Analysis of 25,000 Lab-Confirmed COVID-19 Cases in Wuhan: Epidemiological Characteristics and Non-Pharmaceutical Intervention Effects

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Huge Thanks to Our Staff

- HSPH Biostat: Amanda King, Elizabeth Solinga
- HSPH IT: Shawn DeAntonio, Katherine Targett
- HUIT: Maria Apse, Scott Yockel
Participants are welcome to comment and ask questions using Zoom chat
Dr. Anthony Fauci, Director of the NIH National Institute of Allergy and Infectious Diseases testified about COVID-19, during a Senate Committee on March 3.
Stock Market
Local Grocery Stores, MA (March 12, 2020)

BJ, Natick

Roche Brother, Wellesley
A lot of public panic right now

I would like to start with a positive message

The Wuhan intervention experience tells us that we can stop the COVID-19 outbreak
Main Goals

- What can we learn from the Wuhan experience in controlling for the COVID-19 outbreak?
- What worked and what did not work?
- Take home messages
The manuscript is on MedRxiv


- A summary of the key findings is at my tweet @XihongLin
Thank all of my Tongji SPH co-authors for their tireless work on finishing this manuscript in a short time. The gained knowledge benefits US and other countries at this critical time.
Key Point: Wuhan Experience tells us the COVID-19 Outbreak Can Be Controlled by Effective Interventions: Centralized Quarantine

Effective reproductive number $R_t$
Wuhan

Population size: 11M
Wuhan: A Beautiful City
Wuhan: A Beautiful City

East Lake, Cherry Blossom
Dec 8, 2019: First case: close to the Huanan Seafood Market
Dec 8, 2019: First case: close to the Huanan Seafood Market

Wuhan CDC (n=25,961): December 8 – February 18

Closed on Jan 1, 2020
Dec 8, 2019: First case: close to the Huanan Seafood Market

Jan 11, 2020: Start of Spring Festival Travel
Dec 8, 2019: First case: close to the Huanan Seafood Market
Jan 11, 2020: Start of Spring Festival Travel
Dec 8, 2019: First case: close to the Huanan Seafood Market

Jan 11, 2020: Start of Spring Festival Travel

Nanshan Zhong (Jan 20, 2020)
Confirmed human-to-human transmission

Wuhan CDC (n=25,961): December 8 – February 18
Dec 8, 2019: First case: close to the Huanan Seafood Market

Jan 11, 2020: Start of Spring Festival Travel

Wuhan CDC (n=25,961): December 8 – February 18

Lanjuan Li
Jan 20, 2020
Suggested city lockdown
Dec 8, 2019: First case: close to the Huanan Seafood Market

Jan 11, 2020: Start of Spring Festival Travel

Jan 23, 2020: Start of Cordon Sanitaire
Dec 8, 2019: First case: close to the Huanan Seafood Market

Jan 11, 2020: Start of Spring Festival Travel

Jan 23, 2020: Start of Cordon Sanitaire
Dec 8, 2019: First case: close to the Huanan Seafood Market

Jan 11, 2020: Start of Spring Festival Travel

Jan 23, 2020: Start of Cordon Sanitaire
Due to a very large number of cases, the health care system was under an enormous pressure. There was an overwhelming shortage of medical resources, resulting in many patients not being able to receive medical care.
To address the serious shortage of medical resources,
Dec 8, 2019: First case: close to the Huanan Seafood Market

Jan 11, 2020: Start of Spring Festival Travel

Jan 23, 2020: Start of Cordon Sanitaire

Feb 2, 2020: Fangchang (Mobile Cabin) Hospitals launched
Dec 8, 2019: First case: close to the Huanan Seafood Market

Jan 11, 2020: Start of Spring Festival Travel

Jan 23, 2020: Start of Cordon Sanitaire

Feb 2, 2020: Fangchang (Mobile Cabin) Hospitals launched

Many healthcare workers across China went to help Wuhan.
Dec 8, 2019: First case: close to the Huanan Seafood Market

Jan 11, 2020: Start of Spring Festival Travel

Jan 23, 2020: Start of Cordon Sanitaire

Feb 2, 2020: Fangchang (Mobile Cabin) Hospitals launched

Many donations from China and other countries

Wuhan CDC (n=25,961): December 8 – February 18

Centralized treatment and isolation strategy of four categorized people:
1-confirmed patients
2-suspected patients
3-patients with fever symptoms
4-close contacts of confirmed patients

Huanan Seafood Market (Jan. 1): before Chunyun

Massive human movement outflow during the Chunyun period

Start of the Chunyun period

Onset date

Overwhelmed patients with shortage in medical resources; implementation of a series of countermeasures

Intensive prevention and control measures; substantially reduced transmission and incident cases
Illustration of the Extended SEIR Model

S (susceptible), E (latent), I (ascertained infectious), A (unascertained infectious), H (hospitalized), and R (removed)
Estimated Effective Reproducible Number R

Assume

- Incubation period = 5.2 days
- Infection period = 2.3 days
- # of unascertained cases = # of ascertained cases
- 9 sensitivity analyses
Reported daily COVID-19 infections when there was no intervention before January 23, 2020

Blue = projected trajectory if no prevention had continued

R=3.88  R=3.87
Reported daily COVID-19 infections under lockdown with traffic ban and many quarantined at home between January 23-Feb 1, 2020

Blue = Projected trajectory if this intervention had continued.

R=1.25
Take home message #1: Lockdown with Traffic Ban and Home-Quarantine Helped but was not enough

- Family transmission is common.

- Infected cases might infect family members and close contacts, who could infect others in the community.

- It was challenging for infected cases to seek for medical care due to traffic ban.

- As it was an honor system, it was difficult to enforce cases to stay at home. Some cases might still go out, grocery shopping, resulting in infecting others.

- Traffic ban, mitigation (social distancing) and home quarantine helped reduce $R$ from 3.88 to 1.25, but was not good enough.
So I have decided to make my situation public. I am not in critical condition and am stable, but since about Feb. 23rd have been very sick with the symptoms of #COVID19 minus a high fever. My boyfriend first got sick with these symptoms on Feb. 21st and we are both still ill.
Boston Case Study 1 (Amy Proal)

• Amy’s case is typical and illustrates the issues with home isolation.
• Amy had symptoms on Feb 21, then her boyfriend had symptoms.
• Both could not get tested at MGH.
• Her boyfriend went to see his internist with no mask (as he could not find one).
• If he was infected and went to see doctor by public transportation, he might have infected others but he needed to be helped with transportation.
• The internist and the medical staff in the clinic were likely not fully protected and hence were likely to be infected.
• He was then told by his doctor to go to CVS to get medicine: He would be likely to infect others at CVS if he was a case, but he needed to get medicine.
• If mild cases are not treated early, they are likely to progress and become severe, and are at a much higher risk of death.
Reported daily COVID-19 infections using Centralized Quarantine after Feb 1, 2020

Blue = Projected trajectory if this intervention continues.

R=0.32
Centralized Quarantine Strategies After Feb 1, 2020

- **Group 1**: Test positive
  - Mobile Cabin Hospitals (converted from stadiums or conference centers) (Mild/moderate cases)
  - If progressed to be severe: Transported to regular hospitals, e.g., ICU

- **Group 2**: Suspected cases (cases with symptoms)
  - Centrally quarantined in designated hotels
  - If confirmed case

- **Group 3**: Have Fever
  - Centrally quarantined in designated hotels
  - If confirmed case

- **Group 4**: Close contacts with confirmed or suspected cases
  - Centrally quarantined in designated hotels or university dorms
  - If confirmed case
Measures for Other People During the Centralized Quarantine Period in Wuhan

• Continue home-quarantine
• Continue general traffic suspension
• Provide transportation for groups 1-4 to go to hospitals or designated hotels
• Control frequencies of going out, e.g., grocery shopping, for each household, and arrange grocery delivery
• Healthcare workers who treat patients stay in hotels or other designated facilities to avoid them from infecting family members and communities, if they are infected
• Healthcare workers in contact with cases and exposed subjects are fully protected by PPEs, such as protective suits, medical goggles, caps, face shield, masks and two layers of gloves.
Take home message #2: Centralized Quarantine worked!

Under Centralized Quarantine:

• Infected patients, suspected cases and close contacts were less likely to infect others (reduce transmission).

• Patients received medical care immediately

• Mild cases were treated. This reduced the chance for progressing to be severe cases.

• Made case and close contact management and their medical care access easier
Take home message #2: Centralized Quarantine worked!

• If a patient progressed to become a severe case in a mobile cabin hospital, he/she was immediately transferred to an ICU in a main hospital.

• Reduced the burden on ICU and health care system, which was under an enormous pressure before Feb 1, resulting in many patients without care.

• Avoided suspected cases and close contacts from infecting family members and other community members.
Estimated Numbers of Ascertained and Un-ascertained Cases
Take home message #3: A good proportion are community cases: Testing, Testing, Testing

- We estimated using the SEIR model that about 60% of infected cases were un-ascertained.

- They are often asymptomatic community cases, who could infect others.

- This means increasing testing capacity for early diagnosis is critically important.

- Current issue in US: Low testing capacity (Need an intermediate multi-pronged strategy)
Suspected Cases (cases with symptoms)

On Feb 17-19, Community leaders checked every household, door-by-door, for subjects with symptoms, e.g., fever or cough

Close contacts with cases but without symptoms

Priority 1

If having fever or cough

Priority 2

Priority 3 (not a lot)

Taken for testing

Others
Predicted date of zero case in Wuhan
(Sum of # of ascertained cases and # of un-ascertained cases)

• Early May

• 95% Creditable Interval (Mid-April to Late May)
Take home message 4: A Multi-pronged Approach is needed

- Large scale screening using symptoms (with/without testing kits)
- Increase testing capacity
- Mitigation (social distancing) and home quarantine
- Centralized quarantine for confirmed and suspected cases, symptomatic cases and close contacts (asymptomatic)
Epidemiological Characteristics of 25,000+ Lab-Confirmed COVID-19 Cases
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Before January 11</th>
<th>January 11-22</th>
<th>January 23 - February 1</th>
<th>February 2-18</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total no.</td>
<td>637</td>
<td>4599</td>
<td>12879</td>
<td>7846</td>
<td>25961</td>
</tr>
<tr>
<td>Sex — no. (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>334 (52.4)</td>
<td>2266 (49.3)</td>
<td>6354 (49.3)</td>
<td>3952 (50.4)</td>
<td>12906 (49.7)</td>
</tr>
<tr>
<td>Female</td>
<td>303 (47.6)</td>
<td>2333 (50.7)</td>
<td>6525 (50.7)</td>
<td>3894 (49.6)</td>
<td>13055 (50.3)</td>
</tr>
<tr>
<td>Median age (IQR) - yr</td>
<td>60.9 (19.4)</td>
<td>57.1 (21.3)</td>
<td>57.2 (22.2)</td>
<td>56.4 (24.5)</td>
<td>57.0 (22.7)</td>
</tr>
<tr>
<td>Age group — no. (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-19 yr</td>
<td>2 (0.3)</td>
<td>16 (0.3)</td>
<td>79 (0.6)</td>
<td>193 (2.5)</td>
<td>290 (1.1)</td>
</tr>
<tr>
<td>20-39 yr</td>
<td>71 (11.1)</td>
<td>820 (17.8)</td>
<td>2235 (17.4)</td>
<td>1508 (19.2)</td>
<td>4634 (17.8)</td>
</tr>
<tr>
<td>40-59 yr</td>
<td>235 (36.9)</td>
<td>1742 (37.9)</td>
<td>4929 (38.3)</td>
<td>2851 (36.3)</td>
<td>9757 (37.6)</td>
</tr>
<tr>
<td>60-79 yr</td>
<td>287 (45.1)</td>
<td>1806 (39.3)</td>
<td>5026 (39.0)</td>
<td>2826 (36.0)</td>
<td>9945 (38.3)</td>
</tr>
<tr>
<td>≥80 yr</td>
<td>42 (6.6)</td>
<td>215 (4.7)</td>
<td>610 (4.7)</td>
<td>468 (6.0)</td>
<td>1335 (5.1)</td>
</tr>
<tr>
<td>Healthcare workers — no. (%)</td>
<td>26 (4.1)</td>
<td>411 (8.9)</td>
<td>632 (4.9)</td>
<td>247 (3.1)</td>
<td>1316 (5.1)</td>
</tr>
</tbody>
</table>
Attack Rate Per Day By Gender and Local Healthcare Workers
Attack Rate Per Day By Children Age
Take home message #5: Protect the Four Vulnerable Groups

• Healthcare workers are at a much higher risk of being infected, especially in the absence of protection.

• Elderly people are at a much higher risk of being infected.

• Family members and close contacts of confirmed and suspected cases and close contacts are at a higher risk of being infected

• Children's infection risk is much lower than adults, but the risk increased with time periods.
Centralized Quarantine is Happening in the State of Georgia!

March 12, 2020

attend. The elderly and "medically fragile" should avoid large gatherings, long travel and "certainly avoid getting on a cruise ship," he said.

5:44 a.m. Georgia state park receives 1st patient

A patient who tested positive for the novel coronavirus has been isolated on state park grounds in Georgia, authorities said.

It's the first COVID-19 patient to be transferred to Hard Labor Creek State Park in Morgan County since state authorities prepared the site as a location for isolating and monitoring people who may have been exposed to the deadly virus. Earlier this week, officials installed seven emergency mobile units and delivered supplies in an isolated section of the park that will remain separated from the rest of the property.
Centralized Quarantine is Happening in the State of Georgia!

March 12, 2020

The State of Georgia has quarantined the first COVID-19 patient in a state park which has a site with 7 emergency mobile units.

A patient who tested positive for the novel coronavirus has been isolated on the property. An emergency mobile unit and delivered supplies in an isolated section of the park that will remain separated from the rest of the property.
They were infected before Feb 2 (lack of proper protection). The situation has been much better since Feb 2.
Our healthcare workers do not seem properly protected

ABC News: Kirkland Fire and Rescue ambulance workers walk back to a vehicle after a patient was loaded into an ambulance, Tuesday, March 10, 2020, at the Life Care Center in Kirkland, Wash.,

No protective suit with hood
No medical goggle
No cap
Infection can be through eyelashes and hair
Wuhan’s Strategies for Protecting Healthcare Workers

- Full gear: protective suit, medical goggle, cap, face shield, mask and gloves when seeing suspected cases and exposed subjects.
- Transmission can be through eyelashes and hair
- Developed a stringent protection protocol
- Trained healthcare workers how to follow the protection protocol
Wuhan’s Strategies for Protecting Healthcare Workers

- Suspected cases, e.g., with symptoms, are seen in designated clinics, instead of ER or PCP offices
- COVID-19 hospital level prevention and control management protocol
- Patient management protocol
- Cleaning and disinfection protocol
Take home message #5: These Protection Strategies Worked!

None of the 42,000 external healthcare workers who went to help Wuhan has been infected, according to the news on March 12!

0 out of 42,000 infection!

Full protection, stringent protection and management protocol, training
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>OR (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age group (years)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-40</td>
<td>Ref.</td>
<td></td>
</tr>
<tr>
<td>0-10</td>
<td>0.334 (0.136 - 0.823)</td>
<td>0.017</td>
</tr>
<tr>
<td>10-20</td>
<td>0.637 (0.341 - 1.189)</td>
<td>0.157</td>
</tr>
<tr>
<td>40-60</td>
<td>1.437 (1.295 - 1.595)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>60-80</td>
<td>2.758 (2.490 - 3.054)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>≥80</td>
<td>5.110 (4.420 - 5.908)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>Ref.</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>0.890 (0.837 - 0.946)</td>
<td>0.0002</td>
</tr>
</tbody>
</table>
## Relative Risk (RR) of Severe+Critical Status vs Mild+Moderate Status

<table>
<thead>
<tr>
<th>Outbreak period</th>
<th>Coefficient (CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period 1</td>
<td>Ref.</td>
<td></td>
</tr>
<tr>
<td>Period 2</td>
<td>0.479 (0.397 - 0.577)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Period 3</td>
<td>0.249 (0.208 - 0.299)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Period 4</td>
<td>0.152 (0.126 - 0.184)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

### Occupation

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Coefficient (CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-healthcare worker</td>
<td>Ref.</td>
<td></td>
</tr>
<tr>
<td>Healthcare worker</td>
<td>1.120 (0.958 - 1.308)</td>
<td>0.155</td>
</tr>
</tbody>
</table>
Findings on Severity Risk

- The risk of severity increases with age, and elderly people are at a statistically significant much higher risk of becoming severe (RR=3 for 60-79 and RR=5 for 80+, p-value<0.0001).

- Women have a statistically significant lower risk of becoming severe than men (RR=0.9, p-value=0.002)

- Healthcare workers have a statistically insignificant slightly higher risk of becoming severe compared to general public (RR=1.12, p-value=0.16)
Take home message #6: Early Diagnosis and Early Treatment

• Early diagnosis and early treatment will help prevent cases from progressing to become severe cases, who have a much higher risk of death, like ARDS patients

• Especially for elderly people and healthcare workers.
All the 16 Fangchang (Mobile Cabin) Hospitals in Wuhan were closed on March 10, 2020: Cleared All Patients

Congratulations, Wuhan!
#s of New and Total Current Suspected Cases: Wuhan, Non-Wuhan and Boston, March 13, 2020

These numbers are from internet, and might not be fully accurate
#s of New and Suspected Cases in Italy, March 12, 2020

These numbers are from internet, and might not be fully accurate.
Huge thanks go to all the citizens of Wuhan, the local healthcare workers, and the 42,000 healthcare workers cross the country who went to help Wuhan, for their tremendous sacrifice and efforts.

Acknowledgement

They are my heroes
Concluding Remarks

- As we are at the early stage, starting the effective intervention, centralized quarantine of ill patients and exposed subjects, early, will significantly reduce the number of new infections, stop the outbreak, save lives, relieve the enormous pressure on health system, e.g. a lack of ICU capacity.

- It will protect our beloved family members from being infected, help patients receive immediate medical care early, reduce community transmission, reduce mortality by preventing progression to severity, which has a much higher risk of death.
Everyone is a team member fighting against COVID-19

• Wuhan experience helps us not start from zero.

• Find the best strategy suitable for each city and country by learning from the Wuhan experience

• Good policy, strategy and leadership, cooperation are the key!

• Song “We are the people”

Go Boston!