Scenarios and Projections for COVID-19 in Arizona

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Arizona State University

DRAFT materials prepared for the
Arizona Department of Health Services – Modeling Working Group
Impossible to know if contribution to increased cases is due to increased testing or spread of disease.

Change in testing criteria on 3/28 – no longer testing symptomatic.


Estimates for undetected cases in the US are currently around 1 in 11 (9%-14%).

ADHS has assembled this modeling working group to prepare projections for state.
April 1, 2020 Situation Update

- Daily forecasts derived from ADHS and commercial lab testing data
- Monitor testing data and public health interventions as the basis of estimates
AZ Situation Update

- COVID-19 Testing Results for April 8

<table>
<thead>
<tr>
<th></th>
<th>8-Apr</th>
<th>Positive</th>
<th>Negative</th>
<th>Deaths</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADHS</td>
<td></td>
<td>2,726</td>
<td>31,838</td>
<td>80</td>
<td>34,564</td>
</tr>
<tr>
<td>COVID tracking</td>
<td>8-Apr</td>
<td>151</td>
<td>1,038</td>
<td>7</td>
<td>1,189</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2,726</td>
<td>31,838</td>
<td>80</td>
<td>34,564</td>
</tr>
</tbody>
</table>
Estimating Undetected Cases

Current estimates from J. Shaman (2020) and A. Perkins (2020) that 9% - 14% of infections are detected.
Epidemiology Signal

- Growth is rapid, but has slowed
- Doubling times
  - March 17-24: 1.7 days
  - March 25-April 8: 5.3 days
- Does not include undetected cases

4/8: ADHS data show positive confirmations are currently 7% of all tests.

4/8: Growth is slowing down. 3/16 limited gatherings; 3/20 bars and restaurants close; 3/31 stay-at-home.

Arizona COVID-19 Testing

0 500 1000 1500 2000 2500 3000

3/16
3/20
3/31
4/8

Positive  Deaths
Testing Signal

• Information about negative tests results released March 27.
  • Positive test result drops to <10%.
• Range of 8%-10% is consistent with other US cities with community spread.
Transmission

- Early stochastic effects
- Fast exponential growth
- Slowing growth
Model1 Details

Transmission Dynamics:
- $\beta_A = 0.55 \times \beta_S$
- $\beta_P = 0.55 \times \beta_S$
- $\beta_S = 0.30$
- $\beta_{home} = 0.20 \times \beta_S$
- $\beta_{hosp} = 1 \times \beta_S$
- $\beta_{ICU1} = 0.20 \times \beta_S$
- $\beta_{hosp} = 0.20 \times \beta_S$

\[0.1 = 0.45 \times p_D \Rightarrow p_D = 22\%\]

Results in an overall mortality of 2% among symptomatic individuals.
Pyramid of Disease Severity

• The assumed parameters in the model are all sourced from recent results

• The top of the pyramid implies significant healthcare resource requirements
### Table 1: Estimated parameters for COVID-19 clinical progression, and literature sources

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Parameter</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incubation Period</td>
<td>$E + I_p$</td>
<td>4 days</td>
<td>Cai et al., 2020; Laio et al., 2020; Lauer et al., 2020;</td>
</tr>
<tr>
<td>Proportion of Asymptomatic Infections</td>
<td>$A$</td>
<td>18.5%</td>
<td>Mizumoto et al., 2020</td>
</tr>
<tr>
<td>Asymptomatic viral shedding</td>
<td></td>
<td>0.55</td>
<td>Li et al., 2020</td>
</tr>
<tr>
<td>Duration of mild/presymptomatic phase of infection</td>
<td>$I_p$</td>
<td>2 days</td>
<td>Wei et al., 2020</td>
</tr>
<tr>
<td>Infection rate for $I_s$ and $I_h$ cases</td>
<td></td>
<td>0.30</td>
<td>Pei &amp; Shaman, 2020</td>
</tr>
<tr>
<td>Duration of LR symptoms before hospital admission</td>
<td>$I_s$</td>
<td>3 days</td>
<td>Zhou et al., 2020</td>
</tr>
</tbody>
</table>
# Assumptions & Parameters

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Parameter</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of infection</td>
<td>$I_r+I_s$</td>
<td>5 days</td>
<td>Tindale et al., 2020; Ferguson et al., 2020; Chen et al., 2020; Wang et al., 2020; Zhou et al., 2020</td>
</tr>
<tr>
<td>(Time from symptoms to hospitalization)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospitalization rate of Is cases</td>
<td>$p_H$</td>
<td>20%</td>
<td>Wu et al., 2020</td>
</tr>
<tr>
<td>Proportions of hospitalizations that go to the ICU</td>
<td>$p_{ICU}$</td>
<td>45%</td>
<td>Guan et al., 2020; Wu &amp; McGoogan, 2020</td>
</tr>
<tr>
<td>Proportion of mild infections</td>
<td>$1-p_H$</td>
<td>80%</td>
<td>Wu et al., 2020; Yang et al., 2020</td>
</tr>
<tr>
<td>Duration of illness from symptom onset</td>
<td></td>
<td>23 days</td>
<td>Verity et al., 2020</td>
</tr>
<tr>
<td>Time from symptom onset to death</td>
<td></td>
<td>17 days</td>
<td>Verity et al., 2020; Wu et al. 2020</td>
</tr>
<tr>
<td>Case Fatality Rate</td>
<td>$p_d$</td>
<td>2%</td>
<td>Wu et al., 2020</td>
</tr>
<tr>
<td>Overall ICU Mortality</td>
<td>$p_{ICU}$</td>
<td>22%</td>
<td>Grasselli et al., 2020</td>
</tr>
</tbody>
</table>
Scenarios and projections

- We considered five scenarios to provide a range of projections on:
  - Total number infected – includes asymptomatic and pre-symptomatic
  - Total symptomatic patients – includes all patients who are non-hospitalized
  - Hospitalized patients – patients in regular hospital beds and ICU
  - Patients in ICU
  - Patients on a ventilator

<table>
<thead>
<tr>
<th>Scenario ID</th>
<th>$\beta_s$</th>
<th>Assumed Total Infected Individuals on 4/8/20</th>
<th>Assumed Summer Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario#1</td>
<td>0.30</td>
<td>20,383</td>
<td>On May 15, $\beta_s$ reduces to 0.15</td>
</tr>
<tr>
<td>Scenario#2</td>
<td>0.25</td>
<td>20,383</td>
<td>On May 15, $\beta_s$ reduces to 0.15</td>
</tr>
<tr>
<td>Scenario#3</td>
<td>0.30</td>
<td>1,853</td>
<td>On May 15, $\beta_s$ reduces to 0.15</td>
</tr>
<tr>
<td>Scenario#4</td>
<td>0.25</td>
<td>1,853</td>
<td>On May 15, $\beta_s$ reduces to 0.15</td>
</tr>
<tr>
<td>Scenario#5</td>
<td>0.30</td>
<td>20,383</td>
<td>On May 15, $\beta_s$ reduces to 0.05</td>
</tr>
</tbody>
</table>
### Scenarios:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario 1.</strong></td>
<td>Assumes all infections are known based on a reporting rate of 9% (18530 initial unreported cases, and 1853 reported cases) and “moderate” (modeled by transmission rate for symptomatic patients, $\beta_S \sim 0.30$) social distancing. The estimate of unreported cases obtained by an estimate provided by Shaman et. al. 2020. Assumes no additional mitigation. Summer effect is modeled by reducing $\beta_S$ by half on May 15.</td>
</tr>
<tr>
<td><strong>Scenario 2.</strong></td>
<td>Assumes a reporting rate of 9% (18530 initial unreported cases and 1853 reported cases) and “maximal” social distancing (modeled by transmission rate for symptomatic patients, $\beta_S \sim 0.25$). Assumes ongoing mitigation. Summer effect is modeled by reducing $\beta_S$ by half on May 15.</td>
</tr>
<tr>
<td><strong>Scenario 3.</strong></td>
<td>Assumes that the current reported cases reflect the actual number of infected individuals as of 4/8/20 (1853 initial infected) and moderate social distancing (modeled by transmission rate for symptomatic patients, $\beta_S \sim 0.30$). Summer effect is modeled by reducing $\beta_S$ by half on May 15. Assumes no additional mitigation.</td>
</tr>
<tr>
<td><strong>Scenario 4.</strong></td>
<td>Assumes that the current reported cases reflect the actual number of infected individuals as of 4/8/20 (1853 initial infected) and maximal social distancing (modeled by transmission rate for symptomatic patients, $\beta_S \sim 0.25$), Summer effect is modeled by reducing $\beta_S$ by half on May 15. Assumes no ongoing mitigation.</td>
</tr>
<tr>
<td><strong>Scenario 5.</strong></td>
<td>Same as Scenario 1 with extreme summer-time transmission effects (heat or distancing); reduced transmission rate, $\beta_S$ to 0.05 after May 15. Assumes no additional mitigation for social distancing.</td>
</tr>
</tbody>
</table>
Total Infected

• Total infected includes asymptomatic and pre-symptomatic individuals, who may be transmitting the disease

• The sharp decline in Scenario #5 due to the reduction in transmission rate due to summer effect
  • Assumes May 15 for reduction in transmission
  • Summer effects not yet known
Symptomatic Infections

• A large number of the symptomatic infections will recover at home
  • Due to social distancing measures, we assumed that these individuals with transmit the disease at a lower rate
Hospitalized Infections

• A portion of the hospitalized infections are in ICU, which we track separately due to the significant resources need to care for ICU patients

• Under our mid-range scenario (Scenario #2), the number of hospitalized patients hit 13,091 on May 23

• Scenario #4 estimates a max of 1258 patients on May 23, similar to IHME estimates of 1203 on April 22
Patients in ICU

• ICU resources can be critical to save lives
• In particular, several sources have pointed to longer ICU stays by patients that eventually recover
• ICU stays can be as long as 14+ days for these patients
Patients on Ventilator

• A significant fraction of patients (~88%) need mechanical ventilators in ICU
• Rate of mortality among patients on mechanical ventilator is higher than other causes of ARDS (~67%)
### Maximum Daily Counts: All scenarios

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>High</th>
<th>Mid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Infected</td>
<td>6,875</td>
<td>175,695</td>
<td>88,466</td>
</tr>
<tr>
<td>Peak Hospitalized (Daily)</td>
<td>1,259</td>
<td>31,670</td>
<td>15,428</td>
</tr>
<tr>
<td>Peak ICU (Daily)</td>
<td>591</td>
<td>14,981</td>
<td>7,126</td>
</tr>
<tr>
<td>Peak Ventilators (Daily)</td>
<td>520</td>
<td>13,183</td>
<td>6,270</td>
</tr>
</tbody>
</table>
Projected Infections: Low, medium, high

![Graph showing projected infections: Low, medium, high with current interventions indicated.](image-url)
Projected Hospitalizations: Low, medium, high

(Estimate Made 4/20)
Projected ICU visits: Low, medium, high

(Projected ICU visits: High, Med, Low
(Estimate Made 4/20))

Low Interventions
Hi Interventions

Current
Projected Ventilator Use: Low, medium, high

Assumes 88% ventilator utilization for ICU patients
Model Comparison: All scenarios

- Our model predicts infections will peak around the middle of May
- Model is highly-sensitive to social distancing and increased temperature
- A wide range (1-2 order of magnitude) in outcomes is still feasible with uncertainty in undetected cases
Recommendations:

1. Adopt a baseline planning scenario with “low” and “high” excursions.
2. Discuss & reach consensus on importance of predicting peak week.
3. Update forecasts based on new information weekly(?)
4. Prioritize additional analysis