacts in time to contain further spread of the epidemic effectively. Finally, a considerable amount of publicity work has been done to guide and build a good awareness of the epidemic in the public with the help of the media, to allow everyone to acquire basic knowledge of the prevention of COVID-19. The Qinghai model has been extremely effective in preventing and controlling the COVID-19 epidemic so far in Qinghai Province, which is well worth being shared with other Chinese regions, as well as being applied to other epidemic diseases.

5. Insights from the Qinghai model for responses to emergency infectious diseases such as COVID-19

The comparison of characteristics between plague and COVID-19 was summarized in Table 2, showed that COVID-19 and plague have similarities in biohazards classification, infectivity, transmission route, pathogenicity, population susceptibility and preclinical susceptibility. Considering the Qinghai model for PPC has scored remarkable results, Qinghai PPC would work for COVID-19, and three strategic aspects for the prevention and control of this virus infection are listed below [20,21].

5.1. The legislative branch

It is both necessary and important to establish and improve the laws and regulations applicable to tackling local infectious disease emergencies. Therefore, the Qinghai Province government has set up a permanent leading group specializing in investigating, monitoring and dealing with sudden incidents of contagious diseases (Fig. 2). In our case, the group, headed by the local government leader, consists of the head of the local health department and an infectious disease specialist, who provide professional guidance not only on decision making but also on conducting the overall coordination, inspection, and supervision of various local governmental departments.

5.2. Health and disease control departments

1) A surveillance team for animal-related epidemic diseases was established. Their monitoring priority is to focus on livestock markets and areas densely inhabited by wildlife (e.g., bats). By combining flow detection and fixed detection, the team collected and identified samples from suspected cases, assessed the local epidemic state of the animal-related infectious disease, and built a reliable model and system so as to predict sudden advances in disease. 2) The role of the physician has been further

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**Table 2**

| Aspects                | Plague                  | COVID-19               |
|------------------------|-------------------------|------------------------|
| Classification of disease | Category A              | Category B but implemented for category A |
| Pathogen               | Bacterium; *Yersinia pestis* | Virus; SARS-CoV-2      |
| Biohazards classification | Level 3                  | Level 3 or Level 4      |
| Infectivity            | Highly                   | Highly                 |
| Transmission route     | Respiratory tract; Contact; Blood (Pneumonic, Septicemic plague); Flea bite (Bubonic plague) | Respiratory tract; Contact; Blood |
| Pathogenicity          | Severe                   | Severe                 |
| Infection incubation   | 1–9 days                 | 1–14 days              |
| Susceptibility         | High incidence of susceptible population | High incidence of susceptible population |
| Preclinical susceptibility | Exist and high          | Exist and high         |
| Mortality              | Without timely intervention of antibacterial drugs exceeds 80% | The exact death rate is not known, but it currently stands at about 3% |
| Test methods           | Culture; PCR; Rapid Diagnostic Test (RDT) for F1-antigen; antibody detection by serology | RT-PCR; detecting of SARS-CoV-2 IgM and IgG antibody |
| Clinical symptoms      | High fever, chills, weakness, headache, lymphadenopathy (bubonic plague); vomiting, respiratory distress (pneumonic plague) tachycardia; shock; Disseminated Intravascular Coagulation (DIC) | Fever, fatigue and cough are common. A few have nasal congestion, runny nose, sore throat, muscle pain and diarrhea. Acute respiratory distress syndrome and septic shock in severe patients |
| Treatment              | Isolation; symptomatic support; antibacterial treatment (Streptomycin preferred or gentamicin, doxycycline) | Isolation; symptomatic support; Lack of effective antiviral drugs |

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Fig. 2. Overview of each department's roles in the organizational structure.
emphasized and clarified, which requires the initial-diagnosis doctor to be responsible for the diagnosis and treatment of emergency infectious diseases, such as fever of unknown origin or suspected SARS-CoV-2 infections. Clinician training at all levels should be strengthened in the prevention and control of infectious diseases such as COVID-19, and multiple annual training courses for the whole staff training should be held. 3) The local government made laws and regulations forbidding people from culling wild animals, and supervised the hunting of wild animals, especially those associated with the infectious diseases, such as bats. The community actively encourages the exposure of the aforementioned illegal practice. Those who sell wild animals and endanger public safety shall be given severely punishment, and those who inform against such activities shall be moderately awarded. 4) Researches aimed at preventing and controlling unexplained or new infectious diseases (e.g., COVID-19), in laboratories with high bio-safety levels, should be increased, and ground-level researches aimed at effective inspection, prevention and control, diagnosis, drug treatments, and vaccines for highly pathogenic diseases should be increased in dealing with sudden epidemic situations.

5.3. Cross-functional coordinations

The functional advantages of public security, transportation, agriculture and animal husbandry, forestry, industry and commerce, civil aviation, railway, and other departments were fully utilize. Close coordination and cooperation among departments should be encouraged to strengthen communication of information on prevention and control work, and promptly to investigate and deal with illegal hunting, predation, and trafficking of wild animals, especially bats and other potentially infected non-human hosts, to strictly prevent the spread of wild animal diseases to humans.

6. Discussion

At the end of 2019, a pneumonia outbreak of unknown causes led to many deaths in Wuhan, China. It was confirmed by the etiological testing that this pneumonia was caused by a novel coronavirus with extreme infectiousness to humans, which triggers a serious public health emergency response. In China, the pneumonia caused by this Coronavirus has been identified as a category B infectious disease by the National Health Commission. However, because of its highly infectious nature, prevention and control measures have been taken in accordance with those for category A infectious diseases. The pneumonia caused by the novel Coronavirus was tentatively named “Novel Coronavirus Pneumonia (NCP)” in Feb. 8, 2020 by the Chinese Health Agency [22]. The WHO then has officially named it COVID-19 [4,5], and the corresponding pathogen was named SARS-CoV-2 by the International Committee on Taxonomy of Viruses (ICTV) in Feb. 11, 2020 [6]. Compared with traditional influenza, COVID-19 is more infectious, has a higher fatality rate, and humans are highly susceptible to it, especially the elderly people. Based on the research from and insight into the Qinghai PPC Model, this study explains why it is not by accident that Qinghai Province has made remarkable achievements in controlling human plague to non-existent levels for eight consecutive years under their implementation of the prevention and control model [3]. The Qinghai PPC model has been used as a model for the successful implementation of many measures to control the COVID-19 epidemic, containing the infectious disease in a short time period. At the same time, both prevention and clinical treatments have achieved four good “zero” results: zero new cases identified, zero suspected cases occurring, zero infections among medical staff, and zero patients have died. Although the epidemic of COVID-19 has now been dampened down and society is returning to the normal state of production and normal life in China, the epidemic is still rampant around the world. As of Mar.10, 2020, 114 countries around the world were in the midst of the COVID-19 epidemic, and 118,000 people in Italy, South Korea, Iran and other countries had been identified as affected by COVID-19 [23]. The WHO fully affirmed China’s actions against COVID-19 [24]. China has also provided active assistance and support to these countries, such as Italy and Iran, and contributed to the WHO response to COVID-19.

The prevention of infectious diseases is of great benefit to present and future generations of people. The mission, although arduous, is satisfying when successful. While respecting biosafety controls, the QIEDPC aims to develop a deeper understanding of the complexities, difficulties, and long-term nature of the prevention and control of all kinds of emergency infectious diseases. Clearly, as the goal for preventing and controlling epidemics if pandemics are to be avoided, priorities should be given to the following: controlling an epidemic during its initial stages, strengthening the science around prevention and control, and ensuring that full attention is paid to implementing prevention and control strategies.

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Conflict of interest statement

The authors declare that there are no conflicts of interest.

Author contributions

Haisheng Wu: Conceptualization, Formal analysis, Writing - original draft. Qingwen Zhang: Conceptualization, Resources. Hailian Wu: Formal analysis, Visualization, Writing - original draft. Hu Wang: Funding acquisition, Resources. Xiaojing Xu: Visualization, Writing - original draft, Writing - review & editing.

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