A mathematical modeling consortium for COVID-19 epidemic prediction and resource allocation in: South Africa

8 April 2020

Dr Brooke Nichols, Asst Professor
Boston University School of Public Health, Boston, USA
Health Economics and Epidemiology Research Office, Johannesburg, South Africa
**Epidemic modeling**: cumulative cases, cases detected, hospitalized, ICU visits
Consortium structure

• Daily check-ins with modelers
  • Twice weekly model runs and testing of assumptions in a group
  • Open collaborative communication between lead modelers regarding refinement of assumptions

• Weekly updates with government

• Weekly input from the clinicians society of SA to discuss assumptions and scenarios
HE$^2$RO model structure and data sources
### Data point

- **GIS**
- GIS location of all healthcare facilities
- GIS location of all labs
- GIS location and capacity of laboratory equipment that can conduct COVID tests

### Capacity

- Hospital beds/ICU beds by facility
- Testing capacity (including person-time required due to more lab-staff intensive front-end PCR)
- Human resource capacity: national number of healthcare workers by cadre

### Underlying population

- Population by province by age & SVI/NLI

### Burden of comorbidities

- Number of people suppressed on ART by small area
- Total number of people living with HIV by small area
- TB burden

### Costs*

- Cost of laboratory tests
- Rapid full costing of different test types
- Hospitalization costs

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**First:** what can do we have and what can we use to make better predictions?
Assumptions and modeling strategy

• Using South African data sources to update the pen source Covid-19 model developed by the Neher lab at Univ. of Basel (https://neherlab.org/covid19/)

• Need for hospitalisation/ critical care: differ by age strata (1)

• Data on social vulnerability index (SVI)

• Added separate sets of predictions and underlying assumptions regarding contact rate (and therefore transmission probability and effective reproductive number) (2), and resource availability for each SVI quintile, then recompiled
(1) Underlying population data by SVI

Population pyramids (absolute numbers, Gauteng) by SVI quintile

Lowest quintile

Quintile 2

Quintile 3

Quintile 4

Highest quintile

Social Vulnerability Index (SVI) is based on a number of indicators which includes: Population Density, Household size, LSM, car ownership (reliance on public transport). The information is then linked to StatsSA enumerator area and a score out of 1 formulated. The lower the score the more vulnerable. Areas which clustered here have scores of .25 or lower.

Map Created by Right to Care GIS and Planning
(2) Reproductive number dependent on population density/communal spaces/etc. (which is also co-linear with SVI) ($\beta = c(\text{contact rate}) \times p(\text{probability of transmission})$) $c(\text{contact rate})$ higher in areas with communal living and communal resources.

<table>
<thead>
<tr>
<th>SVI quintile</th>
<th>Total population size</th>
<th>Reproductive number (no intervention)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4,497,939.00</td>
<td>3.2</td>
</tr>
<tr>
<td>2</td>
<td>5,226,576.00</td>
<td>2.7</td>
</tr>
<tr>
<td>3</td>
<td>1,735,753.00</td>
<td>2.2</td>
</tr>
<tr>
<td>4</td>
<td>1,496,456.00</td>
<td>2.2</td>
</tr>
<tr>
<td>5</td>
<td>664,002.00</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Increasing contact rates

Reproductive number in different areas can be re-estimated regularly

*Contact rates by SVI estimated through prior work in flu*
Given timelines, wanted to use an infrastructure that had already been developed:

Neher lab
University of Basel, Switzerland
Figure 1. A schematic illustration of the underlying model. S corresponds to the 'susceptible' population, E is 'exposed', I is 'infectious', R 'recovered', H 'severe' (hospitalized), C 'critical' (ICU), and D are fatalities.
Since the Swiss group hadn’t parameterized for South Africa in any sub-national way: popped the hood on the model so we could re-parameterize for South Africa by provinces specifically

https://github.com/neherlab/covid19_scenarios
Built in underlying known data and flexibility
Literature and consensus expert opinion

Results

This output of a mathematical model depends on model assumptions and parameter choices. We have done our best (in limited time) to check the model implementation is correct. Please carefully consider the parameters you choose and interpret the output with caution.

Run   Export

Log scale

Cases through time

- Susceptible
- Infectious
- Patients in ICU
- ICU overflow
- Recovered
- Cumulative deaths
### Scenario

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial suspected cases</td>
<td>5</td>
</tr>
<tr>
<td>Imports per day</td>
<td>1</td>
</tr>
<tr>
<td>Hospital Beds (est.)</td>
<td>2282</td>
</tr>
<tr>
<td>ICU/CMU (est.)</td>
<td>53</td>
</tr>
<tr>
<td>Confirmed cases</td>
<td>WC - Low</td>
</tr>
<tr>
<td>Simulation time ran</td>
<td>23 Mar 2020</td>
</tr>
<tr>
<td></td>
<td>04 Oct 2020</td>
</tr>
</tbody>
</table>

### Epidemiology

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual average $R_0$</td>
<td>3.2</td>
</tr>
<tr>
<td>Latency [days]</td>
<td>3</td>
</tr>
<tr>
<td>Infectious period [days]</td>
<td>4</td>
</tr>
<tr>
<td>Seasonal forcing</td>
<td>0.1</td>
</tr>
<tr>
<td>Seasonal peak</td>
<td>July</td>
</tr>
</tbody>
</table>

### Mitigation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of points</td>
<td>100</td>
</tr>
</tbody>
</table>

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**Parameters also for calibration**
In depth parameter estimation
National budgeting
Resource needs estimation and tools
Starting next week, direct programming of their model to increase capacity
Acknowledgements

Contact: Brooke Nichols  (e) brooken@bu.edu (skype) brooke.e.nichols