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Original Research

The effect of dispatch of national medical teams to Wuhan on its control and prevention of COVID-19



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ABSTRACT

Objectives: As a unique prevention and control measure, the dispatch of national medical teams to Wuhan has played a key role in protecting Wuhan against COVID-19. This study aimed to quantitatively evaluate the effect of this key measure in reducing infections and fatalities.

Study design: A scenario analysis is used in this study, where the forming of scenarios is on the basis of the stages of medical to Wuhan. We divided the evaluation into 4 scenarios: Scenario I—no dispatch, Scenario II—dispatch of 4599 medical staff, Scenario III—dispatch of 16,000 staff, and Scenario IV—dispatch of 32,000 staff.

Methods: The extended Susceptible-Exposed-Infectious-Recovered-Death model was adopted to quantify the effect of the dispatch of national medical teams to Wuhan on COVID-19 prevention and control.

Results: The dispatch dramatically cuts the channels for the transmission of the virus and succeeds in raising the cure rates while reducing the fatality rates. If there were no dispatch at all, a cumulative total of 158,881 confirmed cases, 18,700 fatalities and a fatality rate of 11.77% would have occurred in Wuhan, which are 3.2 times, 4.8 times and 1.5 times the real figures respectively. The dispatch has avoided 108,541 confirmed cases and 14,831 fatalities in this city.

Conclusions: The proven successful measure provides valuable experience and enlightenment to international cooperation on prevention and control of COVID-19, as well as a similar outbreak of new emerging infectious diseases.

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Introduction

One of the most common phrases in global health literatures is 'diseases know no borders', which has been widely noted that strengthening global cooperation to meet health challenges is an important consensus of the international community.¹ With the establishment of the World Health Organization (WHO), the governance of global public health crisis has already possessed specific international norms, organizations, and operational mechanisms, and has extensive cooperation in prevention and control of infectious diseases. Presently, the international health cooperation mechanism of infectious diseases guided by the international health regulations (2005) has been the most widely used cooperation mechanism. After the outbreak of the COVID-19 in Wuhan, on a regular basis, China timely updated the WHO, relevant countries, and regional organizations, on the development of the disease, released the genome sequence of virus, and

cooperated with the international community, developing diagnostic reagents, drugs, and vaccines.²

Fighting against the epidemic needs cooperation, so does the medical treatment of patients.³ The sudden outbreak of COVID-19 in Wuhan put an overwhelming strain on its medical resources. A severe shortage of medical staffs and hospital beds occurred at the early stage as the number of infections surged. To fight against the virus, China launched the largest medical assistance since the founding of the PRC. After the lockdown in Wuhan, the central government assembled 346 national medical teams from across the country, resulting in a total of 42,600 medical personnel being dispatched to Hubei Province, especially to Wuhan city (Fig. 1). China provides a typical case for dispatching medical teams to the outbreak started and the hardest-hit place of the pandemic. If there is no dispatch of medical teams to the hardest-hit place, the overwhelming burden on medical resources would become more and more serious, a sharp rise in the infections and substantial increase in the mortality would have occurred.

Numerous studies have focused on evaluating the effects of the non-pharmaceutical interventions, such as lockdowns and quarantines.^{4–8} All research studies unanimously showed the

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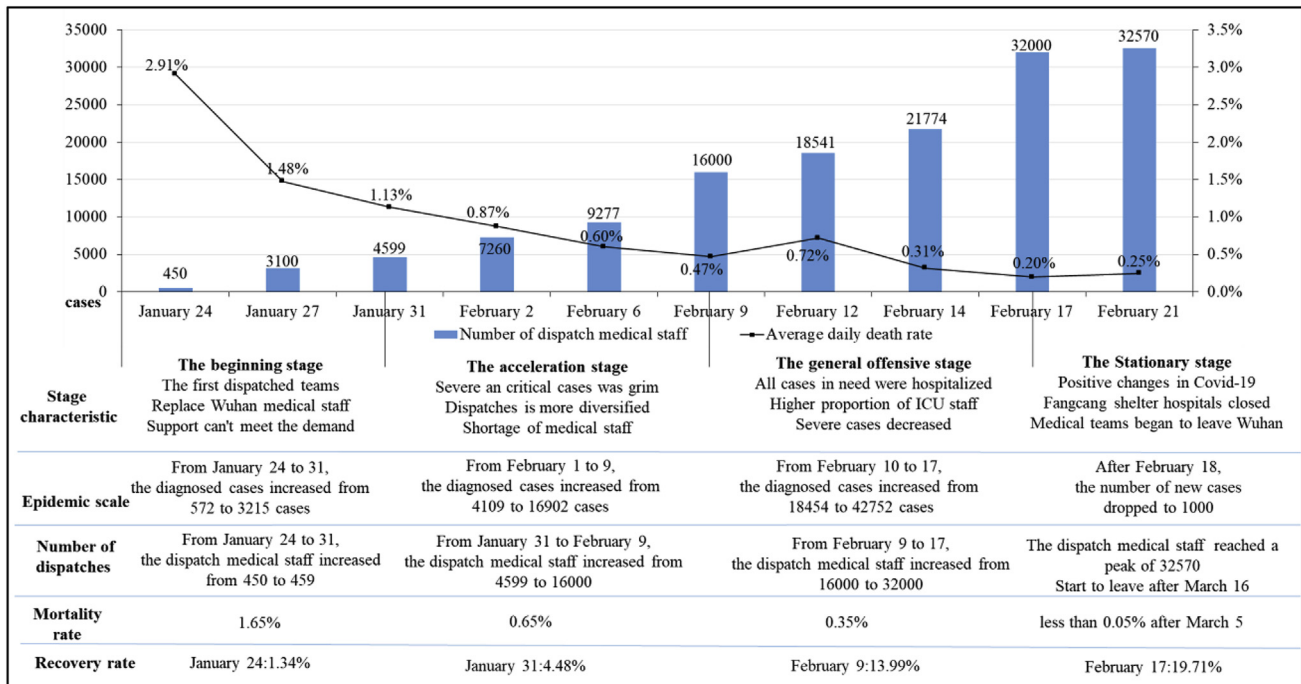


Fig. 1. Stages of the medical dispatch to Wuhan.

prevention and control measures can effectively prevent the transmission of the epidemic, and reduce the infections and mortalities. However, there have been few studies focusing on the effects of dispatching medical teams. In light of the importance of this measure, we adopted a Susceptible-Exposed-Infectious-Removed-Deceased (SEIRD) model, to quantitatively evaluate the effect of dispatching national medical teams on the prevention and control of COVID-19 in Wuhan. The research can provide some enlightenment for global health cooperation.

Methods

(1) SEIRD Model

Based on the classic SEIR model, we included deceased ceases (D) to the model,⁴ thus SEIRD model, an extended model of SEIR, is formed as follows:

$$S_{(t+1)} = S_{(t)} \frac{-\beta_1 r_{(t)} I_{(t)} S_{(t)}}{N_{(t)}} - \frac{\beta_2 r_{(t)} E_{(t)} S_{(t)}}{N_{(t)}} \quad (1)$$

$$E_{(t+1)} = E_{(t)} \frac{\beta_1 r_{(t)} I_{(t)} S_{(t)}}{N_{(t)}} + \frac{\beta_2 r_{(t)} E_{(t)} S_{(t)}}{N_{(t)}} - \alpha E_{(t)} \quad (2)$$

$$I_{(t+1)} = I_{(t)} - \gamma I_{(t)} + \alpha E_{(t)} \quad (3)$$

$$R_{(t+1)} = R_{(t)} + \gamma I_{(t)} \quad (4)$$

$$D_{(t+1)} = D_{(t)} + \kappa I_{(t)} \quad (5)$$

where the S, E, I, R, and D denote the susceptible population, the latent population, the infected population, the recovered population, and the deceased population, respectively. $N_{(t)} = S_{(t)} + E_{(t)} + I_{(t)} + R_{(t)} + D_{(t)}$, β_1 denotes the rate of transmission for the susceptible to exposed; β_2 denotes the rate of transmission for

the susceptible to infected; α denotes the incubation rate; γ denotes the recovery rate; κ denotes the mortality rate, r denotes the number of contacts. This model indicates that in a scenario where there is no intervention, everyone in a given area may become infected within a certain period of time.

(2) Scenario and parameter setting

The incubation rate was the reciprocal of the incubation period, we assumed the incubation period to be 7 days based on the existed researches.⁴ The daily new mortality rate was assumed to be the average of the ratio of the number of daily new deaths in the past 5 days to the existing confirmed cases. β_1 and β_2 were established based on settings determined by Yang et al. (2020). The number of contacts (r) on January 23 was established as 3. After February 17, contacts were reduced to 0, because Wuhan has realized to put four categories of people—confirmed cases, suspected cases, febrile patients who might be carriers, and close contacts—under classified management in designated facilities, such as be tested, isolated, hospitalized, or treated. The number of contacts between January 24 and February 16 monotonically decreased based on the Fourier equation. The recovery rate was obtained by fitting the number of current confirmed cases. The fitting model is as follows:

$$\frac{dI}{dt} = \beta \frac{IS}{N} - \gamma I \quad (6)$$

Assume that when $t = 0$, the number of infections $I = 1$, $N \approx S$, we further derive:

$$I_{(t)} = e^{(\beta-\gamma)t} \quad (7)$$

Eq. (7) was applied to fit the recovery rate under different situations. Table 1 shows the parameters under the different scenarios.

As per the medical dispatch stages (Fig. 1), referring to existed researches,¹⁰ we divided the evaluation into 4 scenarios:

Table 1
The parameter of SEIRD model.

| Scenario | γ | κ | β_1 | β_2 | α |
|--|-----------------------------------|----------|-----------|-----------|----------|
| Scenario I No dispatch | 0.0134 (CI : 0.0086–0.0168) | 0.023 | 0.15747 | 0.78735 | 0.1429 |
| Scenario II Dispatch of 4599 medical staff | 0.048 (CI : 0.0241–0.0719) | 0.015426 | | | |
| Scenario III Dispatch of 16,000 medical staff | 0.1399 (CI : 0.1281–0.1517) | 0.011174 | | | |
| Scenario IV Dispatch of 32,000 medical staff | 0.19708 (CI : 0.18815–0.206) | 0.008 | | | |

Note: The confidence interval of the recovery rate is 95%.

Scenario I: No Dispatch. Based on data availability, and the need for all scenarios to begin in the same stage after the Wuhan lockdown, we established the starting time of this scenario as January 23, when the public transportation stopped. Take this day as the base date, we were able to more completely separate the net effect of the dispatch from other measures like outbound travel restrictions and quarantines. The probabilities of transmission and infection were set based on existed research.⁴ The transmission probabilities β_1 and β_2 were 0.15747 and 0.78735, respectively. The infection probability was 0.1429. The recovery rate was 0.6748, as per the fitting of model (11). The daily new mortality was 0.023, which was the 5-day average value before and after January 23.

Scenario II: Dispatch of 4599 Medical Teams. With the continuous increase in the number of dispatched teams, admission capacity and treatment in designated hospitals had improved. Many confirmed cases were admitted, the number of contacts continued to decline, and the recovery rate gradually increased. At this stage, we fitted the probability of recovery to be 0.7055, and the average daily new mortality for the five days before and after January 31 was 0.0154.

Scenario III: Dispatch of 16,000 Medical Teams. With the construction and opening of the Fangcang Shelter Hospitals, more dispatched medical teams were assigned to those hospitals, and more confirmed cases were admitted and treated. At the same time, as people were quarantined, the number of contacts continued to decline, the recovery rate continued to increase, and the new mortality continued to decrease. At this stage, we fitted the recovery probability to be 0.7974. The average daily new mortality for the five days before and after February 9 was 0.01117.

Scenario IV: Dispatch of 32,000 Medical Teams. In this scenario, for the four categories of people in Wuhan, all suspected and confirmed were admitted in the hospital and thus were treated. The number of contacts dropped to a level close to zero, and the fitted recovery probability was 0.8546. The daily new mortality rate during the 5 days before and after February 17 was 0.008.

(3) Data sources

The related COVID-19 pandemic data, including daily confirmed cases, cumulative confirmed cases, and the number of deaths of Wuhan, were collected from the official website of the Health Commission of Hubei Province. The population in Wuhan was 9 million^a in the model. We set the outbreak period of the COVID-19 pandemic as 150 days, from January 23 to June 20, 2020.

^a Data source: Introduction by the Mayor of Wuhan at the press conference on prevention and control of COVID-19 pandemic in Hubei Province on January 26, 2020.

Table 2
The number of infections, deaths, and mortality rate under different scenarios.

| Scenario setting | Cumulative number of infections | Cumulative number of deaths | Mortality rate (%) |
|--|---------------------------------|-----------------------------|--------------------|
| Scenario I No dispatch | 158,881 | 18,700 | 11.77 |
| Scenario II Dispatch of 4599 medical staff | 110,261 | 12,408 | 11.25 |
| Scenario III Dispatch of 16,000 medical staff | 67,151 | 6946 | 10.34 |
| Scenario IV Dispatch of 32,000 medical staff | 55,808 | 4410 | 7.90 |
| Actual situation (as of June 20) | 50,340 | 3869 | 7.69 |

Note: The confidence interval of the data is 95%, and the calculation period of COVID-19 pandemic is 150 days (January 23rd to June 20th, 2020). The mortality rate is the ratio of the number of total deaths to the number of infections in this scenario.

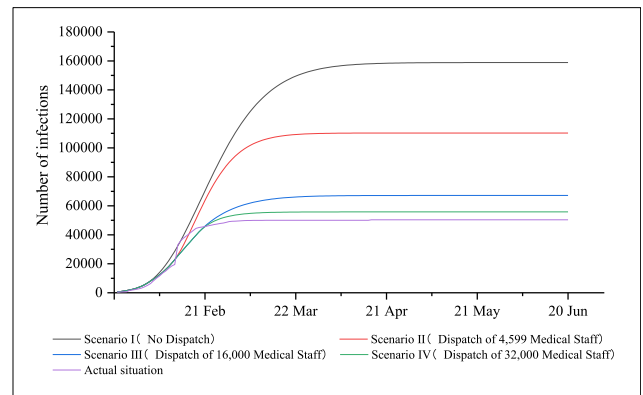


Fig. 2. The number of cumulative infections under different scenarios.

Results

(1) Effects of reducing infections

The dispatch of medical teams played a vital role in reducing infections of the epidemic in Wuhan (Table 2). In the 'no dispatch' scenario (Fig. 2), the number of people infected with COVID-19 is estimated to have reached 158,881, which is nearly 3.2 times the actual number of infections (as of May 30, the same below). The dispatch is estimated to have reduced the number of infections by 108,541, reflecting a significant effect in blocking the transmission, and thus making critical contributions to defending Wuhan against the pandemic.

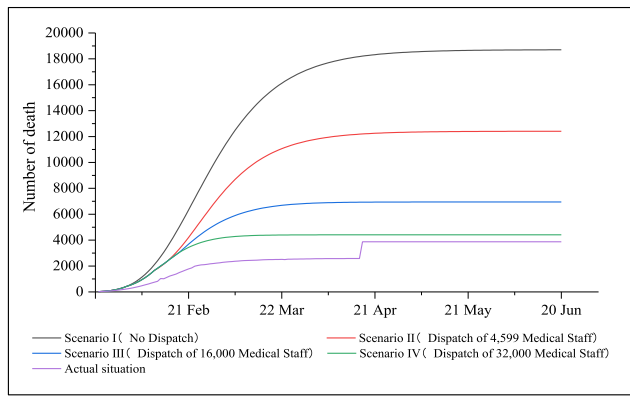


Fig. 3. The number of cumulative death under different scenarios.

In scenario II (dispatch of 4599 medical teams), the infections would reach to 110,261 which would reduce by 48,620 compared with the 'no dispatch' scenario. In this scenario, the infections would have incrementally increased by 59,921, or in other words, 1.19 times of the actual situation. Compared with the 'no dispatch' scenario, the effect of the subsequent dispatch of 16,000 (scenario III) and 32,000 (scenario IV) medical teams on inhibiting infection was estimated to be magnified by 1.9 times and 2.1 times, and the infected people would reduce by 91,730, and 103,073, respectively. This shows that the continuous increase in dispatching medical teams played an increasingly important role in blocking the pandemic and controlling severe cases.

(2) Effects of reducing deaths

The dispatch of medical teams significantly increased the cure rate of confirmed cases and reduced the mortality rate (Fig. 3). In the 'no dispatch' scenario, the deaths would have reached 18,700, more than 4.8 times the actual number of deaths. It is also estimated that the mortality rate could have reached 11.77%, more than 1.5 times the actual mortality rate and 2.1 times the national average level. The dispatched medical teams are estimated to have directly saved more than 14,831 lives in Wuhan.

If the number of dispatched medical team remained 4599 (scenario II), it is estimated that the number of deaths would have reached 12,408, and the mortality rate would have increased to 11.25%. The number of deaths would have increased by 8539 or 2.2 times, and the mortality rate would have increased by 3.57%, which means an increase of 46% compared with the actual situation. In the scenario III and IV, the estimated results show that the number of deaths would have reached 6946 and 4,410, and the mortality rate would have increased to 10.34%, 7.90%.

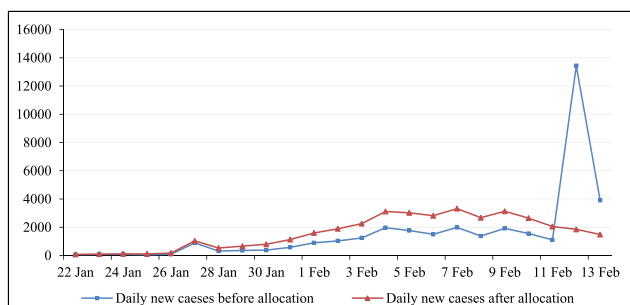


Fig. 4. New confirmed cases before and after the allocation.

Discussion

(1) Robustness test

To ensure the credibility of the estimation results, a test was conducted to assess the robustness of adopted SEIRD model. We allocated new cases with a sudden increase due to the inclusion of clinically diagnosed cases within the total number of confirmed cases for February 12 and 13, 2020. The allocation period was from January 23 to February 11. The Gaussian equation was used as the allocation model:

$$f(x) = a_1 * e^{-\left[\frac{(x-b_1)}{c_1}\right]^2} \tag{12}$$

In expression (12), the parameters of the Gaussian curve fitted after the allocation were $a_1 = 2885$, $b_1 = 17.93$, and $c_1 = 9.427$. Under the robustness test (Fig. 4), factors such as the increase in the number of initial confirmed cases, the increase in the recovery rate, and the decrease in the daily new mortality rate caused by the allocation of the case data did not lead to significant differences compared with the calculated results before the allocation. After the allocation (Table 3), the scale of the pandemic and the number of deaths showed a slight increase. The magnitude of the increase was mostly controlled within 10%, and there was no abnormal changes in the daily data. In 'no dispatch' scenario, the numbers of infections and deaths after the allocation increased by only 1.9% compared with the numbers before allocation. This demonstrates the robustness of the estimation results of the SEIRD model.

(2) Conditions for the dispatch

The successful cross-regional dispatch needs several conditions. First, government should have a strong ability to organize and coordinate the national medical teams for cross-regional assistance. Although it is very difficult for the central government to organize cross-regional rescue in some countries, it can be coordinated and organized by relevant social organizations and doctors' associations. Such measures are already in place in Germany and the United States, although as non-governmental or local governments' actions. Second, cross-regions' or -countries' medical qualification should be mutually recognized, so that the dispatched staffs can carry out normal medical treatment. The dispatch of medical teams cross countries will encounter the problem of whether the medical qualification certificate is mutually recognized. The third is to have a unified medical insurance system as a guarantee. China has a national consistent medical insurance system, and most of the treatment funds are paid by the state. However, if the cross-regional medical insurances are paid by different entities, it will be difficult to rush for assistance. So How to establish a closer transnational and cross-regional cooperation is a critical issue, which still needs to be further studied.

Conclusion

Using a SEIRD model, this study quantitatively evaluated the effect of medical dispatch to Wuhan to defend against the COVID-19. The estimated outcomes were based on the scenarios of 'no dispatch' and 'dispatch' with 4,599, 16,000, and 32,000 medical teams, comparing the modeled infections, deaths, and mortality rate of COVID-19 with the actual figures. The main findings are as follows. First, the dispatched medical teams effectively inhibited the spread of pandemic. Without the dispatch, the infections of

Table 3

The comparison of the estimated results of the robustness and normal test.

| Scenarios | Results before the allocation | | Result of the robustness test | | Comparison | |
|--------------|-------------------------------|------------------|-------------------------------|------------------|----------------------------|------------------------|
| | Number of infections | Number of deaths | Number of infections | Number of deaths | Added number of infections | Added number of deaths |
| Scenario I | 158,881 | 18,700 | 161,871 | 19,055 | 2990 | 355 |
| Scenario II | 110,261 | 12,408 | 115,786 | 13,222 | 5525 | 814 |
| Scenario III | 67,151 | 6946 | 73,383 | 7831 | 6232 | 885 |
| Scenario IV | 55,808 | 4410 | 62,184 | 4818 | 6376 | 408 |

Note: the confidence interval of infections and deaths are 95%, and the calculation period of the robust test is also 150 days: from January 23 to June 20, 2020.

COVID-19 are modeled to have reached 158,881, which is nearly 3.2 times the actual number of infections. The dispatch is estimated to have reduced the number of infections by 108,541. Second, the dispatch of medical teams significantly increased the cure rate of confirmed cases, and thus reduced the mortality rate. Without the dispatch, the number of deaths from COVID-19 was modeled as 18,700, which is more than 4.8 times the actual fatality. It is also estimated that the mortality rate could have reached 11.77%, more than 1.5 times the actual mortality rate and 2.1 times the national average level. The medical dispatch is estimated to have directly saved more than 14,831 lives in Wuhan. Third, the strategy of continuously increasing the scale of the dispatch was reasonable. Estimated results showed that compared with the 'no dispatch' scenario, the subsequent dispatch of 16,000 and 32,000 medical teams on inhibiting infection was estimated to be magnified by 1.9 times and 2.1 times, respectively; the effect on reducing the deaths of severe cases was estimated as being magnified by 1.9 times and 2.3 times, respectively. This showed that the continuous increase in dispatching medical teams play an increasingly important role in blocking the pandemic, controlling severe cases, and saving lives. In this article, we just evaluate the infection and mortality in Wuhan area. In fact, if the epidemic in Wuhan is not controlled in time, the disease would spread to other areas, in which case the infections and deaths will be immeasurable, so the effect of medical dispatch to Wuhan is actually much more significant than the evaluation result in the model.

The cross-regional assistance provided by national medical teams discussed in this article provides important insights to inform the transnational response to the COVID-19, as well as to other emerging infectious diseases. The COVID-19 is continuing to spread globally, threatening the health of human beings. The Chinese government assembled and dispatched medical team on a large scale to the hardest-hit areas of the pandemic, achieving significant positive effects and providing valuable experiences that the world can benefit from. To deepen international cooperation in responding to the pandemic, international organizations and medical associations should implement inter-governmental cooperation mechanisms and other organizational methods to assemble medical teams from a wider range of coverage, and then focus dispatched teams on the hardest-hit areas of the pandemic. Beyond restricting population movement and implementing temporary quarantines, these measures would improve the pressure-resistant capacity and treatment capacity of medical systems, alleviate the run on medical resources, inhibit the resulting increase in mortality

rate, and save more lives while inhibiting the spread of the pandemic.

Author statements

Ethical approval

Not required.

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Competing interests

None declared.

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