Research Report

A Comparison of National and International Approaches to COVID-19-Related Measures

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Preface

As nations around the world and states in the United States confront the COVID-19 crisis, many governments and public health experts look to comparisons with other nations or states to gauge their progress in containing the spread of the virus. Yet, the validity of cross-national and cross-state comparisons is complicated by variations in the way that key indicators—such as case identification, hospitalization, and mortality—are measured and reported. This report presents the results of a rapid evaluation of the comparability of commonly used COVID-19 measures within the United States and across countries, and makes recommendations for the use and development of measures that would allow for more standardized and valid comparisons.

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Background and Purpose

As the COVID-19 pandemic spread in early 2020, government, public health, academic, and other entities began collecting and reporting data on COVID-19-related measures, including case identification/testing, hospitalization, mortality, and excess mortality. Given baseline differences among countries in the structure of health care, political systems, culture, and many facets of government and society, as well as the inherent differences in methods of health outcome data collection, measurement, and reporting, we would expect international variation in COVID-19-related measures. Similarly, we would also expect variation in COVID-19-related measures among states across the United States. However, to track how well different countries and U.S. states are responding to the pandemic—and to make valid cross-country and cross-state comparisons of key outcomes—uniform measures are needed.

In this report, we present the results of a rapid evaluation of the comparability of commonly used COVID-19 measures within the United States and across countries. We also make recommendations for the use and development of measures that would allow for more valid comparisons.

Methods

Our analysis included measures used in the early stages of the pandemic (December 2019–May 2020), including

- case identification/testing (i.e., number of tests conducted and test results)
- hospitalization (i.e., hospitalizations attributed to COVID-19)
- mortality (i.e., deaths attributed to COVID-19) and excess mortality (i.e., the difference between observed and expected mortality).

We performed a rapid high-level assessment of common approaches for data collection, computing, and reporting of these measures in five illustrative countries (Australia, China, Germany, Italy, and the Republic of Korea) and in ten illustrative states (California, Illinois, Louisiana, Michigan, Missouri, New Jersey, New York, South Carolina, Texas, and Washington), using a review of publicly available literature and data sources. To further understand the longitudinal evolution of COVID-19 measure data collection, calculation, and reporting, we conducted a case study of one country (Australia) and one state (Washington). Finally, to develop an understanding of the real-time challenges with COVID-19 death certification in the United States, we conducted a roundtable with forensic pathologist medical examiners from a subset of the states listed above.

Results

Our analysis revealed tremendous variability in data collection, calculation, and reporting for all the COVID-19 measures under study—across countries and across U.S. states. Measurement methods varied widely among geographic areas and changed over time within areas. The biases introduced by the measurement issues we identified may result in both underestimates and overestimates. This variability limits the validity of cross-state and cross-national comparisons of these measures during the time period studied.

The most common areas where we observed measurement differences across countries and U.S. states are as follows.

Case Identification/Testing

- *Variations in testing criteria, capabilities, and access.* There have been large differences in the use of testing among areas and over time, resulting in different populations being tested in different localities (e.g., only sicker patients in some places, as opposed to patients from the broader acuity spectrum in others).
- *Lag time in reporting test results*. There has been considerable variation in lag times for reporting the results of tests between localities. As a result, cross-country and cross-state comparisons of data from different time periods and the use of data for comparison may not reflect the most current numbers tested.
- *Variation in reporting requirements.* We observed variation among states and countries in terms of whether case count/test result reporting is mandatory, implying that there is likely variation in the completeness of data. Not all localities report both rates of testing per capita and the test positivity rate.
- *Variation in types of tests used*. There are different types of COVID-19 tests available (nucleic acid, antigen, antibody tests), each with different uses, as well as multiple tests within each category and different types of facilities and methods for processing tests. Testing rates reported by localities typically do not account for these differences.

Hospitalization

- *Variation in what counts as a COVID-19 hospitalization.* There has been variation in whether hospitalization counts include patients who are hospitalized with suspected COVID-19 but without a test result confirming presence or absence of the disease. There has also been variation in whether care for COVID-19 patients in lower-acuity settings is included in hospitalization counts.
- *Variations in inpatient testing criteria.* Similar to the issues related to testing measures, variation in inpatient testing criteria may lead to differences in the rate of detection of COVID-19 cases and related hospitalization rates.
- *Variation in whether hospitalization raw counts versus cumulative counts or rates (e.g., per 100,000 population) are reported* make cross-locality comparisons impossible or invalid if different measures are used for comparison.
- *Variation in COVID-19 hospitalization requirements and reporting timelines.* Some localities require reporting of COVID-19 hospitalizations. The timing of reporting among localities may vary, both within countries and U.S. states and across them.

Mortality

- *Variation in how mortality rates are defined.* The case-fatality rate uses confirmed COVID-19 cases as the denominator, whereas the population mortality rate uses total population as the denominator.
- *Variation in whether both deaths "of" and "with" COVID-19 are counted.* Deaths "of" COVID-19 are those for which COVID-19 is deemed to be the main cause of death; those "with" COVID-19 are deaths where COVID-19 is a co-existing condition or has contributed to death.
- *Variation in whether "probable" COVID-19 deaths are included in total death counts.* "Probable" COVID-19 cases are those with consistent symptoms but without a positive test result confirming the disease.
- *Potentially inaccurate death certification by community- or hospital-based physicians.* Medical examiners participating in our roundtable discussion reported concerns about the limited training that physicians receive in reporting the cause of death on death certificates and how this may affect mortality data.
- *Variation in whether out-of-hospital deaths are included in the death counts.* Many COVID-19 deaths have occurred outside of hospitals, but these have not consistently been included in mortality rates.
- *Variation in how widely post-mortem testing is conducted.* Localities vary in how much post-mortem COVID-19 testing they conduct and the indications for post-mortem testing.
- *Variation in reporting of location.* We observed differences in whether mortality is reported based on the jurisdiction of residence versus the location of testing or treatment, which can produce inconsistent counts within localities and complicate cross-locality comparisons.
- *Retrospective revision of the number of deaths may result in the final death counts being higher (or lower) than originally reported.* In some localities, the final number of reported deaths may change for a given timeline because of delays in formal death certification. If the final determination of cause of death is different than what was initially reported, COVID-19 deaths may initially be under- or overcounted.
- *Variations in whether excess mortality is reported as a pandemic outcome.* Rather than relying on certification of COVID-19 as an underlying cause of death, excess mortality compares total observed mortality rates with expected rates, adjusting for underlying trends based on historical experience. We observed variation in whether states and countries consistently report excess mortality as a pandemic outcome.

Cross-Cutting Findings

- All the COVID-19-related measures currently in use have limitations. There are also specific strengths and weaknesses associated with each type of measure, and each communicates a different type of information.
- Some of the limitations pertain to multiple measures. For example, issues that affect the accuracy of case identification/testing measurement—including limiting testing to sicker individuals and lag time in reporting—also affect the denominator used to compute the COVID-19 mortality rate, and the numerator used to compute COVID-19 hospitalizations and COVID-19 mortality.

- Our environmental scan revealed high prevalence of COVID-19 infection among residents of congregate living facilities (e.g., long-term care facilities and nursing homes). This population is often older and frail with multiple comorbidities, and they are at higher risk for poor outcomes from COVID-19. Therefore, particular focus on tracking testing and mortality among this population is important.

Example

To demonstrate the potential impact of measurement variation on key COVID-19 measures, we share this example. Especially early in the pandemic, many countries and U.S. states limited COVID-19 testing/case identification to sicker patients and those hospitalized. As the pandemic progressed, most localities expanded testing to include mildly symptomatic and asymptomatic individuals. Table S.1 demonstrates how the test positivity rate (defined as the number of positive tests over all tests conducted) and mortality rate (COVID-19 deaths per 100,000 population) both decline over time as testing is broadened to include individuals with less severe symptoms.

Table S.1. Variation in Testing Availability on Testing/Case Identification and COVID-19 Mortality Using Simulated Data

	Distribution of Tested Cases by Symptom Severity					
Time Period	**Severe (20% test positive; 15% mortality)**	**Moderate (10% test positive; 3% mortality)**	**Mild (5% test positive; 0.5% mortality)**	**Asymptomatic (0.5% test positive; 0.1% mortality)**	**Test Positivity Rate[a]**	**Mortality Rate[b]**
Time 1	95%	5%	0%	0%	19.5%	2.9%
Time 2	60%	20%	10%	10%	14.6%	1.9%
Time 3	20%	20%	30%	30%	7.7%	0.7%

NOTES: Time 1 through Time 3 represent evolving testing practices from early in the pandemic onward: Only those with severe and moderate symptoms are tested in Time 1; at Time 3, individuals across the range of symptom severity are tested. In this example, at Time 1, 95% of those tested are severely ill and 5% are moderately ill. Given the state test positivity rates and COVID-19 mortality rates, the test positivity rate is 20% x 95 + 10% x 5 = 19.0 + 0.5 = 19.5, and, among those who test positive, the mortality rate is 15% x 19 + 3% x 0.5 = 2.85 + 0.015 = 2.9. As the proportion of tested cases shift from the severely ill to those who are moderately symptomatic, mildly symptomatic, or asymptomatic, the test positivity rate and mortality rate decline.

[a] Test positivity rate among all cohorts tested at Time 1, 2, and 3, respectively.

[b] Mortality rate among all confirmed COVID-19 cases at Time 1, 2, and 3, respectively.

Recommendations

Based on these findings, we recommend the following steps to the U.S. Department of Health and Human Services, the Centers for Disease Control and Prevention (CDC), and other U.S. government agencies to aid in developing measures for valid comparisons across states and countries.

- Assess the root causes of the lag in states' reporting of mortality and other information to the federal government.
- Explore ways to facilitate more timely reporting of the number of COVID-19 tests conducted, test results, hospitalizations, and excess mortality.
- Develop national standards around testing criteria (i.e., who to test), data collection, and reporting.
- Make the test positivity rate a standard component of reporting COVID-19 testing; states should report the total number of tests conducted, as well as those that are positive.
- Prioritize reporting of COVID-19 hospitalization per 100,000 population (i.e., the CDC definition of hospitalization rate) for surveillance purposes.
- Increase post-mortem testing capabilities to capture undiagnosed COVID-19 cases.
- Encourage continuing medical education for practicing clinicians to improve documentation of cause of death for COVID-19 and future public health emergencies and require more education and training around death certification in medical schools and residency training programs.
- Use a measure of excess mortality—the excess number of deaths observed during the pandemic relative to the expected number based on historical data—to compare the effects of COVID-19 across countries and states.
- Encourage more systematic reporting of all measures separately for congregate living facilities (e.g., nursing homes, short-term nursing facilities).
- Encourage systematic reporting of multiple measures (e.g., testing positivity rate, hospitalizations per 100,000 population, and excess mortality) given the strengths and limitations of each individual measure.
- Explore the development of a composite COVID-19 index that includes a combination of testing, hospitalizations, and/or mortality and that leverages the strengths of each of the related datasets.

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We dedicate this report to patients, caregivers, and frontline providers fighting the pandemic in the United States and around the world.

1. Introduction

As nations around the globe respond to the COVID-19 pandemic, policymakers want to know how well their nations are doing in combating the virus. They can gauge progress by comparing their nation's testing/case identification, hospitalizations, mortality, and excess mortality statistics against those of neighboring countries or other countries of interest. The same is true of states in the United States. U.S. policymakers are interested in how states are faring over time and in comparison with one another, especially given state-by-state variations in the public health policies that U.S. states are implementing to mitigate the threat.

Yet, these comparisons can be misleading. There are important differences in the structure of health care, political systems, culture, and many facets of government and society that may translate into variations in data collection, analysis, and reporting across nations. Specifically, for COVID-19-related measures, these factors may affect measurement of case identification/testing, hospitalizations, deaths, and other outcomes. Similarly, there may be variations in how U.S. states collect and report these data. Such variations complicate the ability to make apples-to-apples comparisons in publicly reported data across state and national borders.

The goals of this analysis were to (1) describe the status of COVID-19 measurement in terms testing/case identification, hospitalizations, mortality, and excess mortality during the time period studied; (2) evaluate how such measurement varies among countries and across U.S. states; and (3) make recommendations for the use and development of measures that would allow for more valid comparisons.

To reach these goals, we performed a rapid assessment of common approaches for computing and reporting COVID-19-related measures (case identification/testing, hospitalizations, mortality, and excess mortality) in five illustrative countries (Australia, China, Germany, Italy, and the Republic of Korea) and in ten illustrative states (California, Illinois, Louisiana, Michigan, Missouri, New Jersey, New York, South Carolina, Texas, and Washington). To understand challenges with COVID-19 death certification, we conducted a remote roundtable with medical examiners from a subset of these states.

The remainder of this report is organized as follows. In Chapter 2, we describe the methods we used to compare measurement approaches across countries and U.S. states. In Chapter 3, we describe the measurement issues and variation that we identified. Finally, In Chapter 4, we discuss these results and make recommendations for improving COVID-19 measurement.

2. Methods

Measure Definitions

We performed a rapid high-level assessment of common approaches for data collection, computing, and reporting of COVID-19 measures. We selected a set of measures for COVID-19 currently in use, including case identification/testing, hospitalizations (as a measure of morbidity), mortality, and excess mortality. Our first task was to identify accepted definitions of each measure before evaluating the strengths and potential challenges associated with each and considering alternate measures.

- *Case identification/testing* includes both the number of tests conducted and the test results. Case identification/testing can refer to both testing for acute infection (i.e., antigen or polymerase chain reaction [PCR] testing) and testing for prior infection (i.e., antibody testing). Examples of rate calculations that use this measure include infection rate (e.g., number of cases/100,000 population) and test positivity rate (the number of positive tests over all tests conducted)
- *Number of hospitalizations* refers to those hospitalized with confirmed COVID-19 infection through antigen or PCR testing and, in some cases, persons under investigation (e.g., those who are hospitalized with suspected COVID-19 whose test results are pending or test negative but are still clinically suspected of having COVID-19). An example of a rate that commonly uses this measure is hospitalization rate—the cumulative number of COVID-19 hospitalizations per 100,000 population, which may or may not include persons under investigation.
- *COVID-19 mortality* refers to deaths attributed to COVID-19. Examples of rates that use this measure are the mortality rate (e.g., COVID-19 deaths per 100,000 population) and case fatality rate (COVID-19 deaths per confirmed COVID-19 cases). *Excess mortality* refers to the difference between observed and expected mortality. An example of a rate that uses this measure is the percentage increase in deaths (excess mortality over expected deaths).

Sampling Strategy

Illustrative countries and states were selected in consultation with the Assistant Secretary for Planning and Evaluation. Because of funding limitations and the quick-turn project timeline, we limited the environmental scan *a priori* to ten U.S. states and five countries. The countries (Australia, China, Germany, Italy, and the Republic of Korea) were selected from a list of those with the top ten highest number of confirmed COVID-19 cases per 100,000 population as of May 28, 2020, and from the Group of Seven (G7) countries. The ten states were selected for one of three reasons: They were among those with the top ten highest number of cases per 100,000 population (New York, New Jersey, Louisiana, Michigan); they were among states with few or

no medical examiners who are also forensic pathologists (Louisiana, Michigan, Missouri, South Carolina); and they were among the states that had the earliest confirmed cases in the United States (California, Washington). The states were also sampled to ensure geographic representation (Northeast, Midwest, South, West/Southwest). The states with the greatest number of cases and those with the earliest confirmed cases were selected because they were more likely to provide the measurement data this project sought. States with few or no forensic pathologists were selected because such states may face more challenges around consistent COVID-19 death certification. Funding and project timeline limitations also prohibited us from conducting a roundtable with medical examiner equivalents from other countries and from conducting similar roundtables with other key stakeholders (e.g., those with measurement or practical expertise around case identification/testing and hospitalizations).

Search Strategy

The analysis included measures used in the early stages of the pandemic (December 2019–May 2020). In our environmental scan, we searched the peer-reviewed literature (articles published in peer-reviewed academic journals) and gray literature (non-peer-reviewed publications or information available online on government, public health, academic, and other relevant websites) for data related to the COVID-19 measures of interest: case identification/testing, hospitalization, COVID-19 mortality, and excess mortality. It is important to note that it often takes months for manuscripts to be published in peer-reviewed, academic journals; therefore, information from the gray literature may reflect current measurement and reporting practices more accurately. Further, with the exception of Germany and China—where team members fluent in the native language translated non-English documents—our environmental scan was limited to English-only documents.

For the review of peer-reviewed literature, we drew on the PubMed search engine and searched on the following terms: *COVID-19* OR *coronavirus* AND *testing* OR *hospitalizations* OR *mortality* OR *deaths* OR *metrics* OR *measures* OR *outcomes*. For the gray literature review, we started with a targeted review of the World Health Organization (WHO) website and relevant government and academic institution websites for the countries in our sample. For the environmental scan of U.S. states, we started with a targeted review of non-peer-reviewed content on the Centers for Disease Control and Prevention (CDC) website followed by the individual departments of health, public health, and hospital association websites of each state. For each country and state, we also conducted a Google search using search terms similar to those used for the PubMed search.

We used this same search strategy to conduct two case studies, one of Australia (Appendix C) and one of Washington State (Appendix D), to develop a more in-depth understanding of COVID-19-related measurement issues and evolution of measurement over time since the start of the pandemic. Australia was chosen based on significantly lowered case counts over time and

on hospital capacity, which appeared to be manageable at the time the choice was made. Washington was chosen based on the fact that it was the U.S. first state where COVID-19 cases were confirmed, allowing a longer timeframe for evaluation of how related measurement occurred.

As part of the environmental scan around COVID-19-related measures, we graded the data we gathered based on the numbers and types of sources that support the data (e.g., government or academic organization, peer-reviewed manuscript). We graded the evidence from the environmental scan for the key environmental scan findings associated with each measure (Appendixes A and B). The grading approach we used in described in Appendix A.

Medical Examiner Roundtable

To better understand current challenges with identifying and certifying COVID-19-related deaths, we conducted a 1.5-hour roundtable via conference call with medical examiners from seven of the ten states examined in the environmental scan: California, Illinois, Michigan, Missouri, New Jersey, Texas, and Washington. We were unable to recruit participants from the remaining three states in our sample. All the medical examiner participants were forensic pathologists. Through referral from colleagues, forensic pathologists were recruited through the National Association of Medical Examiners. Given the variation in medical examiner credentials within and across states, we recruited forensic pathologists for consistency, high likelihood of having a similar approach to death certification, and visibility into any variation in death certification in their respective states. A representative from one of the nation's premier toxicology labs also participated for a total of eight roundtable participants.

We used a semistructured guide (Appendix E) to moderate the discussion. Questions focused on current practices around COVID-19 death certification, related challenges, and whether additional state and federal guidance is needed. Detailed notes were taken during the roundtable and subsequently analyzed by two study team members using a rapid qualitative analysis technique to identify key themes (Watkins, 2017).

3. Results

Our analysis revealed tremendous variability in data collection, calculation, and reporting for all the COVID-19 measures under study—both across countries and across U.S. states. Measurement methods varied widely among geographic areas and changed over time within areas. This variability limits the validity of cross-state and cross-national comparisons of these measures during the time period studied.

Observed Areas of Variability in Measures

We evaluated three categories of COVID-19 measures across the countries and U.S. states: case identification/testing, hospitalization, and mortality. These are subject to measurement bias. In the sections below, we present results from all the project data sources related to COVID-19 to advance understanding of the key issues that may affect cross-country and cross-state comparisons. The majority of issues identified apply both to the countries and the U.S. states.

When considering measures that depend on testing (such as case counts), which can take several hours to many days to process and report, or on the collection, reporting, and processing of death certificates, timeliness of the data is important. For example, the CDC provides provisional weekly COVID-19 death counts, and the more recent weeks of CDC data reported will typically not include all deaths in a state because of reporting lags and potential need for retrospective correction by reporting states.

If bias and timeliness issues equally affect the measures of countries and states, or if the effects are constant over time, it could be possible to estimate and apply adjustments to the measures to allow comparisons between places and over time. However, the nature and extent of these issues often varies across places and over time within places, to an extent that is often unknowable.

COVID-19 Case Identification/Testing Measurement

Case identification and testing measurement issues can introduce biases that can result in both underestimates and overestimates of COVID-19 cases. As a result, it is difficult to determine whether the test positivity rates (i.e., the number of positive tests over all tests conducted) in these areas during the study period are systematically higher or lower than true population values. Many of the measurement issues identified likely bias measures toward an underestimate. Capture bias, which results from exclusive data collection methods, frequently leads to underreporting of COVID-19 cases. For example, if only the sickest people are tested, then mild or asymptomatic cases will be missed. Capture bias may occur because of shortages in

testing equipment or personnel that lead to tests being administered only to hospitalized patients with suspected COVID-19.

Other measurement issues are likely to bias measures toward an overestimate. For example, if only the sickest people are tested, then the testing positivity rate will be relatively high. For some of the identified measurement issues, it is not possible to determine the direction of the bias. Cases where faulty test kits are used or samples are mishandled or misprocessed could bias case counts in either direction. Further, where results of tests with different specificity and sensitivity are used, it is not possible to identify the direction of the bias since the false positive (i.e., a positive test in someone who does not have COVID-19) and false negative (i.e., a negative test in someone who has COVID-19) rates of tests currently in use are largely unknown.

The variations in data collection, computing, and reporting with respect to case identification noted in Table 3.1 may apply both within and across countries and within and across U.S. states.

Table 3.1. Measurement of Testing/Case Identification and Likely Biases

Issues	Direction of Bias
• Testing shortages and poor access to testing[a] • Limiting testing to severely ill patients in hospital setting as opposed to community; limited, if any, testing of asymptomatic or mildly symptomatic individuals and decedents • Variations in reporting requirements • Lag time in reporting test results[b] • Inconsistent testing criteria or testing procedures[c]	Underestimate number of cases, especially in most recent periods
• Use of unauthorized or faulty kits[d] • Use of different types of tests with unknown specificity and sensitivity[e] • Combining reporting of different types of tests (e.g., nucleic acid and antibody testing)	Unknown direction of bias—may underestimate or overestimate number of cases

NOTE: The content in this table specifically pertains to PCR and antigen testing (i.e., testing for acute COVID-19 illness) as opposed to antibody testing (i.e., testing for prior COVID-19 illness in recovered individuals).
[a] Gill, 2013.
[b] CDC, 2020a. *Lag time* refers to the time it takes from when a patient is swabbed for COVID-19 and the media is sent to the lab for testing to the time the test result becomes available and is reported.
[c] Bialek et al., 2020; World Health Organization, 2020a. Includes reserving testing for patients in acute care settings.
[d] Eder, Twohey, and Mandavilli, 2020.
[e] Eder, Twohey, and Mandavilli, 2020. *Specificity* refers to the ability of a test to correctly identify individuals without the disease of interest, and *sensitivity* refers to the ability of a test to correctly identify individuals with the disease of interest.

Variations in who is tested. There have been large differences in the use of testing among areas and over time, in part due to testing shortages, resulting in different populations being tested in different localities (e.g., only sicker patients as opposed to patients from the broader acuity spectrum). For example, in China, testing was initially focused in Wuhan and surrounding regions and conducted among sicker, older adults and those hospitalized. As of mid- to late-April 2020, large-scale testing began with businesses reopening (Eder, Twohey, and Mandavilli, 2020). Further, we observed considerable variation in post-mortem testing capabilities, which

may result in undercounting deaths in localities with less capability. Differences in testing rates per capita could be due to demand for tests or limits in test supply and capacity. Differences in testing criteria also directly affect test positivity rates, which would be higher when tests are more highly targeted to sicker patients.

Results from the Australia and Washington State case studies (Boxes 3.1 and 3.2, respectively) demonstrate some of the issues outlined above, and they are described further, in turn, below.

Box 3.1. COVID-19 Testing Measurement Issues from the Australia Case Study

- States and territories report cases daily to the Australian Government Department of Health, with varying reporting times (Australian Government Department of Health, 2020a).
- The government emphasizes reporting and generates regular reports.
- Numbers are revised when further information is available.
- Cases are split by jurisdiction and where the patient resides, not based on where testing is performed or where patients were infected (Australian Government Department of Health, 2020d).
- *Possible* COVID-19 cases are declared either a suspected case or a probable case; probable cases were defined as suspected cases with inconclusive testing or that couldn't be tested and were not included in the case counts.
- Testing criteria have changed and currently all provinces suggest testing for any flu-like symptom (Australian Government Department of Health, 2020d; Lab Tests Online, 2020).

For the full results from the Australia case study, see Appendix C.

Box 3.2. COVID-19 Testing Measurement Issues from the Washington State Case Study

- Since reporting the first U.S. COVID-19 case in late January, Washington gradually expanded its testing criteria to reflect changing CDC guidelines (Ghose, 2020a; KUOW Staff, 2020a).
- Amidst a shortage of supplies (Bush, 2020), testing later ramped up to include drive-through testing (Ghose, 2020a) and antibody testing (Kirschman, 2020).
- As of mid-May, the state Department of Health encouraged testing even without symptoms (Washington State Department of Health, 2020a).
- Reported numbers and percentages of tests have been affected by variation in laboratory results, swabbing techniques, and separate reporting of probable cases and confirmed cases (*The Atlantic* COVID Tracking Project, "Our Data," 2020).
- The state reports the number of people tested and reports the number of confirmed cases and laboratory tests as of the previous day (Washington State Department of Health, 2020a). The state started reporting negative test results mid-April 2020 so that the proportion of tests that are positive can be calculated (Washington State Coronavirus Response, 2020).

For the full results from the Washington State case study, see Appendix D.

Variation in reporting requirements. We observed variation among states and countries in whether case count/test result reporting is mandatory, implying that there is likely variation in the completeness of data. In particular, we observed variation in specific aspects of how testing measures are reported. For example, the South Carolina Health Alert Network reports the number of new cases, cumulative number of cases, and cumulative case rate per 100,000 (South Carolina Health Alert Network, 2020). Alternatively, the South Carolina Department of Health and Environmental Control reports the number of positive tests reported in a day divided by the number of tests performed on that day (South Carolina Department of Health and Environmental Control, 2020b). Not all localities report both rates of testing per capita and the test positivity rate. The underreporting of negative tests in some states may bias the test positivity rate upward, since it removes cases from the denominator.

The story from a frontline provider in Box 3.3 demonstrates one of the measurement challenges we identified in our environmental scan—undercounting cases because of limited testing capabilities. Undercounting cases also has the potential consequence of artificially increasing the COVID-19 mortality rate by decreasing the denominator.

Box 3.3. COVID-19 Testing Story from the Frontline

> "During one of my shifts in the emergency department after the first confirmed COVID-19 case in Michigan was announced, a young man in his twenties came in with cough, shortness of breath, and fever. He had no sick contacts and had been traveling but not to an outbreak epicenter. He complained of body aches and appeared dehydrated. In those early days of the pandemic, we were told that there were only three hundred tests for the whole state and that we need to be very selective about who we test. Instead of testing him for COVID-19, I sent a "viral respiratory panel" testing for viruses that cause the common cold and tested him for the flu. He tested negative for the flu and positive for the Respiratory Syncytial Virus (RSV)—a virus that causes the common cold. To this day, I believe the patient likely had concurrent COVID-19 based on his clinical presentation. However, given the testing challenges at the time, he was likely never tested and won't be counted as a COVID-19 case in the state of Michigan."
>
> —emergency physician in Michigan

Lag time in reporting test results. There is considerable variation among localities in lag times for reporting the results of tests. This variation may result in cross-country and cross-state comparisons of data from different time periods and/or using data for comparison that may not reflect the most current numbers tested. For example, in Germany there was a reporting lag time to the government of up to five days—which may have resulted in inaccurate within and across country comparisons within certain timeframes. The rates of testing and test results have also been subject to retrospective revision in some cases. This may also result in comparisons of inaccurate numbers if revised rates are not consistently used.

Variation in types of tests used. There are different types of COVID-19 tests available (nucleic acid, antigen, antibody tests)—each with different uses. Further, there are multiple tests available within each category, each with potentially different specificity and sensitivity, which may result in under- or overcounting cases within and across different localities to different degrees. There are also different types of facilities that process tests, and variation in how samples are collected and processed. We observed variation in whether testing from private/commercial labs is captured, and variation in the timing of inclusion of such data, which may result in undercounting cases or delays in reporting correct counts. Testing rates reported by localities typically do not account for these differences.

Variations in inpatient testing criteria. Similar to the issues related to testing measures discussed above, variation in inpatient testing criteria (often guided by testing capabilities) may lead to differences in the rate of detection of COVID-19 cases and related hospitalization rates.

Variations in reporting timeline by different locations. As demonstrated by the Washington State case study (Box 6), we observed differences in reporting lag times (e.g., not publishing

estimates on the weekend), which may result in comparisons of data from different time periods and/or using data that may not reflect the most current number of hospitalizations.

COVID-19 Hospitalization Measurement

As shown in Table 3.2, numerous issues affecting the measurement of hospitalization and hospitalization rates can introduce biases. The variations in data collection, rate calculation, and reporting in hospitalization measurement noted in Table 3.2 may apply both within and across countries and within and across states. Each of the issues is described in more detail below.

Table 3.2. Issues Affecting Measurement of Hospitalization and Hospitalization Rates and Likely Biases

Issues	Direction of Bias
• Testing shortages[a] • Inconsistent testing criteria[b] • Whether care for COVID-19 patients in lower acuity settings count as hospitalizations • Variation in whether hospitalization reporting is mandatory • Variation in reporting timeline by different locations	• Will bias downward the number of COVID-19 hospitalization cases • The extent of the bias will vary from place to place and over time, depending on extent of shortage and resulting testing criteria used
Variations in including persons under investigation in hospitalization count. Some states make this distinction clear while others do not.	Could potentially overestimate the number of COVID-19 hospitalizations for those states that include persons under investigation that are later deemed not to have COVID-19. Yet, the magnitude of this bias may still not exceed the true population count, especially where testing rates are low.
Unclear measures for counting a hospitalization (directly from emergency room, readmission for same patient, transfers)	Where double counting is taking place (a patient appears at Hospital X and is transferred to Hospital Y), one COVID-19 hospitalization is counted twice, which would bias upward the number of COVID-19 hospitalizations at the county/community/state level.
Use of different denominators for calculating hospitalization rates (e.g., using National Center for Health Statistics vintage 2018 bridged-race postcensal population estimates versus the American Community Survey)[c]	May affect comparisons if there is significant population migration in and out of a country or state (e.g., Florida).
Variation in whether hospitalization counts are raw counts versus cumulative counts or rates (e.g., per 100,000 population) are reported	Makes cross-locality comparisons impossible or invalid if different measures are used for comparison.

[a] Gilbert, 2013.
[b] Bialek et al., 2020; World Health Organization, 2020a.
[c] CDC, 2020e.

Variations in who is counted. Since March 2020, a growing number of hospitals include persons under investigation with pending tests as COVID-19 hospitalizations, which will tend to increase the hospitalization rate. In addition, testing availability affects how many hospitalized patients are tested and results obtained prior to discharge or death. In Table 3.3, we simulated the effects of the treatment of persons under investigation and the availability of rapid tests on

hospitalization rates. On each of three dates, we assume there are 1,000 COVID-19 hospitalizations in a state. We assume that, early in the pandemic, when testing was limited, only 10 percent of these patients had tests ordered and positive test results received before the patient was discharged or died. By April 30, more tests were available, and 60 percent of COVID-19 hospitalized patients were tested, half of whom did not yet have results. We assume that, by May 31, 90 percent of hospitalized patients were tested. We estimate that including persons under investigation approximately doubles the number of hospitalizations considered COVID-19-associated.

Table 3.3. Variation in Testing and Classification of Hospitalized Patients and COVID-19 Hospitalizations Using Simulated Data

Date	Actual Cases with COVID-19	Percentage of Actual Cases Tested and Results Returned Pre-Discharge or Death	Number of Persons Under Investigation	COVID-19 Hospitalization Count (includes test + patients only)	COVID-19 Hospitalization Count (includes test + patients and persons under investigation)
March 31	1,000	10%	0	100	100
April 30	1,000	30%	30%	300	600
May 31	1,000	50%	40%	500	900

Results from the Australia and Washington State case studies (Boxes 3.4 and 3.5, respectively) demonstrate some of the issues outlined above, and they are described further, in turn, below.

Box 3.4. COVID-19 Hospitalization Measurement Issues from the Australia Case Study

- Hospitalizations for COVID-19 are reported by individual states and collected by the federal government.
- Reporting of hospitalizations is done by both private and public hospitals and is the responsibility of physicians (Government of South Australia, 2020).
- Hospitalization rates are presented generally as snapshots or point prevalence, making determination of cumulative hospitalizations difficult.
- Data reporting from hospitals across states and territories is temporally staggered.
- The Australian Government and the Commission on Safety and Quality in Health Care is working with the public and private health sectors to align reporting standards (Australian Commission on Safety and Quality in Health Care, 2020).

For the full results from the Australia case study, see Appendix C.

Box 3.5 COVID-19 Hospitalization Measurement Issues from the Washington State Case Study

- The Washington State Department of Health has a COVID-19 dashboard that includes a COVID-like illness (CLI) hospitalization chart that shows the number of CLI (those with symptoms concerning for COVID-19) hospitalizations occurring each week (Washington State Coronavirus Response, 2020).
- *The Atlantic*'s COVID Tracking Project, which collects and publishes available testing data for U.S. states and territories, also features hospitalizations by state and relies on the state's Department of Health website as its primary data source; however, for Washington it lacks historical numbers (*The Atlantic*, COVID Tracking Project, "Our Data," 2020; Washington State Department of Health, 2020d).
- The University of Minnesota COVID-19 hospitalization tracking tool also relies on the state's Department of Health website and features the current hospitalization counts for Washington (and every state reporting hospitalization data). This project then provides an estimated hospitalization rate per 100,000 population for Washington state (University of Minnesota, Carlson School of Management, 2020a, 2020b; Washington State Department of Health, May 19, 2020b).
- Not all facilities reported hospitalizations, with 96 percent of facilities reporting hospitalizations retrospectively and 84 percent having identified hospitalizations prospectively as of April 28 (University of Minnesota, Carlson School of Management, 2020b; Washington State Department of Health, May 19, 2020b).
- Due to variation in the number of hospitals reporting, counts of hospitalizations have not been directly comparable from day to day (Ghose, 2020b).

For the full results from the Washington state case study, see Appendix C.

A story from a frontline provider in Box 3.6 brings to life a measurement challenge we have identified with regard to tracking COVID-19 hospitalizations. Hospitalization counts that include or exclude persons under investigation for COVID-19 can potentially affect their accuracy. Further, depending on whether localities include persons under investigation in hospitalization counts, cross-locality (e.g., at the country, state, or substate level) comparisons may be misleading because of this inherent difference in what counts as a COVID-19 hospitalization.

Box 3.6. COVID-19 Hospitalization Story from the Frontline

> "For weeks after the first confirmed case in our state, it would take three days or longer for COVID-19 test results to come back. During that time any patient admitted to the hospital with a pending test would be considered a person under investigation. Not all would test positive. So, including persons under investigation into COVID-19 hospitalization counts during that time could potentially lead to overcounting cases. This is not as much of an issue now with testing turnaround time being four to six hours—depending on time of the day."
>
> —emergency physician in Michigan

We found variations in the way hospitalizations are measured, the settings that are included, and which patients are counted.

Variation in whether hospitalization raw counts versus cumulative counts or rates (e.g., per 100,000 population) *are reported* makes cross-locality comparisons impossible or invalid if different measures are used for comparison. For example, the Australia case study showed that hospitalization rates are reported as point prevalence (i.e., COVID-19 prevalence at a particular point of time), making cross-country comparisons of cumulative hospitalizations difficult (Box 7). Further, different denominators may be used for calculating hospitalization rates (e.g., using National Center for Health Statistics vintage 2018 bridged-race postcensal population estimates versus the American Community Survey; CDC, 2020e), which may also complicate comparisons across localities.

Variations in how care settings are counted. COVID-19 patients are treated in a variety of settings. We observed variation in whether patients cared for outside of hospitals, in community settings, are counted. For example, in the Republic of Korea, some lower-acuity patients were cared for in community settings in order to make hospital beds available for sicker COVID-19 patients. It is unclear whether patients taken care of in community settings, including those in long-term care facilities, were included in the COVID-19 hospitalization counts. Further, there is variation in whether persons under investigation—patients who are hospitalized with suspected COVID-19 but without a test result confirming presence or absence of the disease—have been included in hospitalization counts. There may also be variation in whether only COVID-19 patients directly admitted from the emergency department are counted in total hospitalization counts and whether transfers from other facilities and readmissions are included.

Mortality

The variations in data collection, rate calculation, and reporting in death measurement and excess mortality noted in Tables 3.4 and 3.5 may apply both within and across countries and within and across states. In the case of excess mortality, related data were reported to the CDC differently by states, such that it is not possible to tell from the information provided by the CDC

when provisional data were mostly complete and for which states. In 2015 to 2016 provisional data, completeness was lower (less than 25 percent) in the first few weeks following the date of death and then increased over time, such that data were generally at least 75 percent complete within eight weeks of when the death occurred. This means that the most accurate comparisons that use excess mortality based on the CDC-processed information require going back more than two months. It also implies that accurate comparisons will not be possible until we are well out of the time frame of interest (e.g., data needed to get robust estimates of excess death rates in 2020 will not be available until March or April of 2021).

Table 3.4. Measurement of Deaths and Likely Biases

Issues	Direction of Bias
• Testing shortages, resulting in some places prioritizing living patients over decedents[a] • Lag time in test results,[b] leading to some death certificates being completed without testing result[c] • Inconsistent testing criteria,[d] resulting in some patients with COVID-19 symptoms dying while hospitalized before being tested • Exclusion of COVID-19 deaths outside of a health care setting • Lag time in death reporting due to time it takes to process death certificates[b, c, e]	• These factors will underestimate the number of COVID-19 deaths. • Correspondingly, they will underestimate COVID-19 death rates and case fatality rates.
• Inconsistent coding or reporting of probable deaths • Inconsistencies in whether both deaths "of" and "with" COVID are included in death counts • Inconsistent training on how to complete death certificate; hospital-based clinicians more likely to record the proximate cause of death without noting probable role of COVID-19 • Retrospective updating of death counts from earlier weeks increasing or decreasing death rates as new and updated death certificate data are received[b]	Can lead to under- or over-estimating death counts.
Variation in how COVID-19 mortality is measured (e.g., case fatality rate uses confirmed COVID-19 cases as the denominator, whereas the population mortality rate uses total population as the denominator)	Makes cross-locality comparisons impossible or invalid if different measures are used for comparison.

[a] Gilbert, 2013.
[b] CDC, 2020a.
[c] The bias will be especially strong in the more recent periods.
[d] Bialek et al., 2020; World Health Organization, 2020a.
[e] Worldometer, 2020.

Table 3.5. Measurement of Excess Mortality and Likely Biases

Issues	Direction of Bias
Reporting lag time	Will generally lead to an underestimate of deaths; adjustments can be based on the average in prior years submitted to a centralized system, but the current year's data may be submitted more quickly or more slowly.
Inability to distinguish non-COVID-19 from COVID-19 cases	This will overestimate the number of COVID-19 deaths if all excess mortality is assumed to be due to COVID-19. Rather, excess mortality reflects an upper bound of COVID-19 cases.
Variation in whether excess mortality is reported as a pandemic outcome	Will not allow for cross-locality comparisons if certain locations do not report this outcome.

Variation in whether both deaths "of" and "with" COVID-19 are counted. Deaths "of" COVID-19 are those where COVID-19 is deemed to be the main cause of death; those "with" COVID-19 are deaths where it is a co-existing condition or contributing to death. The attribution of mortality to an underlying cause on the death certificate may be performed by medical examiners, coroners, or physicians, and it is subject to some degree of uncertainty. Death certificates differentiate between people who were COVID-19-positive but whose death is attributed to a different underlying cause (e.g., congestive heart failure; deaths "with" COVID-19) and those for whom COVID-19 was the underlying cause (deaths "of" COVID-10). We observed variation in whether deaths "with" COVID-19 were included along with deaths "of" COVID-19 in mortality counts. Further, testing shortages may contribute to prioritizing testing for the living, as opposed to decedents, leading to low post-mortem testing.

Variation in whether "probable" COVID-19 deaths are included in total death counts. "Probable" COVID-19 cases are those with consistent symptoms but without a positive test result confirming the disease. The CDC-issued guidance on April 14, 2020, recommending that deaths due to probable COVID-19 be included in mortality counts. Differences in when and to what extent the CDC guidelines are followed by states contribute to variations in mortality rates. Further, some states report confirmed and probable cases separately.

For example, from April 14 onward, Michigan included both probable and confirmed cases. Similarly, as of April 30, 2020, New York City included both probable COVID-19 deaths and confirmed (positive lab test) COVID-19 deaths. However, New York State only reported confirmed cases, including those from New York City (New York City Department of Health, 2020). Outside the United States, Australia, for example, does not include suspected and probable cases in COVID-19 case estimates (Australian Government Department of Public Health, COVID-19 National Incident Room Surveillance Team, 2020a).

Potentially inaccurate death certification by community- or hospital-based physicians. Medical examiners participating in our roundtable discussion reported concerns about the limited training that physicians receive in reporting the cause of death on death certificates. This could contribute to lack of accuracy in death certificate data for deaths occurring in the hospital, where physicians typically provide death certificate information.

Variation in whether out-of-hospital deaths are included in the death counts. Many COVID-19 deaths have occurred outside of hospitals, but these have not consistently been included in mortality rates. This may result in underreporting of total deaths in localities that only report in-hospital mortality. Of particular importance, deaths among nursing home residents (who may be particularly vulnerable) may not be reported separately. For example, in Germany, deaths that occur outside hospital settings are included as "associated with" COVID-19, whereas Italy includes both in-hospital and out-of-hospital deaths in its total COVID-19 death count. Of particular importance, deaths among nursing home or long-term care facility residents may not be reported separately. In New Jersey, more than 11,000 cases were reported in such settings (Chidambaram, 2020). Given that many of the residents of such facilities are older adults, often with multiple comorbidities, keeping track of cases and deaths in these settings is important.

Variation in how widely post-mortem testing is conducted. We observed differences among localities and over time in the extent to which post-mortem testing for COVID-19 was conducted. This may result in undercounting COVID-19 deaths in localities with more limited post-mortem testing capabilities.

Variation in reporting of location. We observed differences in whether mortality is reported based on the jurisdiction of residence versus the location of testing or treatment, which can produce inconsistent counts within localities and complicate cross-locality comparisons. For example, in Washington State, on April 18, 2020, data cleaning removed 190 confirmed cases that were discovered to be out-of-state residents (*The Atlantic* COVID Tracking Project, "Washington," 2020).

Retrospective revision of the number of deaths may result in the final death counts being higher (or lower) than originally reported.

Lag time in reporting due to backlog of death certification may make cross-state and within-state comparisons invalid at a given point in time because of data not being updated or accurate. For example, in Michigan, there were concerns around death report "batching," which may have resulted in differential delays in data processing/reporting from some counties. Therefore, some jumps in reported deaths were likely due to backlogs of cases classified as coronavirus deaths after health officials reviewed death certificates (Bridge, 2020; Rice, 2020).

Variations in whether excess mortality is reported as a pandemic outcome. Rather than relying on certification of COVID-19 as an underlying cause of death, excess mortality compares total observed mortality rates to expected rates, adjusting for underlying trends based on historical experience. We observed variation in whether states and countries consistently report excess mortality as a pandemic outcome.

Results from the Australia and Washington State case studies (Boxes 3.7 and 3.8 respectively) demonstrate some of the issues outlined above.

Box 3.7. COVID-19 Mortality and Excess Mortality Measurement Issues from the Australia Case Study

- Australia reports crude death rates (number of COVID-19 deaths per 100,000) and case-fatality rate (number of COVID deaths per 1,000 COVID-19 cases).
- Suspected and probable cases are not included in COVID-19 death estimates (Ting, Scott, and Workman, 2020).
- Given limited numbers of cases and deaths, this makes excess mortality calculations less meaningful.

For the full results from the Australia state case study, see Appendix C.

Box 3.8. COVID-19 Mortality and Excess Mortality Measurement Issues from the Washington State Case Study

- Deaths may be reported by health care providers, medical examiners and coroners, local health departments, and others before being included in the statewide count.
- As of April 14, 2020, the CDC included probable deaths with confirmed deaths (Faust and del Rio, 2020). Thus, the numbers for Washington, which reports probable cases and confirmed deaths separately, may increase as past data are revised.
- Excess mortality included deaths from COVID-19 and other factors, such as fewer people seeking treatment for other illnesses during the pandemic.

For the full results from the Washington state case study, see Appendix D.

Key themes on the subject of mortality rates that emerged from the medical examiner roundtable discussion (Table F.1 in Appendix F) support the findings from the environmental scan. The roundtable participants expressed concerns about insufficient post-mortem testing capabilities. As described by one participant, "We had challenges in getting access to [post-mortem] testing. We were at the very bottom of the priority list for this equipment."

They also voiced concern about insufficient death certification education among community- and hospital-based clinicians potentially leading to erroneous death certification. According to one participant, "Death certificates are notoriously completed wrong, or not well. They either list every diagnosis they have, or just put cardiac arrest or something."

As described in Box 3.9, the accuracy of COVID-19 death certification may be compromised depending on the comfort level of the certifying hospital-based clinician in death certification—a

concern echoed by medical examiner roundtable participants. This can result in over- or undercounting deaths.

Box 3.9. A COVID-19 Death Certification Story from the Frontline

"I was working as an emergency physician in Flint, Michigan, during the early days of the pandemic when more and more cases of COVID-19 were being identified. One day EMS [emergency medical services] alerts us that they are bringing in a patient with severely abnormal vital signs. She was breathing very poorly, had a low blood pressure, and was unconscious. When the patient arrived she was barely breathing and as the paramedics transferred her to our resuscitation bay we were unable to detect a pulse. We started CPR, placed a breathing tube, gave her medications with the hope of restarting her heart, all to no avail, and she passed away. I called her son, both to tell him the sad news but also to gather more information to find out what happened. He gave me a story of vague difficulty breathing and respiratory symptoms leading up to this but no smoking gun that would clearly let me know what happened. I had a strong suspicion that this death was due to the novel coronavirus but no proof. All I had was a clinical picture of a patient without heart or lung problems, vague respiratory problems that had been increasing, a physical exam without good hints at another source such as heart failure, and a heart rhythm that made it more likely that difficulty breathing rather than a heart attack caused her demise. The medical examiner talked to me, I shared my concerns, and she as well noted difficulties in ascertaining which deaths should be counted as an official statistic for COVID-19. To this day I am not sure if my patient was counted or not."

—emergency physician in Michigan

Participants observed that variation in death certification practices (for example, due to variable adherence to CDC guidance) can make cross-state comparisons of U.S. death counts challenging. One participant noted

> The CDC guideline is pretty specific about what "probable" deaths are. You have to have compelling evidence of death due to COVID-19. They give an example of an elderly woman with an underlying disease who refuses treatment . . . and dies. . . . I think when they say compelling, they mean compelling. There is probably great variation, and people aren't following what the CDC says.

All these factors can contribute to variability in COVID-19 mortality data collection, rate calculation, and reporting and consequently challenge cross-locality mortality comparisons.

Cross-Cutting Findings

As outlined above, all the COVID-19 measures currently in use have limitations. Some of the issues pertain to multiple measures. For example, the issues that affect the accuracy of case identification/testing measurement—including limiting testing to sicker individuals and lag time in reporting—also affect the denominator used to compute the COVID-19 mortality rate and the

numerator used to compute COVID-19 hospitalizations and COVID-19 mortality. However, there are also specific strengths and weaknesses of each type of measure, and each communicates a different type of information.

Further, our environmental scan revealed high prevalence of COVID-19 infection among residents of congregate living facilities (e.g., long-term care facilities and nursing homes). This population is often older and/or frail, with multiple comorbidities and higher risk for poor outcomes from COVID-19. Therefore, particular focus on tracking testing and mortality among this population will be important.

4. Discussion and Recommendations

To track how well different countries and U.S. states are responding to the pandemic—and to make valid cross-country and cross-state comparisons around key outcomes—government, public health, academic, and other entities need to use uniform measures. Given baseline differences in the structure of health care, political systems, culture, and many facets of government and society, as well as the inherent differences in methods of health outcome data collection, measurement, and reporting, we would expect variation around COVID-19-related measures across and within countries. Similarly, we would also expect variation in COVID-19-related measures among U.S. states.

With this challenge in mind, in this project we aimed to assess the scientific validity of measures commonly used to evaluate several dimensions of the COVID-19 crisis, including case identification/testing, hospitalization, mortality, and excess mortality.

Our analysis revealed tremendous variability in data collection, calculation, and reporting for all the COVID-19 measures under study—both within and across countries and U.S. states.

The most common factors leading to measurement differences across countries and states are

- the availability and targeting of testing capabilities (especially earlier in the pandemic)
- testing of mildly symptomatic and asymptomatic individuals
- reporting lag
- the need for retrospective data updates/corrections for testing, hospitalizations, and mortality
- the use of different measures for testing, hospitalizations, and mortality across localities.

The measurement challenges posed by this variability highlight the need for identification of those measures that could permit valid cross-country and cross-state comparisons to inform policy and guidelines that can facilitate more consistent data collection, rate calculation, and reporting.

Ideally, the measures (and their components) used to compare differences between two or more countries or U.S. states would be unbiased (i.e., accurate), reliable (i.e., consistent), and timely.

We identified several broad measurement issues that contribute to challenges with cross-country and cross-U.S. state comparisons. First, the issues that affect the accuracy of case identification/testing measurement—for example, limiting testing to sicker individuals and lag time in reporting—also affect the denominator used to compute COVID-19 mortality rate and the numerator used to compute COVID-19 hospitalization and COVID-19 mortality. Second, measures that do not rely on commonly available population estimates and vital statistics are subject to more measurement issues. Because of greater reliability of the denominator, measures

based on total population (e.g., cases per 100,000) can be used with more confidence than measures based on the COVID-19 population alone (e.g., hospitalization rate among COVID-19 patients). Third, the bias introduced by the measurement issues identified is likely to result in both underestimates and overestimates of COVID-19 measures of interest. As a result, it is difficult to determine whether currently used rates are systematically higher or lower than true population values.

As far as case identification/testing is concerned, variation in testing capabilities, testing criteria, and access to testing can result in differences in populations tested across localities. National standards for testing criteria, testing data collection, and reporting are needed. Further, there is variability in how testing is measured (e.g., testing rate versus test positivity rate). For example, not all localities report negative cases. To allow for cross-locality COVID-19 testing comparisons, the test positivity rate should be considered as the standard for COVID-19 test reporting. The test positivity rate is the percentage of positive tests out of all tests administered. At the time the environmental scan was conducted, the Republic of Korea and the state of South Carolina reported test positivity rates. Washington State reported total tests conducted and total number of positive tests—from which test positivity rate can be calculated. Again, all the testing related measures have limitations. However, we recommend the test positivity rate because it can serve two functions. First, it can provide a signal in locations where COVID-19 is known to be widespread as to whether a given country or state is engaging in sufficient testing. According to the WHO, 3 to 12 percent of tests are positive in countries with widespread testing. Some reports indicate that, in the United States, as high as 17 percent of tests are positive (Washington State Coronavirus Response, 2020; World Health Organization, 2020b; Coronavirus Resource Center, Johns Hopkins University & Medicine, 2020). If accurate, this high rate likely reflects the limited testing of asymptomatic and mildly symptomatic individuals that occurred during the early phases of the pandemic. Second, once a country or state achieves sufficiently widespread testing and sufficient timeliness in the reporting of the test positivity rate, the rate can be used to identify "hot spots."

Other measures, such as the testing rate in a population, provide information on how many people have been tested in a given interval but do not convey information as to whether the rate of testing is appropriate given the prevalence of COVID-19 in that community. The COVID-19 rate provides information on the prevalence of COVID-19 in a community, but it provides no information as to whether testing is widespread enough to be likely to capture missed asymptomatic or mildly symptomatic cases.

Some states update the reported number of positive cases and tests administered frequently on their dashboards. But other states are reporting less frequently. To maximize the surveillance potential of the test positivity rate, frequent reporting is required, and states may require guidance or resources to be able to do this. Some states are reporting the number of people tested and not necessarily the number of tests administered. But high-risk individuals, such as first responders, require frequent, repeated testing. Therefore, states should be encouraged to also

report the total number of tests administered. States should also be encouraged to report testing for acute infection (i.e., antigen testing or polymerase chain reaction testing) separately from antibody testing. There are reports that some states (for example, Texas) combine the two types of testing in a way that makes it impossible to distinguish the two, obscuring the actual number of tests for active infections.

It is estimated that more than one-third of COVID-19 confirmed deaths are in congregate living facilities, and these are 11 percent of all cases (Yourish et al., 2020). But these may be undercounts, because many states do not report this information disaggregated by location type. Given the high prevalence of COVID-19 infection among residents of congregate living facilities—and that this population tends to be older with co-morbidities—states should more systematically and completely report test positivity rates separately for congregate living facilities. Florida is one example of a state in which congregate living facilities report their data. Setting federal reporting standards for this purpose will be important. It may be that in such settings, more frequent and broader testing is required than in the general population to identify presymptomatic and asymptomatic people and to prevent outbreaks among residents and staff.

In the case of COVID-19 hospitalizations, there is variation across localities regarding whether cases or rates are reported and whether cumulative hospitalizations or only current hospitalizations are reported. Further, there is variation in the disease severity of patients hospitalized with COVID-19. COVID-19 hospitalization rates (as defined by the CDC) should be considered as the standard for surveillance purposes (Karaca-Mandic, Georgiou, and Sen, 2020). Consistent reporting of both current and cumulative COVID-19 hospitalizations will be important for understanding the trajectory of the pandemic and its impact on acute care facilities across countries and U.S. states. The COVID-19 hospitalization rate is the proportion of the population in the country or state who are hospitalized and who test positive for COVID-19. In addition to being a marker for COVID-19 acute care utilization, this measure is a marker of more severe COVID-19 illness and will likely reflect both the prevalence of COVID-19 and the age and health of the population (in terms of comorbidities). States with a high proportion of older adults or with high rates of chronic diseases (such as heart disease or diabetes), those with high proportions of low-income populations and high social determinants of health needs, and those with increased susceptibility due to having more ACE2-receptors will likely have higher rates of COVID-19 hospitalization than states with a younger and healthier population profile but with similar COVID-19 prevalence rates (South, Brady, and Flynn, 2020).[1] This measure may allow targeting of medical personnel and resources to states with more significant COVID-19-related health care needs and postponing of elective procedures and other changes so that hospitals can

[1] ACE2 is a an protein found on the surface on many human cell types. The virus that causes COVID-19 binds to the ACE2 protein (ACE2 acts as a "receptor"), so it is believed that individuals with more ACE2 are more susceptible to COVID-19.

shift their efforts to caring for COVID-19 patients. This will also facilitate consistent within-state reporting—for example, at the county level.

As noted in the report, there are many issues with measurement of the COVID-19 mortality rate that pose significant challenges to cross-locality comparisons. There is variation in whether mortality is reported based on location of residence versus location of testing or treatment. Depending on the locality, both deaths "of" and "with" COVID-19 may be included in death counts. Similarly, there is variation in whether probable deaths are included in death counts, and in the United States there is concern over variability in adherence to CDC guidelines on inclusion of probable cases. Further, in the United States there is concern regarding the accuracy of COVID-19 death certification by community- and hospital-based clinicians. Given these challenges with COVID-19 mortality measurement, consideration should be given to a measure of excess mortality—a measure that does not depend on determining the cause of death—to compare the effects of COVID-19 across countries and states consistently.

Excess mortality is the number of deaths in a period beyond what would be expected (typically calculated as the average number of deaths during the same period in prior years adjusted for the size of the population and other characteristics). COVID-19 mortality rates, or the percentage of people who die from COVID-19, will be biased to the extent that deaths that can be directly attributed to COVID-19 are miscoded as a cause other than COVID-19. The extent of this bias will vary across countries, states, place of death (in-home versus hospital), and over time as a function of testing availability and local, state, and national policies. The excess mortality rate will usually be unbiased because it relies on existing death reporting systems from year to year, so the excess mortality rate is less subject to systematic bias. Further, excess mortality is a measure of all deaths during a given timeframe, from both COVID-19 and other conditions, and can be used as an indicator of how well the health system absorbed the "shock" from the pandemic among all patients. However, a limitation of excess mortality is that it may include excess mortality due to other co-occurring pandemics or local events/factors. For example, one study in *The Lancet* showed that two patients in Singapore who had false positive rapid tests for Dengue Fever—a condition that can present similarly to COVID-19—were later confirmed to have COVID-19 (Yan et al., 2020). Any deaths due to COVID-19 versus Dengue Fever would not be distinguishable when reported as part of excess mortality. Excess mortality has an additional disadvantage in that it is not always reported in a timely manner, though in most cases it should be more quickly reported than COVID-19 mortality. Measuring COVID-19 mortality requires attributing of the cause of death, whereas all-cause mortality is simply a record that a death occurred and does not require assessing the cause of death (i.e., whether it is due to COVID-19, opioid overdose, heart attack, etc.).

Timely reporting of COVID-19 tests conducted, test results, hospitalizations, and excess mortality will be critical to track the effects of the pandemic. States report this information at different rates, and some use old methods of transmission, such as fax. The CDC estimates that 63 percent of all deaths are reported to the CDC within 10 days of the date of death (CDC,

2020g). Other sources, such as Johns Hopkins University, collect COVID-19 mortality more quickly by combing it directly from state dashboards and other sources (Center for Systems Science and Engineering, 2020b). It is not clear whether excess mortality using provisional deaths can likewise be collected more quickly from states directly.

Finally, given all the outlined limitations of the various measures evaluated in this report, consideration should be given to the development of a composite index—one that includes a combination of testing, hospitalizations, and mortality—and leverages the strengths of each of the related datasets. If such a composite index is developed through careful selection of the most robust data available, it could potentially be used as a measure of how well countries or U.S. states are responding to pandemics.

Recommendations

Based on these findings, we recommend the following steps to the U.S. Department of Health and Human Services, CDC, and other U.S. government agencies to aid in developing measures for valid comparisons across states and potentially countries:

- Assess the root causes of the lag in states' reporting of mortality and other information to the federal government.
- Explore ways to facilitate more timely reporting of the number of COVID-19 tests conducted, test results, hospitalizations, and excess mortality.
- Develop national standards around testing criteria (i.e., who to test), data collection, and reporting.
- Make the test positivity rate a standard component of reporting COVID-19 testing. States should report the total number of tests conducted, as well as those that are positive.
- Prioritize reporting of COVID-19 hospitalization per 100,000 population (i.e., the CDC definition of hospitalization rate) for surveillance purposes.
- Increase post-mortem testing capabilities to capture undiagnosed COVID-19 cases.
- Encourage continuing medical education for practicing clinicians to improve documentation of cause of death for COVID-19 and future public health emergencies and require more education and training around death certification in medical schools and residency training programs.
- Use a measure of excess mortality—assessing the excess number of deaths observed during the pandemic compared with the expected number based on historical data—to compare the effects of COVID-19 across countries and states.
- Encourage more systematic reporting of all measures separately for congregate living facilities (e.g., nursing homes, short-term nursing facilities).
- Encourage systematic reporting of multiple measures (e.g., testing positivity rate, hospitalizations per 100,000 population, and excess mortality) given the strengths and limitations of each individual measure.
- Explore the development of a composite COVID-19 index that includes a combination of testing, hospitalizations, and mortality and that leverages the strengths of each of the related datasets.

Appendix A. Country-Specific Issues

As part of the environmental scan around COVID-19-related measures, we graded the data we gathered based on the numbers and types of sources that support the data (e.g., government or academic organization, peer reviewed manuscript). Using this grading schema, the colors of the content in the Appendix A tables correspond with Grade A (green), Grade B (blue), and Grade C (purple) evidence, respectively. The grades are also indicated in brackets after each item. Ultimately, these grades refer to the number of authorities who support the evidence, not the relative strength of the evidence. So, for example, Grade C evidence could, in theory, be stronger than Grade A. One example of this is cases where there is minimal supporting data from a recognized authority (Grade A), but more supporting data from multiple peer-reviewed or gray literature sources (as was the case for measuring hospitalization rates across some U.S. states in our sample).

- Grade A: Supported by a recognized authority (e.g., CDC, WHO, country, state, or local government, public health or other related authority) and by one or more peer reviewed and/or gray literature sources.
- Grade B: Supported by a recognized authority (e.g., CDC, WHO, country, state, or local government, public health or other related authority).
- Grade C: Supported by one or more peer reviewed and/or gray literature sources.

Table A.1. COVID-19 Case Identification/Testing-Related Data Collection, Rate Calculation, and Measurement Issues by Country

Country	Populations and Scale of Case Identification/Testing (Only sicker? Post-mortem?)	Testing Measurement and/or Reporting	Other Issues
Australia	People with mild symptoms are typically not tested (Lab Tests Online, 2020). [C]	Possible COVID-19 cases are declared either a suspected case or a probable case. Suspected cases initially were defined as persons with an acute respiratory illness (initially defined as fever and one or more signs of respiratory illness) and a history of travel or residency to a location reporting SARS-CoV-2. Probable cases were defined as suspected cases with inconclusive testing or testing that could not be performed. These are not counted in statistics for COVID-19, which alters official case counts (Lab Tests Online, 2020). [C] Testing criteria, however, have changed and at this time all provinces recommend testing for any flu-like symptom without the aforementioned requirements of sick contacts or a fever (Lab Tests Online, 2020). [C] States and territories report daily to the Australian Government Department of Health (Australian Government Department of Health, 2020a). [B] Numbers are revised when further information is available. [B] Cases are split by jurisdiction and where the patient resides, not where testing is performed or where they were infected (Australian Government Department of Health, 2020d). [B]	Testing in Australia is approved by the Therapeutic Goods Administration and approved tests are placed in the Australian Register of Therapeutic Goods (ARTG). [B] This implies a certain degree of quality control over which tests are used (Australian Government Department of Health, 2020b). [B]
Germany	Testing nearly doubled between March and April 2020, coinciding with more liberal testing criteria (Robert Koch-Institut, 2020a, 2020c; Government of Germany, Federal Ministry of Justice and Consumer Protection and the Federal Office of Justice, 2020). [C]	Data are collected by the Robert Koch Institute (RKI), a German federal government agency and research institute responsible for disease control and prevention (Robert Koch-Institut, 2020a). [B] Positive case rates per 100,000 population is assessed (Robert Koch-Institut, 2020e). [B]	

Country	Populations and Scale of Case Identification/Testing (Only sicker? Post-mortem?)	Testing Measurement and/or Reporting	Other Issues
	Although testing is more available, people with minimal symptoms may not get tested. [C] Germany is a federation of states, and the implementation of testing sites was the responsibility of individual states. Therefore, the rate of testing increased at different speeds; however, ultimately all results are reported federally to RKI (Government of Germany, Federal Ministry of Justice and Consumer Protection and the Federal Office of Justice, 2020). [C]	Cases definition begins with clinical suspicion. People with pneumonia OR acute respiratory symptoms OR death due to an illness receive a COVID test. Those with a positive test are considered a "case" (Robert Koch-Institut, 2020c). [B] People who have been exposed to the virus due to contact with a known case are designated "persons under investigation" (Government of Germany, Federal Ministry of Justice and Consumer Protection and the Federal Office of Justice, 2020). [B] COVID-19 is categorized as a reportable disease, so it is a physician's responsibility to report cases to the local health ministry, who reports to RKI (Robert Koch-Institut, 2020e). [B] There is an approximately five day lag in reporting of all cases (Norddeutscher Rundfunk [NDR], 2020). [B]	
Italy	Beginning on February 25, testing was only performed if patients were symptomatic, not in settings where other illnesses were suspected as cause of patients' symptoms (Fondazione IRCCS Policlinico San Matteo, 2020). [C] People were instructed to call an emergency number if they were symptomatic. Those who were not instructed to report to the hospital often were never tested (BR24, 2020). [C] Those who died at home or a nursing home were rarely tested (Ciminelli and Garcia-Mandicó, 2020; Onder, Rezza, and Brusaferro, 2020). [C]	The National Register of the Resident Population (ANPR) provides a single integrated database for citizen's data in Italy. Only municipalities that meet the following conditions report data that "(I) have experienced an increase in mortality of at least 20% in 2020 relative to the average of the five preceding years, and (ii) are deemed to have provided accurate information are included." and include the regions Lombardia, Veneto, Emilia-Romagna, Piemonte, Marche, Liguria, and Toscana (Ciminelli and Garcia-Mandicó, 2020). [B] At the outset of the COVID-19 outbreak, the Italian National Institute of Health (Instituto Superiore di Sanità [ISS]) launched a surveillance system to collect information on all people with COVID-19 throughout the country. Data on all COVID-19 cases were obtained from all 19 Italian regions and the two autonomous provinces of Trento and Bozen (Government of Italy, Ministry of Health, 2020b). [B]	

Country	Populations and Scale of Case Identification/Testing (Only sicker? Post-mortem?)	Testing Measurement and/or Reporting	Other Issues
		The official website of the Ministry of Health reports testing data that is updated daily (Government of Italy, Ministry of Health, 2020a, 2020b). The Ministry of Civil Protection has a dashboard with this information (Government of Italy, Department of Civil Protection, 2020a, 2020b). [B]	
China	Testing was initially focused on those in Wuhan and nearby regions, especially those that showed up at fever departments and at hospitals. [C] Those who got tested were disproportionately sicker, older, and/or with bad outcomes. [C] Large scale testing has been ongoing since mid- to late April, when businesses began reopening (Sina News Finance Blog, 2020). [C] Wuhan rolled out massive testing on all 11 million residents starting early May because of new confirmed cases (Davidson, 2020). [C] According to a social media report (Sina News Finance Blog, 2020), a total of 899,000 tests were conducted in the city of Wuhan since April 8 (the day the city ended the shutdown that began January 23). [C]	Testing data are collected at the local level and, since April 13, have been reported to the National Health Commission (NHC) on a daily basis (Tong et al., 2019; Yang et al., 2020; Tsang et al., 2020). [A] Case definition was initially narrow and was gradually broadened to allow detection of milder cases and those without epidemiological links to Wuhan, China, or other known cases (Koh and Cunningham, 2020). [A] Between January 15 and March 3, 2020, seven versions of case definition for COVID-19 were issued by the National Health Commission in China. [A] Hubei province in China changed its case definition twice in a two week period—from laboratory-confirmed cases to clinically-confirmed cases without laboratory tests, then back to laboratory-confirmed cases. This caused confusion in the reported number of cases (Koh and Cunningham, 2020). [A] Testing is reported by local hospitals based on results from three departments: fever clinic, emergency department, and inpatient. Hospitals report the number of tests conducted and the number of positive cases. However, exact numbers of testing are not publicly available on the NHC website. [B]	There are sporadic reports of test results being inconsistent (Liu and Harney, 2020). As a result, some test kits exported to the European countries were returned. [C] There were multiple responses and explanations addressing the issue (e.g., the test kit by the manufacturer Shenzhen Bioeasy Biotechnology was not among those approved by the government, and that the protocols for collecting sample was not strictly followed by the user according to the manufacturer ("Responses to Shenzhen Bioeasy Biotechnology Low-Accurate Test Kit," 2020). [C]

Country	Populations and Scale of Case Identification/Testing (Only sicker? Post-mortem?)	Testing Measurement and/or Reporting	Other Issues
		China's Center for Disease Control and Prevention reports real time (daily) national statistics based on data collected by NHC through its China Information System for Disease Control (CISDCP) platform (Chinese Center for Disease Control and Prevention, 2020; China Information System for Disease Control and Prevention, 2020). It reports new suspected cases, confirmed cases, and deaths. In addition, it reports cumulative cases covering mainland China, Hong Kong, Macau, and Taiwan. However, it does not include counts of tests conducted. [B]	
Republic of Korea	The government implemented large-scale walk-through and drive-through testing (대한민국청와대 [Korea Blue House], 2020; Kim and Lee, 2020). [A] Following testing, patients are classified by disease severity (i.e., as mild, moderate, severe, and critical), and patients with moderate to critical status are immediately quarantined or hospitalized (대한민국청와대 [Korea Blue House], 2020; Kim and Lee, 2020). [A] As of April 8, 2020, 638 health centers and medical institutions were operating screening stations, of which 95 percent (606 locations) were equipped to run samples onsite (Republic of Korea Ministry of Health and Welfare, 2020). [A]	The Ministry of Health and Welfare (MOHW) website reports total tests conducted, positive cases, and positivity rate (i.e., positive tests/total number of tests), negative cases, and number of tests in progress. Reported by MOHW (Republic of Korea Ministry of Health and Welfare, 2020). [B]	According to the government (Kim and Lee, 2020; Republic of Korea Ministry of Health and Welfare, 2020), the time it takes for the legal process to approve test kits has been cut from 80 to as few as seven days without sacrificing accuracy (98–99% accuracy rates). [B]

Country	Populations and Scale of Case Identification/Testing (Only sicker? Post-mortem?)	Testing Measurement and/or Reporting	Other Issues
	As a result of scaling up testing facilities and obtaining fast-track approval for diagnostic kits, the maximum daily testing capacity increased from 3,000 people in February to approximately 20,000 people as of April 3 (Republic of Korea, Korea Ministry of Health and Welfare, 2020). [A]		

Table A.2. COVID-19 Hospitalization-Related Data Collection, Rate Calculation, and Measurement Issues by Country

Country	Definition of hospitalizations (only confirmed or also persons under investigation?; only count those in hospital setting or other setting as well, for example community setting?)	Hospitalization Measurement and/or Reporting	Other Issues
Australia	Hospitalizations in both private and public hospitals are included (Australian Commission on Safety and Quality in Health Care, 2020). [B]	Hospitalizations are in some instances reported as a "snapshot" or point prevalence; other times they are reported as cumulative prevalence.[33] [C] Hospitalizations for COVID-19 are reported by individual states and collected by the federal government (Australian Government Department of Health, 2020a; Australian Government Department of Health, 2020d). [C] Hospital data are reported by Australia's federal and state/territory authorities at different times of the day, so data points across states/territories may be representative of a different point in time than those reported at the federal level (Australian Government Department of Health, 2020d). [C]	Since testing is rapidly available, the lag between suspected and confirmed cases (persons under investigation versus case) is generally short (Australian Government Department of Public Health, COVID-19 National Incident Room Surveillance Team, 2020a). [C]
Germany	Hospitalized patients that test positive for COVID-19 are reported as COVID-19 hospitalizations (Robert Koch-Institut, 2020c). [B]	Hospitals are required to report hospitalized patients who test positive for COVID-19. These are centrally reported to the Health Ministry (Robert Koch-Institut, 2020e). [B] RKI reports hospitalizations; however, not all community clinics report all patients who test positive for COVID-19 ("Wie andere Länder zählen: Nicht alle Corona-Toten kommen in die Statistik [How Other Countries Count: Not All Corona Deaths Are Included in the Statistics," 2020). [B]	

Country	Definition of hospitalizations (only confirmed or also persons under investigation?; only count those in hospital setting or other setting as well, for example community setting?)	Hospitalization Measurement and/or Reporting	Other Issues
Italy	N/A	Epidemiological data are collected daily by institutions across Italy's 20 regions that send those data to the Italian Ministry of Health. The Italian Ministry of Health, in turn, sends the data to the Italian Civil Protection Department. The database is subject to daily updates and integrations (Onder, Rezza, and Brusaferro, 2020; Morettini et al., 2020). [B]	
China	N/A	NHC collects national data (Yang et al., 2020; Tsang et al., 2020). Number of COVID-19-related hospital encounters are reported by each province and collected by NHC, but NHC does not report on numbers or rates of COVID-19 admissions (National Health Commission of the People's Republic of China, 2020a). NHC does report number of patients discharged from hospitals who have recovered from COVID-19. [B]	There were reports that due to Wuhan's hospital bed shortages in January, patients with severe symptoms were not getting hospitalized and were dying at home. [C] An article in Caijing magazine on February 2 featured interviews with 10 Wuhan families about their COVID-19. Experiences. The article, which received wide public attention, covered issues related to hospitalization and noted that people had died without being included in official counts in January. [C] The report by Caijing was reposted widely online but soon disappeared on all platforms in mainland China. It can still be found on the world wide web outside of China (Matters, 2020). [C]

Country	Definition of hospitalizations (only confirmed or also persons under investigation?; only count those in hospital setting or other setting as well, for example community setting?)	Hospitalization Measurement and/or Reporting	Other Issues
Republic of Korea	In order to increase hospital bed capacity, Korea developed a system to stratify patients (Kim and Lee, 2020; Republic of Korea, Korea Ministry of Health and Welfare, 2020). Very sick patients would be bedded in ICU or regular hospital beds, whereas lower acuity patients would be treated in "community treatment centers" (CTC) (Choi et al., 2020). This makes interpreting the number of hospitalizations in Korea difficult as it is not clear whether those treated in CTCs are included in hospitalization counts. [A]	It is unclear exactly how many people have been hospitalized to date. [B] The Ministry of Health and Welfare (MOHW) does report numbers released from quarantine and numbers still quarantined. [B] As of May 15,' the total number of patients hospitalized was not publicly reported by the MOHW (Republic of Korea, Korea Ministry of Health and Welfare, 2020). [B]	

NOTE: N/A = data not available at the time the environmental scan was conducted.

Table A.3. COVID-19 Mortality Related Data Collection, Rate Calculation, and Measurement Issues by Country

Country	Definition of deaths (e.g., only in hospital or out-of-hospital as well? Confirmed or probable as well?)	Mortality Measurement and/or Reporting	Other Issues (e.g., how widely post-mortem testing is conducted)
Australia	Suspected and probable cases are not included in COVID-19 case estimates (Australian Government Department of Health, COVID-19 National Incident Room Surveillance Team, 2020b). [C] If someone dies of the virus without being tested, they aren't counted in the Case Fatality Rate (CFR) (Australian Government Department of Health, COVID-19 National Incident Room Surveillance Team, 2020b). [C]	Crude death rates (number of COVID-19 deaths per 100,000) and case fatality rates are reported (Australian Government Department of Health, COVID-19 National Incident Room Surveillance Team, 2020b). [C] Information on a death certificate is the primary source for gathering Australian mortality statistics. After a death is registered, the Office of Births, Deaths, and Marriages (BDM) sends the certificate to the Australian Bureau of Statistics (Government of South Australia, 2020). [B]	
Germany	In-hospital deaths *of* and *with* COVID-19 are both counted in the total COVID-19 death counts (Simmank, Schumann, and Wittmann, 2020). [B] Non-hospital deaths are included as "associated with" COVID-19 (Robert Koch Institut, 2020b). [A] Standard regulations for post-mortem testing where released by the German Society of Forensic Medicine to aid in the systematic conduct of regular post-mortem testing which will resume throughout the pandemic. Post-mortem examinations are not restricted to known COVID-19 cases (Stang, 2020). [A]	Mortality data is reported by Bundeslands (i.e., states), listing total count and cases/100,000 deaths (Robert Koch-Institut, 2020c). Different states have used different testing approaches; however, data is collected centrally and combined with the RKI data (Robert Koch-Institut, 2020c). [B] RKI had initially recommended that autopsies not be performed due to danger to personnel. Now they recommend autopsies on suspected COVID-19 cases if indicated as a component of the autopsy to determine the cause of death (Robert Koch Institut, 2020d). [C]	
Italy	After an initial, extensive testing strategy of both symptomatic and asymptomatic contacts of infected patients in a very early phase of the	N/A	

Country	Definition of deaths (e.g., only in hospital or out-of-hospital as well? Confirmed or probable as well?)	Mortality Measurement and/or Reporting	Other Issues (e.g., how widely post-mortem testing is conducted)
	epidemic, on February 25, the Italian Ministry of Health issued more stringent testing policies. This recommendation prioritized testing for patients with more severe clinical symptoms who were suspected of having COVID-19 and required hospitalization. Testing was limited for asymptomatic people or those who had limited, mild symptoms. [B] This testing strategy resulted in a high proportion of positive results, i.e., 19.3% (positive cases, 21,157 of 109,170 tested as of March 14, 2020), and an apparent increase in the case-fatality rate because patients who presented with less severe clinical disease (and therefore with lower fatality rate) were no longer tested (case-fatality rate changed from 3.1% on February 24 to 7.2% on March 17). These milder cases, with low fatality rate, were thus no longer counted in the denominator (Onder, Rezza, and Brusaferro, 2020). [B] Confirmed in and out-of-hospital COVID-19 deaths are included (Europa Today, 2020). [B] The death counts don't distinguish between those who die "of" or "with" COVID-19 (Europa Today, 2020; Instituto Superiore di Sanità, 2020). [C] Patients that died at home or in nursing facilities had limited to no testing (Morettini et al., 2020; Instituto Superiore di Sanità, 2020). [C]		

Country	Definition of deaths (e.g., only in hospital or out-of-hospital as well? Confirmed or probable as well?)	Mortality Measurement and/or Reporting	Other Issues (e.g., how widely post-mortem testing is conducted)
China	There is no clear national guideline for including probable/suspected cases on the death certificate (National Health Commission of the People's Republic of China, 2020b). [C] Public data mostly capture deaths that occur in hospitals. [C] In the early days of the pandemic, testing capabilities were limited in overwhelmed hospitals where many patients were dying—so many deaths with comorbid conditions were not counted toward COVID-19 deaths. [C]	The government acknowledged miscalculation and adjusted the death toll in Wuhan on April 17 (National Health Commission of the People's Republic of China, 2020b). [B] National data are not available in published peer-reviewed studies. Most published studies focus specifically on Wuhan, and on the early phases of the pandemic from December 2019 to January 2020 (Tong et al., 2020; Yang et al., 2020; Tsang et al., 2020; Zhou et al., 2020; Wang, Tang, and Wei, 2020; Hua and Shaw, 2020). [B] NHC collects national data (National Health Commission of the People's Republic of China, 2020a; Yang et al., 2020; Tsang et al., 2020). [B] However, neither NHC nor WHO report death rates for China. They only report case numbers. [B] The China CDC platform[61] reports national total deaths, including Hong Kong, Macau, and Taiwan. [B]	The deceased are typically quickly cremated locally (He, Dehner, and Dunn, 2020)—hence those who die with symptoms unlikely to get post-mortem testing. [C]
Republic of Korea	Both in hospital and out-of-hospital deaths are included in death counts. [C] Not clear whether probable death as a result of COVID-19 is defined or included. [C]	MOHW reports case fatality rate (CFR) (Republic of Korea, Korea Ministry of Health and Welfare, 2020). [B] Mortality data is reported by the Central Disaster and Safety Countermeasure Headquarters (CDSCHQ) on the MOHW online platform. [B]	

Table A.4. COVID-19 Excess Mortality-Related Data Collection, Rate Calculation, and Measurement Issues by Country

Country	Excess Mortality Measurement And/or Reporting	Other Issues
Australia	Guidance was published by the Australian Bureau of Statistics for certifying deaths due to COVID-19. It detailed how to record COVID-19 on death certificates (including comorbidities), and advised using proper terminology according to the World Health Organization (Australian Bureau of Statistics, 2008). [B]	There have been too few cases for meaningful measurement of excess mortality.
Germany	Germany contributes to the project EuroMOMO to detect and measure excess mortality related to seasonal influenza, pandemics, and other public health threats (https://www.euromomo.eu/) (European MOrtality MOnitoring) (EuroMOMO, 2020b; Government of Germany, Federal Statistical Office, 2020). [B] EuroMOMO is a network of epidemiologists/sites who collect weekly reports on deaths from all causes in 24 European countries, covering 350m people (EuroMOMO, 2020a). [C] EuroMOMO collects mortality information and compares to similar time periods in prior years (EuroMOMO, 2020a). [C]	
Italy	Pooled mortality estimates and calculations are available from the European registry EuroMOMO (Porcheddu et al., 2020). [B] Death registry data are available from ISTAT, the Italian Statistical Agency (Onder, Rezza, and Brassaferra, 2020). [C]	It is likely that excess mortality are largely older adult or frail people who died at home or in residential facilities, without being hospitalized and therefore without being tested for COVID-19 (Foresti, 2020). [C]
China	N/A	
Republic of Korea	N/A	

NOTE: N/A = data not available at the time the environmental scan was conducted.

Appendix B. State-Specific Issues

As part of the environmental scan around COVID-19-related measures, we graded the data we gathered based on the numbers and types of sources that support the data (e.g., government or academic organization, peer reviewed manuscript). Using this grading schema, the colors of the content in the Appendix B tables correspond with Grade A (green), Grade B (blue), and Grade C (purple) evidence, respectively. The grades are also indicated in brackets after each item. These grades refer to the number of and source(s) that support the data, not the relative strength of the evidence. So, for example, Grade C evidence could, in theory, be stronger than Grade A.

- Grade A: Supported by a recognized authority (e.g., CDC, WHO, country, state, or local government, public health or other related authority) and by one or more peer reviewed and/or gray literature sources.
- Grade B: Supported by a recognized authority (e.g., CDC, WHO, country, state, or local government, public health or other related authority).
- Grade C: Supported by one or more peer reviewed and/or gray literature sources.

Table B.1. COVID-19 Testing Related Data Collection, Rate Calculation, and Measurement Issues by State

State	Populations and Scale of Case Identification/ Testing (Only sicker? Post-mortem?)	Testing Measurement and/or Reporting	Other Issues (e.g., variation in test sensitivity and specificity, concern for fraudulent tests)
California	Especially in the early stages of the pandemic, in some counties that ramped up testing, not enough people were presenting for testing due to community concerns around test shortages and not wanting to further overwhelm already depleted healthcare and public health resources (Barry-Jester, Hart, and Bluth, 2020). [C] Testing deserts are most severe in the rural north and lower-income urban neighborhoods (Barry-Jester, Hart, and Bluth, 2020). [C]	The California Department of Public Health provides a real-time dashboard that shows "lab-tests reported statewide" from March 20 to present (California Department of Technology, 2020a; *The Atlantic* COVID Tracking Project, "California," 2020). [A]	Some studies are poorly designed, for example, by introducing bias through focusing the study sample on data collected through social media or from patients that are tested through drive-throughs only, potentially raising prevalence rates (Krieger, 2020; California Department of Public Health, 2020a). [C] There was a sudden increase in the number of tests conducted in California on April 22, 2020. This increase was due to test results from additional data sources (not included in total counts up to that date) being included in the total counts for the state (California Department of Public Health, 2020a; California Department of Technology, 2020b). [B]
Illinois	Initially the state suffered from a shortage of functional tests and supply chain problems. Some supply chain problems have been overcome through assistance from local universities and increased capacity at state-owned labs (Petrella and Lourgos, 2020). [C] As of mid-April, the governor eased testing guidelines, allowing anyone with symptoms to be tested with a doctor's order (Petrella and Lourgos, 2020). [C] The Illinois Department of Public Health provides a dashboard that summarizes testing site locations (Illinois Department of Public Health, 2020c). [B]	Total tests performed at Illinois Department of Public Health (IDPH), commercial, or hospital labs are reported to IDPH. Deaths are included in the number of positive cases (Illinois Department of Public Health, 2020b). Testing statistics for the state of Illinois are reported on the IDPH dashboard. [A] Some data has not been provided to the Department of Public Health by commercial labs. The department is working with them to obtain necessary data and update case count maps (Illinois Department of Public Health, 2020a). [B]	Cases are tracked by ZIP code of residence, not exposure or treatment (Weisenstein and Szalinksi, 2020). [B] The Governor had announced the shortcomings of five testing machines from Thermo Fisher that promised to run 200 tests per hour. There was an issue with the accuracy of Thermo Fisher machines (Thometz, 2020). [C]

State	Populations and Scale of Case Identification/ Testing (Only sicker? Post-mortem?)	Testing Measurement and/or Reporting	Other Issues (e.g., variation in test sensitivity and specificity, concern for fraudulent tests)
Louisiana	The Louisiana State Department of Health (LSDH) recommends COVID-19 testing for anyone who is experiencing symptoms (Louisiana Department of Health, 2020a). [B] As of March 21, testing expanded from hospitalized patients to any symptomatic individual (City of New Orleans, 2020). [B] As of March 31, wide-spread testing was not occurring in the state (Robinson, 2020). [C] As of May 3, the Louisiana state laboratory started accepting samples for asymptomatic patients that meet CDC guidance for those who need to be prioritized for testing (Louisiana Department of Health, 2020c). [B]	The LSDH provides a summary COVID-19 dashboard, updated daily, which includes the total number of tests performed by the State Lab as well as total number of tests performed by commercial providers (Louisiana Department of Health, 2020b). [A] This LSDH dashboard is what feeds the historical count of numbers of tests on *The Atlantic*'s COVID Tracking Project data page for Louisiana. It summarizes the number of new tests performed per day, total positive and negative tests. [A]	Testing sites for drive-through COVID-19 testing available to the public is generally provided by private laboratory groups (Louisiana Department of Health, 2020c). [B] Site locations and operations change frequently for public COVID-19 testing (Robinson, 2020). [B]
Michigan	Michigan expanded testing criteria on April 20, 2020 to extend beyond symptomatic patients to include first responders and healthcare workers with or without symptoms and critical infrastructure workers (Michigan Department of Health and Human Services, 2020a). [B] As of April 30, COVID-19 testing is no longer prioritized for hospitalized patients (State of Michigan, 2020a). [B]	Michigan Department of Health and Human Services (MDHHS) provides a summary of total tests conducted per day along with a visualization of cumulative tests performed (State of Michigan, 2020b). [A] The MDHHS data feeds *The Atlantic*'s COVID Tracking Project and tracks how many tests are conducted in the state (*The Atlantic* COVID Tracking Project, "Michigan," 2020). [A]	Michigan reports the number of specimens, instead of people, tested (*The Atlantic* COVID Tracking Project, "Michigan," 2020). [C] Some hospitals in Michigan stopped using rapid tests due to low reliability, while other localities continue to use them (Smith and Carmody, 2020). [C]

State	Populations and Scale of Case Identification/ Testing (Only sicker? Post-mortem?)	Testing Measurement and/or Reporting	Other Issues (e.g., variation in test sensitivity and specificity, concern for fraudulent tests)
Missouri	As of April 21, 2020, per Missouri Department of Health and Senior Services (DHSS), COVID testing was restricted to symptomatic people with close contacts to a suspected COVID case with a pending laboratory test or a laboratory-confirmed COVID patient, symptomatic first responders, symptomatic residents of congregate living facilities, and symptomatic hospitalized patients (Missouri Department of Health and Senior Services, 2020b). [B] People who do not meet the DHSS criteria may pursue private laboratory testing. Some local health departments in Missouri are offering testing in different settings including drive-thru testing (e.g., MU Healthcare). The drive-thru testing is for patients with mild symptoms who've been assessed by a provider either through a clinic or video visit (Missouri Department of Health and Senior Services, 2020b). [C] On April 29, 2020, Governor Mike Parson announced that the state has capacity to test 50,000 people per week. He also said that Missouri is "now utilizing community sampling in specific counties." This involves testing both symptomatic and asymptomatic people to potentially identify individuals who unknowingly have COVID-19" (KY3, 2020). [C]	Missouri DHHS provides a summary of total tests reported in the state along with a timestamp. [A] These data feed *The Atlantic*'s COVID Tracking Project's daily test counts conducted in the state (*The Atlantic* COVID Tracking Project, "Missouri," 2020; Missouri Department of Health and Senior Services, 2020a). [A]	

State	Populations and Scale of Case Identification/ Testing (Only sicker? Post-mortem?)	Testing Measurement and/or Reporting	Other Issues (e.g., variation in test sensitivity and specificity, concern for fraudulent tests)
New Jersey	Testing is prioritized for persons who are close contacts of confirmed cases, traveled to or from highly affected areas, or are sick and have at least three of the nine CDC-recognized symptoms (State of New Jersey, 2020). [C] As of April 22, was offered and then rescinded for persons without symptoms- reflective of previous state guidance (Kaplan, 2020). [C]	Reported numbers of those who test positive include deaths and results reported by state, commercial, and medical center labs. [B] Negative results include data reported by state labs and many private labs (NJTV News, 2020). [B] The numbers of new cases reported to the state is lower on May 3, 2020, due to a network outage (NJTV News, 2020). [C] Such disruptions may affect data accuracy. [C] The state reports the number of people tested, as of April 27, 2020 (*The Atlantic* COVID Tracking Project, "Missouri," 2020). Comparisons of testing in New Jersey with other states may not be feasible prior to this date. [B]	New Jersey is one of the states that received faulty diagnostic test kits from the CDC, as noted in February 2020. They were made aware of this before specimens from patients were tested (Kopp, 2020). [C]
New York	The FDA granted approval to New York State to conduct testing at all 28 of its public and private labs, bringing testing capacity to 6,000 daily as of March 13, 2020 (New York State Governor's Office, 2020). [B] Testing criteria were expanded to include all first responders, health care workers, and essential employees even if these essential employees are asymptomatic, as of April 27, 2020 (New York State Governor's Office, 2020). [B]	Data on statewide testing for New York is reported by the Office of Public Health, Department of Health. Tests are counted per person per day, i.e., results of multiple specimens tested from the same person on the same day count as a single test of the person, and results of multiple test dates for the same person count as one for each date (New York State Department of Health, 2020b). [B] New York State Department of Health COVID-19 Tracker reports testing data based on its database of reported results from all laboratories' testing samples from New York State residents (New York State Department of Health, 2020a). [B] At the time of this environmental scan, New York state only reported cases from New York City to the CDC (Bialek et al., 2020). [B]	Expanded testing to populations with milder symptoms may have contributed to better case counting in New York State and may, at least partially, explain its higher case count and cumulative incidence compared with other states (ABC 7 Eyewitness News, 2020). [B] New York State launched antibody testing as of April 20, 2020 (ABC 7 Eyewitness News, 2020). [C]

State	Populations and Scale of Case Identification/ Testing (Only sicker? Post-mortem?)	Testing Measurement and/or Reporting	Other Issues (e.g., variation in test sensitivity and specificity, concern for fraudulent tests)
South Carolina	Those who are asymptomatic or have mild symptoms may not get tested in the state (South Carolina Department of Health and Environmental Control, 2020b). [B] Department of Health and Environmental Control (DHEC) prioritizes the identification of COVID-19 infections in congregate settings like nursing homes, assisted living facilities, and extended care facilities. [B] There are approximately 128 city level and four state level locations with testing capabilities across South Carolina's 46 counties (Scott and Molla, 2020). [B] At the time this environmental scan was conducted, some counties had severely limited testing (Weissman, 2020). [C]	DHEC reports the number of positive tests on a given day divided by the total number of tests performed on that day by DHEC's laboratory and private laboratories, multiplied by 100 to get the percent positive (4.4%, for May 3) (South Carolina Health Alert Network, 2020). [C] The South Carolina Health Alert Network (HAN) reports the number of new cases, cumulative number of cases, cumulative case rate per 100,000 persons, and whether the numbers were observed or projected by DHEC (South Carolina Health Alert Network, 2020). [B] COVID-19 Testing and Case Reporting Updates are posted on the South Carolina HAN website (South Carolina Health Alert Network, 2020). [B] DHEC reports laboratory-confirmed cases; the number of positive tests reported for a particular day are considered to be the number of new cases for that day. [B] However, laboratories are not always able to process and test the specimens they receive on the same day they receive them (South Carolina Department of Health and Environmental Control, 2020a). [B]	Some inconsistencies were noted in the data (e.g., calculation errors in negative tests reported) and retrospective corrections were needed (South Carolina Department of Health and Environmental Control, 2020c). [B]

State	Populations and Scale of Case Identification/ Testing (Only sicker? Post-mortem?)	Testing Measurement and/or Reporting	Other Issues (e.g., variation in test sensitivity and specificity, concern for fraudulent tests)
Texas	Texas is one of the states with the lowest per-capita testing rates and has a high positive test rate (Mekelburg, 2020). [C] The rate of cases is high in Donley and Moore counties, but testing is scarce in other rural areas where the virus has not yet been confirmed (Texas Tribune Staff, 2020). [C] Local health officials attribute the low testing rates to inadequacies in the testing kit supply chain (Walters, 2020). [C] State official statements were inconsistent regarding whether counts include presumptive positive tests. And the state does not count coronavirus patients at the San Antonio federal quarantine site (Sparber and Andu, 2020). [C] The state also excludes some positive cases in congregate living facilities, including prisons and nursing homes (Collins and Novack, 2020). [C]	The new state reporting system of the Texas Department of State Health Services (DSHS) uses case counts publicly reported by county instead of slower official case forms from local health departments and regional offices, as of March 21, 2020, yielding an increase in the number of reported cases (Texas Department of State Health Services, 2020a). [C]	Data from the DSHS may be incomplete. The state is not receiving test data from every private lab. Public and private labs prioritize those meeting certain criteria, but each private lab sets its own criteria (Mekelburg, 2020). [C] Data are incomplete, since some private labs did not report the number of negative tests administered and county-level data shows differences in counts compared to state counts (Mekelburg, 2020). [C] A May 16, 2020 article reported that Texas DSHS was combining some antibody test with antigen test results in case totals (Collins and Novack, 2020). The extent to which this was occurring could not be determined. This boosted the number of tests and lowered the positive test rate. [C]

State	Populations and Scale of Case Identification/ Testing (Only sicker? Post-mortem?)	Testing Measurement and/or Reporting	Other Issues (e.g., variation in test sensitivity and specificity, concern for fraudulent tests)
Washington	Prior to the provision of federal aid in May, one of the greatest challenges Washington faced in testing was obtaining supplies to collect samples, namely, swabs and viral transport media (Scott, 2020). [B] Testing criteria were expanded to include people with mild, moderate, or severe symptoms, including newly added CDC symptoms (Washington State Department of Health, 2020e). [B] Prior to March, the ability to get tested is still not widely available for people with mild symptoms. [B] Drive-through testing became available in late March in some communities (Scott, 2020). [B] Early in the pandemic, Charissa Fotinos, who oversees Washington State's COVID-19 testing, recommended the contacts of confirmed cases and people who live or work in congregate facilities be tested if supplies are adequate (Scott, 2020). [C]	The state reports the number of people tested, and it reports confirmed cases and lab tests as of the previous day (Washington State Department of Health, 2020e). [B] Between March 31 and April 15, 2020, the state did not report new negative results. [B] On April 18, 2020, it removed 190 cases because they were non-residents tested in state labs (*The Atlantic* COVID Tracking Project, "Washington," 2020). [B]	As of April 6, there have been delays of up to a week in test result turnaround in several commercial labs (*The Atlantic* COVID Tracking Project, "Washington," 2020). [B] The state recalled 12,000 test kits on April 18, 2020 that had been sent to local health jurisdictions, tribal nations, and state agency partners, due to possible viral transport media contamination (Washington State Department of Health, 2020c). [B] Labs assign individual test result data to the county of origin, then counties or the Department of Health determine the appropriate level of reporting for these cases, but county of origin and the reporting county do not always match (Washington State Department of Health, 2020a). [B]

Table B.2. COVID-19 Hospitalization Related Data Collection, Rate Calculation, and Measurement Issues by State

State	Definition of hospitalizations (only confirmed or also persons under investigation?, only count those in hospital setting or other setting as well, for example community setting)	Hospitalization Measurement and/or Reporting	Other Issues
California	California identifies hospitalizations as confirmed cases and, separately, identifies suspected cases/persons under investigation in the ICU (persons under investigation) (California Department of Public Health, 2020a). [B]	The California Department of Public Health (CDPH) is the state-based source for data on current hospitalizations (California Department of Public Health, 2020a). [A] CalMatters, a nonpartisan, nonprofit journalism outlet, provides a visual representation of current hospitalization rates including total number of confirmed and total number of suspected COVID patients per 100,000 people, for the state by county. It also reports county-based population rates using the 2018 American Community Survey (D'Agostino and Bénichou, 2020). [A] CDPH data feed the University of Minnesota's COVID-19 hospitalization tracking tool, which provides a current hospitalization rate per capita (University of Minnesota, Carlson School of Management, 2020a). [A] CDC includes estimates of cumulative hospitalization rates per population stratified by different age groups on COVID-NET for California as part of its Emerging Infections Program (EIP) (Garg et al., 2020; CDC, 2020e). [A]	California reports the percentage of hospitals reporting these data (~92% of facilities) (Garg et al., 2020). [B]

State	Definition of hospitalizations (only confirmed or also persons under investigation?, only count those in hospital setting or other setting as well, for example community setting)	Hospitalization Measurement and/or Reporting	Other Issues
		CDC COVID-NET includes only laboratory-confirmed cases in its cumulative hospitalization estimates, whereas CDPH provides a summary of hospitalizations for both confirmed and then separately for suspected cases (persons under investigation) (California Department of Public Health, 2020b). [B]	
Illinois	Illinois includes both laboratory-confirmed and persons under investigation in their current hospitalization counts (Illinois Department of Public Health, 2020b). [B]	The Illinois Department of Public Health (IDPH) dashboard reports current hospitalization counts, and counts over certain time periods, for both laboratory-confirmed COVID patients and persons under investigation (Illinois Department of Public Health, 2020b). [A] There is no CDC or state-based cumulative hospitalization count/rate for Illinois (Illinois Department of Public Health, 2020b). [A] *The Atlantic*'s COVID tracking project captures hospitalizations by state but not for Illinois as the state lacks cumulative counts and historical numbers (*The Atlantic* COVID Tracking Project, "Illinois," 2020). [C] The University of Minnesota COVID-19 hospitalization tracking tool reports that they are only able to capture Illinois data on current hospitalization counts and rates, and thus do not show cumulative counts/rates for Illinois (University of Minnesota, Carlson School of Management, 2020a). [C]	There are no measures of the proportion of hospitals reporting hospitalizations in Illinois. [B]

State	Definition of hospitalizations (only confirmed or also persons under investigation?, only count those in hospital setting or other setting as well, for example community setting)	Hospitalization Measurement and/or Reporting	Other Issues
		Illinois is not one of the 14 states included as part of the CDC's hospitalization COVID-NET tool, and thus a cumulative hospitalization rate is not available through this federal resource. In addition, the Illinois Department of Public Health reports only current hospitalization counts and does not provide a cumulative hospitalization count, thus no cumulative hospitalization rate can be estimated (Illinois Department of Public Health, 2020b; CDC, 2020e).[B]	
Louisiana	The state's hospitalization definition includes patients with confirmed COVID-19 through a hospital or commercial lab (and thus does not include persons under investigation) (Louisiana Department of Health, 2020b). [B]	Louisiana Department of Health (LDH) has a COVID-19 dashboard that includes the current number of hospitalized COVID-19 patients. [B] There is no CDC or state-based cumulative hospitalization count/rate for Louisiana (Garg et al., 2020). [A] Reported on the LDH dashboard. [B] Hospitalizations are measured by total counts as opposed to hospitalization rate (Louisiana Department of Health, 2020b). The dashboard feeds the University of Minnesota's COVID-19 hospitalization tracking tool, which provides a current hospitalization rate per capita (University of Minnesota, Carlson School of Management, 2020a). [A]	

State	Definition of hospitalizations (only confirmed or also persons under investigation?, only count those in hospital setting or other setting as well, for example community setting)	Hospitalization Measurement and/or Reporting	Other Issues
		The Atlantic's COVID tracking project also captures hospitalizations by state, but Louisiana lacks cumulative counts and historical numbers (*The Atlantic* COVID Tracking Project, "Louisiana," 2020). This is the same COVID tracking project that feeds Johns Hopkins' tracking for U.S. cumulative hospitalizations (Center for Systems Science and Engineering, Johns Hopkins University, 2020a). Since *The Atlantic* project does not have cumulative hospitalizations on Louisiana, as the Louisiana does not provide those, the state is not included in either tracking tool. [C]	
Michigan	The Michigan state-based resource compiled by the Michigan Health and Hospital Association may include both confirmed cases and persons under investigation depending on the hospital (State of Michigan, 2020a). [B]	Recent hospitalization counts are available through the Michigan Health and Hospital Association (both in aggregate and by hospital). However, these are not reported daily and are cross-sectional (i.e., point prevalence counts); there is currently no publicly available tab to monitor these historical counts to date (State of Michigan, 2020a). [B] Although the Michigan Health and Hospital Association does not report a cumulative hospitalization rate for the state, cumulative hospitalization rates for Michigan may be estimated using CDC COVID-NET (Garg et al., 2020). [A] COVID-NET captures hospitalization rates for those with confirmed COVID-19 (Garg et al., 2020). [C]	In Michigan, state reporting of hospitalizations fell under an emergency order for reporting (Michigan Department of Health and Human Services, 2020b). [B]

State	Definition of hospitalizations (only confirmed or also persons under investigation?, only count those in hospital setting or other setting as well, for example community setting)	Hospitalization Measurement and/or Reporting	Other Issues
		Michigan is not included in the University of Minnesota COVID-19 hospitalization tracking tool due to these reporting issues (University of Minnesota, Carlson School of Management, 2020a). [C]	
Missouri	The Missouri Hospital Association reports confirmed COVID-19 hospitalizations (LiVigni, 2020; Missouri Hospital Association, 2020). [A]	Hospitalizations are measured by total counts and displayed on the Missouri Department of Health and Senior Services website. [A] A "Health Care Utilization" infographic is compiled daily by the Missouri Hospital Association. It includes a current hospitalization count as well as increase in hospitalizations within the past 24 hours (Missouri Hospital Association, 2020). [A] Current (non-cumulative) hospitalization counts and rates are provided for Missouri by the University of Minnesota COVID-19 hospitalization tracking tool (University of Minnesota, Carlson School of Management, 2020a). [C]	The Missouri Hospital Association daily hospitalization report provides a count of total hospitals reporting data. As of May 16, it included data from 109 of 120 hospitals (Missouri Hospital Association, 2020). [B] County counts may differ from state counts (depends on the process for collecting and reporting data) (O'Dea, 2020). [C] Given that there are differences in when some localities or jurisdictions report their data to the state there may be differences in the county-published numbers versus those provided by the state. Further, Texas includes the caveat that "county case numbers may occasionally go down if the case investigation determines the person is a resident of another county or state" (O'Dea, 2020). [C]
New Jersey	The current hospitalization counts include aggregated laboratory-confirmed cases and persons under investigation (*The Atlantic* COVID Tracking Project, "New Jersey," 2020). [B]	New Jersey State Department of Health (DOH) tracks a cumulative count of laboratory-confirmed COVID-19 hospitalizations to date, however this does not include current cases (New Jersey Department of Health, 2020d). [B] CDC does NOT include estimates for cumulative hospitalization rates on COVID-NET for New Jersey (Garg et al., 2020). [A]	

State	Definition of hospitalizations (only confirmed or also persons under investigation?, only count those in hospital setting or other setting as well, for example community setting)	Hospitalization Measurement and/or Reporting	Other Issues
		Current hospitalization counts for both laboratory-confirmed COVID patients and persons under investigation are provided over time on the New Jersey live tracker (New Jersey Department of Health, 2020d). [B]	
		New Jersey DOH has a COVID-19 dashboard in conjunction with the New Jersey Hospital Association that provides current hospitalizations over time and by region (State of New Jersey, 2020). [B]	
		New Jersey's cumulative hospitalization count includes aggregated positive cases and persons under investigation (*The Atlantic* COVID Tracking Project, "New Jersey," 2020). [B]	
		Per the University of Minnesota COVID-19 hospitalization tracking tool, they only capture data on current hospitalization counts and rates, and do not show cumulative counts/rates for New Jersey as the state does not provide those data (University of Minnesota, Carlson School of Management, 2020a). The tool captures the counts from the state-based resource and then provides a current hospitalization rate per 100,000 per population for the state of New Jersey and use the denominator based on American Community Survey, 2018 (New Jersey Department of Health, 2020b). [C]	
		71 of 71 hospital facilities are reporting hospitalizations in the state (Gray, 2020). [B]	

State	Definition of hospitalizations (only confirmed or also persons under investigation?, only count those in hospital setting or other setting as well, for example community setting)	Hospitalization Measurement and/or Reporting	Other Issues
New York	Hospitalizations include aggregated confirmed cases and persons under investigation (*The Atlantic* COVID Tracking Project, "New York," 2020). [B]	Typically reported as per 100,000 in the population of interest (*The Atlantic* COVID Tracking Project, "New York," 2020). [B] *The Atlantic*'s COVID tracking project includes historical numbers for both current hospitalizations as provided by the state and also provides an estimate of cumulative hospitalizations in New York (*The Atlantic* COVID Tracking Project, "New York," 2020). [B] This is the same data source that feeds the Johns Hopkins University summary that features cumulative hospitalizations for New York (*The Atlantic* COVID Tracking Project, "New York," 2020). [C] CDC captures cumulative hospitalization rates on COVID-NET; a subset of counties in New York is included as one of 10 sampled states in its Emerging Infections Program (EIP) sample (Garg et al., 2020; *The Atlantic* COVID Tracking Project, "New York," 2020; New York State Department of Health, 2020a). [A]	New York State did not report discharged (recovered) or cumulative hospitalized for some time, so numbers are not up to date (*The Atlantic* COVID Tracking Project, "New York," 2020; New York State Department of Health, 2020a). [B]
South Carolina	The South Carolina Hospital Association (SCHA) collects percent occupancy for hospitalizations by region across the state (South Carolina Department of Health and Environmental Control, 2020c). [A]	Medical University of South Carolina provides additional modeling and gives stats on hospitalizations; however, limited public information is available (Medical University of South Carolina, 2020). [C] The South Carolina Hospital Association reports data on COVID-19 hospitalizations in the state (South Carolina Hospital Association, 2020). [B]	

State	Definition of hospitalizations (only confirmed or also persons under investigation?, only count those in hospital setting or other setting as well, for example community setting)	Hospitalization Measurement and/or Reporting	Other Issues
Texas	Texas includes only laboratory-confirmed cases in current hospitalization counts (*The Atlantic* COVID Tracking Project, "Texas," 2020). [B]	There is no state-based cumulative hospitalization count/rate for Texas (CDC, 2020e). [B] Texas Department of Health Services has a dashboard that provides laboratory-confirmed COVID hospitalizations for the day (no time trend) (Texas Department of State Health Services, 2020b). But a time trend is available through the University of Minnesota COVID-19 hospitalization tracking tool, as they have been capturing these daily reports from Texas (University of Minnesota, Carlson School of Management, 2020a). [C] The University of Minnesota's COVID-19 hospitalization tracking tool (University of Minnesota, Carlson School of Management, 2020a) captures the counts from the state-based resource and then provides a current hospitalization rate per 100,000 for Texas and uses the denominator based on American Community Survey, 2018. [C] CDC does NOT include estimates for cumulative hospitalization rates for Texas on COVID-NET (Garg et al., 2020; CDC, 2020e). [A]	For Texas, the Department of State Health Services reports that hospitalization and hospital capacity numbers are reported daily by hospitals through eight Hospital Preparedness Program providers—but it is not clear if reporting is required (Texas Department of State Health Services, 2020a). [C]
Washington	Hospitalizations are captured as current and cumulative for Washington per 100,000 adults (University of Minnesota, Carlson School of Management, 2020a). [A]	The Washington State Department of Health (WSDH) has a COVID-19 dashboard that includes a "COVID-like illness" hospitalization chart showing the number of weekly COVID-like illness hospitalizations (Washington State Department of Health, 2020e); these may be reported with a two-week delay (Scott, 2020). [B]	

State	Definition of hospitalizations (only confirmed or also persons under investigation?, only count those in hospital setting or other setting as well, for example community setting)	Hospitalization Measurement and/or Reporting	Other Issues
		Cumulative hospitalization counts among laboratory-confirmed COVID patients are provided in a written report by the Washington State Department of Health (Washington State Department of Health, 2020e). [B]	
		As of May 19, 2020 100% of facilities in the state report hospitalizations. About 96% of facilities have reported hospitalizations retrospectively and 84% of acute care hospitals have their hospitalizations identified prospectively (Evergreen Health, 2020). [B]	
		Washington did not report new negative results between March 31 and April 15, skewing cumulative hospitalization counts (*The Atlantic* COVID Tracking Project, "Washington," 2020). [C]	
		Current, and cumulative hospitalization rates are provided for Washington by the University of Minnesota COVID-19 hospitalization tool (Washington State Department of Health, 2020a; University of Minnesota, Carlson School of Management, 2020a). [C]	
		The Carlson School University of Minnesota hospitalization tracking project (University of Minnesota, Carlson School of Management, 2020a) captures the counts from the state-based resource and provides a hospitalization rate per 100,000 for Washington using a denominator based on the American Community Survey, 2018. [C]	
		CDC does NOT include estimates for cumulative hospitalization rates on COVID-	

State	Definition of hospitalizations (only confirmed or also persons under investigation?, only count those in hospital setting or other setting as well, for example community setting)	Hospitalization Measurement and/or Reporting	Other Issues
		NET for Washington (Garg et al., 2020; CDC, 2020e). [A]	

Table B.3. COVID-19 Mortality Related Data Collection, Rate Calculation, and Measurement Issues by State

State	Definition of deaths (e.g., only in hospital deaths captured or out-of-hospital as well? confirmed or probable as well?)	Mortality Measurement and/or Reporting	Other Issues (e.g., how widely post-mortem testing is conducted)
California	N/A	California Department of Public Health reports cumulative COVID-19 deaths and new deaths and provides related demographic information (Chidambaram, 2020). [B]	
Illinois	N/A	Providers and facilities report data to their local health departments through the Illinois' National Electronic Disease Surveillance System (I-NEDSS), which, in turn, report to IDPH. [B] The Illinois Department of Public Health (IDPH) provides a death rate per population on its COVID-19 dashboard (Illinois Department of Public Health, 2020a). [A] Reported by IDPH. This feeds the *The Atlantic*'s COVID Tracking Project and its reports of deaths for Illinois (*The Atlantic* COVID Tracking Project, "Illinois," 2020). [A]	COVID-19 mortality published by IDPH is provisional, subject to change, and updated weekly (Illinois Department of Public Health, 2020a). [B]
Louisiana	The CDC Provisional COVID-19 Death Counts show nonzero deaths in all settings in Louisiana except rare "dead on arrival." By inference, Louisiana does not exclude cases based on setting (CDC, 2020f). [B]	The Louisiana Department of Health (LDH) provides a COVID-19 dashboard that includes total deaths and a count of "probable" deaths (Louisiana Department of Health, 2020b; Brown et al., 2020). LDH also provides these mortality data by race, underlying health condition, ethnicity, and gender. Reported by LDH. [B]	There have been news reports of mortality counts being under-reported and that it is likely that an additional 15% should be added to the death toll (Brown et al., 2020). [C]
Michigan	From April 14 onward, Michigan has included both probable and confirmed cases, per CDC guidance. [B]	The Michigan Department of Public Health (MDPH) provides a death count and case fatality rate on its COVID-19 dashboard, which is updated daily (State of Michigan, 2020a). [A]	Michigan is reviewing earlier deaths to identify missed probable deaths (State of Michigan, 2020a). [B] As of May 16, 2020, regular reviews of death certificate data maintained in Vital Records reporting systems are conducted by MDHHS staff three times per week. As a part of this process, records that

State	Definition of deaths (e.g., only in hospital deaths captured or out-of-hospital as well? confirmed or probable as well?)	Mortality Measurement and/or Reporting	Other Issues (e.g., how widely post-mortem testing is conducted)
		Reported by MDPH (State of Michigan, 2020a). These data feed into *The Atlantic*'s COVID Tracking Project and its reports of tally of death counts for Michigan (*The Atlantic* COVID Tracking Project, "Michigan," 2020). [A] Deaths must be reported by health care providers or medical examiners/coroners and be recorded by local health departments in order to be counted (*The Atlantic* COVID Tracking Project, "Michigan," 2020). [B] There are concerns that death report "batching" may result in differential delays in data processing/reporting from some counties. This implies that COVID-19 death counts may not be reliable until the majority of deaths are reported (Center for Systems Science and Engineering, Johns Hopkins University, 2020a). [B] Some jumps in reported deaths were likely due to backlogs of cases classified as coronavirus deaths after health officials reviewed death certificates (Bridge, 2020; Rice, 2020). [C]	identify COVID-19 infection as a contributing factor to death are compared against all laboratory confirmed cases of COVID-19 in the Michigan Disease Surveillance System (MDSS). If a death certificate is matched to a confirmed COVID-19 case and that record in the MDSS does not indicate the individual died, the MDSS record is updated to indicate the death and the appropriate local health department is notified. These matched deaths are then included with mortality information posted to the Michigan Coronavirus website. At the time the environmental scan was conducted, this approach resulted in including 19 additional deaths (*The Atlantic* COVID Tracking Project, "Michigan," 2020). [B]
Missouri	Missouri is not excluding deaths outside of health care settings. [B] The state shows provisional COVID-19 death counts in inpatient, outpatient, and home settings (KY3, 2020). [B]	Missouri Department of Health & Senior Services (DHSS) provides a summary of death counts by county, age race/ethnicity, and sex (Missouri Department of Health and Senior Services, 2020b). [A] Reported by Missouri DHSS. [A] This is the same data source used by the Atlantic COVID-19 tracking project for total deaths in the state. [A]	In Missouri, by law, each COVID death is investigated by a health team to ensure its accuracy. [B] Postmortem testing can be approved by Missouri State Public Health Laboratory if an individual would have met the testing criteria prior to death (as of April 22, 2020) (Chidambaram, 2020). [C]

State	Definition of deaths (e.g., only in hospital deaths captured or out-of-hospital as well? confirmed or probable as well?)	Mortality Measurement and/or Reporting	Other Issues (e.g., how widely post-mortem testing is conducted)
New Jersey	New Jersey reported the highest number of cases in long-term care facilities, with over 11,000 cases (New Jersey Department of Health, 2020b). [C]	New Jersey reports COVID-19 deaths on a dashboard populated by the State Department of Health (New Jersey Department of Health, 2020c). Data reports on deaths from the Death Certificate database are maintained by the New Jersey Department of Health, Office of Vital Statistics and Registry. All data shown are for New Jersey residents regardless of where the death occurred (New Jersey Department of Health, 2020c). [B]	Per Governor Phil Murphy of New Jersey, "due to a lag in reporting, most of the deaths recorded in recent days likely occurred over the Easter weekend; the lack of tests and long return rate of results led to a "lag" in reporting" (New Jersey Department of Health, 2020a). [C]
New York	Early in the pandemic, New York State only reported confirmed cases, including those from New York City (New York City Department of Health, 2020). [B] As of April 30, 2020 COVID-19 deaths in New York City include both confirmed (positive lab test) and probable COVID-19 deaths (New York State Department of Health, 2020a). [B]	The New York State Department of Health collects death data from the State Hospital Emergency Response Data System and through daily calls to hospitals and other healthcare facilities (New York State Department of Health, 2020a). [B]	
South Carolina	N/A	South Carolina's Population Health Data Analytics & Informatics and the Division of Acute Disease Epidemiology is responsible for data, analysis, and visualization of COVID-19 demographic data, including COVID-19 deaths (South Carolina Department of Health and Environmental Control, 2020b). [B] Mortality data are reported to DHEC and are not complete until the end of the identified reporting period by hospitals and non-acute facilities (South Carolina Department of	To better inform the public about the scope of COVID-19 impact within nursing homes and extended care facilities, DHEC is providing a twice weekly update on the facilities in the state that have an associated confirmed case or death from COVID-19 (South Carolina Department of Health and Environmental Control, 2020b). [B]

State	Definition of deaths (e.g., only in hospital deaths captured or out-of-hospital as well? confirmed or probable as well?)	Mortality Measurement and/or Reporting	Other Issues (e.g., how widely post-mortem testing is conducted)
		Health and Environmental Control, 2020b). [B]	
Texas	The CDC Provisional COVID-19 Death Counts show nonzero deaths in all settings in Texas except rare "dead on arrival." By inference, Texas does not exclude deaths based on setting. [B] Only the most severe cases are tested, which will overestimate the overall mortality and case fatality rates. [B] Includes probable cases, but they are a small proportion of confirmed cases. [B]	The majority of tests in Texas are from private labs. The state is unable to deduplicate these tests, which will tend to underestimate the case fatality rate in Texas. [B] On March 24, DSHS updated the method of reporting COVID-19 cases in Texas to provide the public with more timely information. The DSHS daily case count now includes all cases reported publicly by local health departments around the state. [B] That change led to the report of an additional 305 cases in the March 24 total (Priest, 2020). [B]	Testing of decedents in Harris County started March 10, 2020 (Priest, 2020). It is not clear which, if any, other counties test decedents or when. [C]
Washington	N/A	The Washington State Department of Health (DOH) is responsible for collecting mortality data. [B] Washington reports deaths as of the previous day (Washington State Department of Health, 2020e). [B] Deaths may be reported by health care providers, medical examiners/coroners, local health departments, or others before they are included in the statewide count (Washington State Department of Health, 2020e). [B]	There is a lag in state reporting of deaths because they are often first reported to the local health department and then to the state. [B] On April 18, data cleaning removed 190 confirmed cases that were discovered to be out-of-state residents (Washington State Department of Health, 2020e). [B]

NOTE: N/A = data not available at the time the environmental scan was conducted.

Table B.4. Excess Mortality Related Data Collection, Rate Calculation, and Measurement Issues by State

State	Excess Mortality Measurement and/or Reporting	Other Issues
California	The new data from the CDC show roughly 4,500 additional deaths from all causes have occurred in 2020 over what would be expected from historical averages for California (Brown et al., 2020). [C]	
Illinois	From February 9 through March 28, Weinberger et al. (2020) found 185 unexpected "excess" pneumonia and influenza deaths in Illinois. During that same time period, Illinois reported 47 COVID-19 deaths (CDC, 2020c). [C] CDC reports excess mortality data for Illinois. [B]	
Louisiana	CDC reports excess mortality data for Louisiana. [B]	
Michigan	CDC reports excess mortality data for Michigan. [B]	
Missouri	Missouri does not report excess mortality. CDC reports excess mortality data for Missouri (CDC, 2020b). [B]	
New Jersey	According to a news report, "Medical examiners say the causes of these excess mortality are not all related to COVID-19, although the respiratory disease is the leading cause. Some of the excess mortality were a result of drug overdoses and household accidents, as well as people suffering heart attacks and strokes who resist going to the hospital because of virus fears" (Bichao, 2020). [C] When we look at the CDC, Provisional COVID-19 Death Counts by Week Ending Date and State, the percent of expected deaths during the week of 04/25/2020 is 135% (CDC, 2020f). [B]	
New York	CDC reports excess mortality data for New York (CDC, 2020b). [B]	
South Carolina	CDC reports excess mortality data for South Carolina (CDC, 2020b). [B]	
Texas	CDC reports excess mortality data for Texas (CDC, 2020b). [B]	
Washington	N/A	

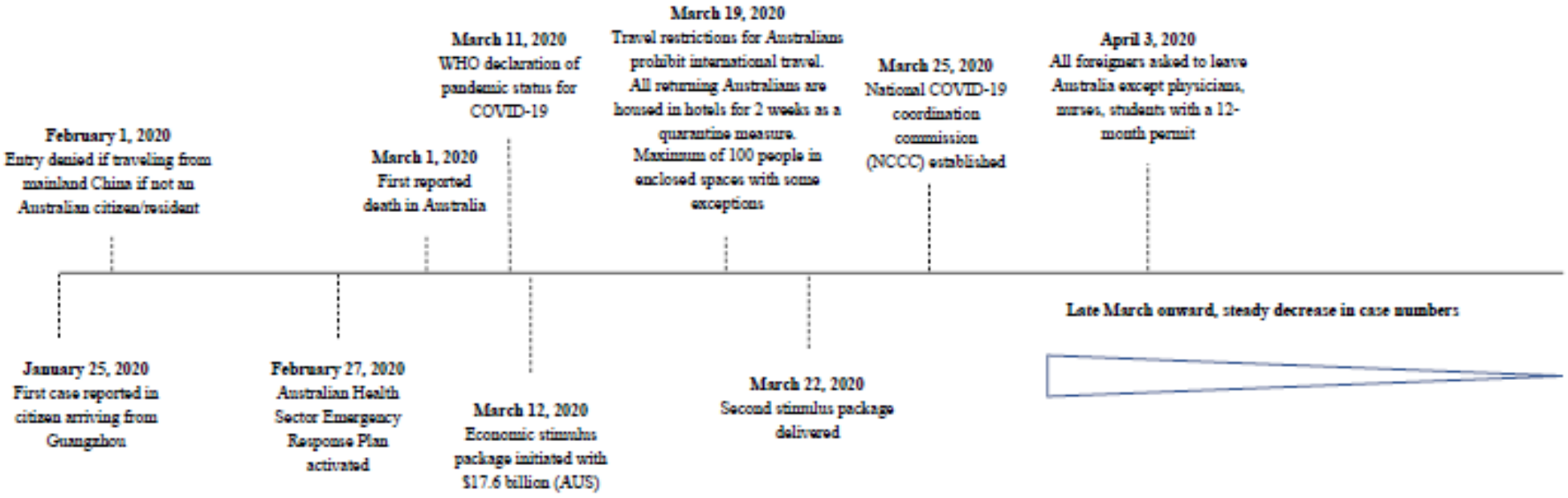
NOTE: N/A = data not available at the time the environmental scan was conducted.

Appendix C. Australia Case Study

We conducted a case study of one country in our sample (Australia) in order to develop a deeper understanding of the longitudinal evolution of COVID-19 measures since the start of the pandemic. Australia was chosen based on its significantly lowered case counts over time and because its hospital capacity, for the most part, was not overwhelmed.

A timeline of key events in Australia since the first confirmed COVID-19 case on January 25, 2020 (Australian Government Department of Health, 2020c), is depicted in Figure C.1. On February 27, the Australian Health Sector Emergency Response Plan for the Novel Coronavirus was issued (Australian Government Department of Health, 2020b).

Figure C.1. COVID-19 Event Timeline for Australia



COVID-19 Testing

Testing in Australia is approved by the Therapeutic Goods Administration (TGA) and approved tests are placed in the Australian Register of Therapeutic Goods (ARTG) (Australian Government Department of Health, Therapeutic Goods Administration, 2020).

At the time this case study was performed, all provinces suggest testing for any flu-like symptom without the aforementioned requirements of sick contacts or a fever (Lab Tests Online, 2020). States and territories report cases daily to the Australian Government Department of Health (Australian Government Department of Health, 2020a). Numbers are revised when further information is available. Cases are split by jurisdiction and where testing is performed (Australian Government Department of Health, 2020a).

The Department of Health publishes epidemiological COVID-19 reports (Australian Government Department of Public Health, COVID-19 National Incident Room Surveillance Team, 2020a, 2020b).

Possible COVID-19 cases are declared either a suspected case or a probable case. Suspected cases initially were declared persons with an acute respiratory illness (defined as fever and one or more signs of respiratory illness) and a history of travel to or residency in a location reporting SARS-CoV-2. Probable cases were defined as suspected cases with inconclusive testing or testing that could not be performed. These are not counted in COVID-19 case counts.

COVID-19 Hospitalizations

Approximately 11 percent of COVID-19 cases in Australia have required hospitalization as of May 14, 2020 (Australian Government Department of Public Health, COVID-19 National Incident Room Surveillance Team, 2020a; Evershed et al., 2020). Intensive care unit (ICU) and ventilator utilization remained low with little concern around related capacity. Hospital beds available per 1,000 people in Australia is 3.84 as per Organisation for Economic Co-operation and Development, Eurostat, World Bank, National Government Record sources aggregated by the open source Our World in Data project (Our World in Data, 2020).

Hospitalizations for COVID-19 are reported by individual states and collected by the federal government. Reporting of hospitalizations is done by both private and public hospitals and is the responsibility of physicians (Australian Commission on Safety and Quality in Health Care, 2020).

Data reporting from hospitals across states and territories is temporally staggered. However, the Australian Government and the Commission on Safety and Quality in Health Care are working with the public and private health sectors to align reporting standards (Ting, Scott, and Workman, 2020). Further, hospitalization rates are presented generally as snapshots/point prevalence, making determination of cumulative hospitalizations difficult.

COVID-19 Mortality and Excess Mortality

Information on a death certificate is the primary source for gathering Australian mortality statistics. After a death is registered, the Office of Births, Deaths, and Marriages sends the certificate to the Australian Bureau of Statistics (Government of South Australia, 2020).

As of May 4, the crude death rate (number of COVID-19 deaths per 100,000) was 0.38 per 100,000. The case-fatality rate (number of COVID deaths per 1,000 COVID-19 cases) was 94/6825 cases, equaling 14 per 1,000. Suspected and probable cases are not included in COVID-19 death estimates. If someone dies of the virus without being tested, they aren't counted in the Case Fatality Rate (CFR). Similarly, if someone contracts the virus and gets well by themselves without being tested, they are not counted as a survivor (EuroMOMO, 2020a).

Guidance was published by the Australian Bureau of Statistics for certifying deaths due to COVID-19. It details how to record COVID-19 on death certificates (including comorbidities) and use of proper terminology according to the WHO (Australian Bureau of Statistics, 2020). Limited number of cases and deaths makes excess mortality calculations less meaningful.

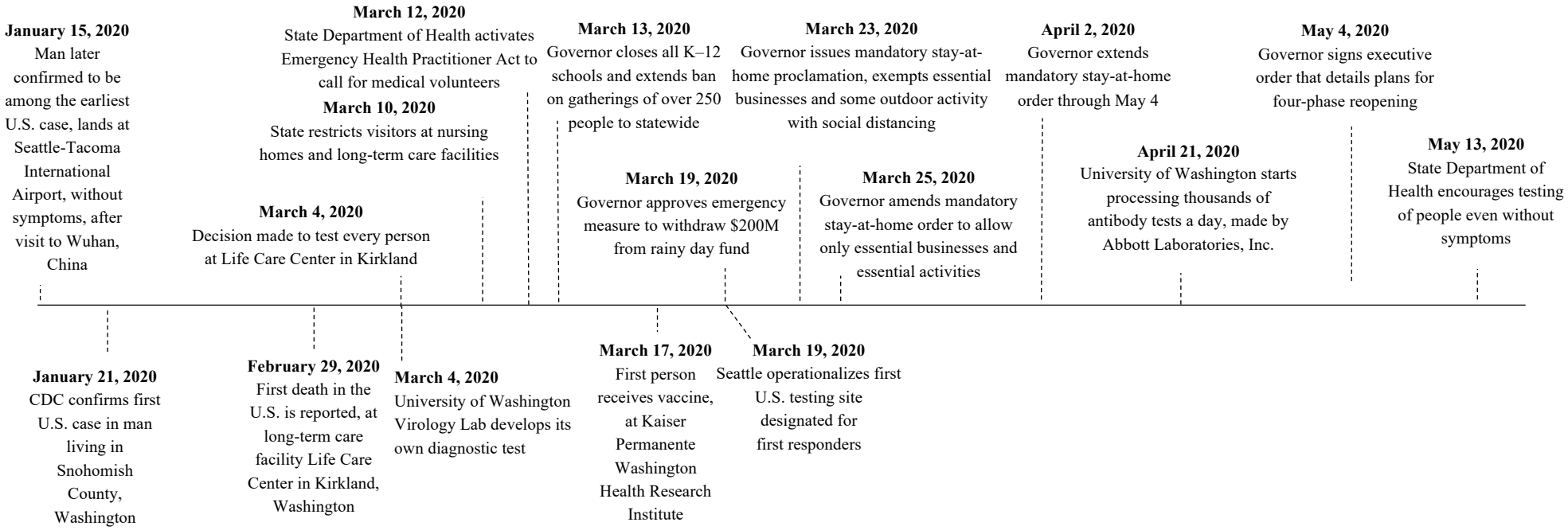
Conclusions

- Testing in Australia initially started with strict requirements but has since been expanded with wider testing availability.
- At this time, all flu-like symptoms can be liberally tested in all provinces.
- Testing and mortality are reported to the central health ministry, with timing of reporting varying among states/territories.
- Australia has low case numbers and case rates with liberal testing.
- The government emphasizes reporting and generates regular reports.
- Based on the limited number of cases and deaths, and available hospital and critical care capacity, Australia's response to the pandemic appears to have been effective. Federal data reporting requirements may have helped in the response.

Appendix D. Washington State Case Study

We conducted a case study of one state in the U.S. from our sample (Washington) to develop a deeper understanding of longitudinal evolution of COVID-19 measures since the start of the pandemic. Washington was chosen because it was the first U.S. state where COVID-19 cases were confirmed, allowing a longer timeframe for evaluation of how related measurement has evolved. A timeline of key events related to the pandemic in Washington is depicted in Figure D.1.

Figure D.1. COVID-19 Event Timeline for Washington State



COVID-19 Testing

One of the first cases of COVID-19 in the United States was reported in Washington State and confirmed by the CDC on January 21, 2020 (CDC, 2020d). The state initially followed CDC guidelines to test only symptomatic people who had contact with a confirmed COVID-19 case or traveled to an area with widespread coronavirus. Their provider would then reach out to the state Department of Health and the CDC to determine if testing was needed (Rasbach, 2020). On February 27, the CDC expanded criteria to allow testing of patients without recent travel to China (Ghose, 2020b). Two confirmed cases were reported on February 27, on the day the state's COVID dashboard was launched. The first person to die of COVID-19 in Washington State, as announced on February 29, was not tested until February 28, in part because the state laboratory was not ready to conduct tests and the CDC had recommended testing only those with symptoms and recent travel to China (Kimball et al., 2020). It appears that COVID-19 had spread in the Seattle area for weeks but went undetected due to failure to test people who had not traveled to China even if they appeared to be infected (Kimball et al., 2020).

Toward the end of February, the CDC expanded the testing criteria to include people who were hospitalized with otherwise unexplained symptoms. On March 4, the governor announced that the federal government would allow expansion of coronavirus testing, and public health officials announced that all people at the care center where the first death occurred would be tested (Gilbert and Gutman, 2020). Meanwhile, the University of Washington's Virology Lab developed its own diagnostic test (Sun, 2020).

On March 9, the governor announced requirements for screening visitors and employees at the start of each shift as part of its restrictions for nursing homes and long-term care facilities, and on March 10 the CDC conducted symptom screening in the nursing facility where the first outbreak happened (Scott, 2020). Even with expanded testing criteria and with one of the first nongovernmental laboratories approved to perform tests in the United States (Ghose, 2020a), the number of tests performed was limited.

One of the persistent challenges was obtaining enough supplies to collect samples, namely, testing swabs and viral transport media (Rasbach, 2020). There was a delay of up to a week in test result turnaround in several commercial laboratories (KUOW Staff, 2020a). In mid-March, the University of Washington expanded its drive-through testing to include first responders and infected patients at its medical center (KUOW Staff, 2020b), and drive-through testing is becoming more available in other communities (Bush, 2020).

The state recalled 12,000 test kits on April 18 that had been sent to local health jurisdictions, tribal nations, and state agency partners, due to concerns about possible viral transport media contamination (KUOW Staff, 2020a). On April 21, the University of Washington started the daily processing of thousands of antibody tests made by Abbott Laboratories, Inc. (KUOW Staff, 2020a), which had produced no false positives as of April 17 (Scott, 2020). By the end of April,

the state Department of Health expanded testing priority to those with symptoms recently adopted by the CDC, such as shaking chills, muscle aches, and loss of taste or smell; included mild symptoms; and recommended testing for a few high-risk groups including asymptomatic people residing in congregate settings and others who had contact with confirmed COVID-19 patients (KUOW Staff, 2020c, 2020d).

As of May 13, the state Department of Health encourages testing even without symptoms (Bush, 2020). However, it remains unclear whether people who die before testing will be tested post-mortem.

As of May 11, 6.8 percent of all tests were positive (Evergreen Health, 2020). The negative rate may vary between laboratories and may depend on the technique of using nasopharyngeal swabs (*The Atlantic* COVID Tracking Project, "Our Data," 2020).

The state reports the number of people tested and reports the number of confirmed cases and laboratory tests as of the previous day (Kirschman, 2020). An effort is then made by laboratories and counties or the Department of Health to assign cases to specific counties, while the state works to ensure that all cases are assigned to one county (Washington State Department of Health, 2020d). Assignments of state also varied, with 190 confirmed cases removed after being shown to be out-of-state residents who had been tested in Washington (Kirschman, 2020). Early on, the state only reported positive test results; it did not report new negative test results between March 31 and April 15 (Kirschman, 2020). The state started reporting negative test results mid-April 2020 (Washington State Department of Health, 2020a), so that the proportion of tests that are positive can be calculated, which allows the Department of Health to identify counties where testing did not keep up with the spread of the infection (Tacoma-Pierce County Health Department, 2020).

Washington illustrates some of the idiosyncrasies around test positivity rates. At least one county (Pierce County) excludes negative tests from the total tested (although the positive tests appear to be retained) or the positive testing rate of long-term care facilities (Tacoma-Pierce County Health Department, 2020). The underreporting of negative tests biases the positive test rate upward (Tacoma-Pierce County Health Department, 2020), since it is removed from the denominator but kept in the numerator. Other counties do not describe how they treat negative tests, so it is uncertain how pervasive this issue is. No information is provided on the percentage of tests administered to long-term care facility residents, so it is difficult to provide an upper or lower bound on the effects of underreporting. Washington reports probable cases separately from confirmed cases, so the numbers may be higher as past data are revised.

COVID-19 Hospitalizations

The CDC does not include estimates for cumulative hospitalization rates on COVID-NET—its surveillance system for laboratory confirmed COVID-19 hospitalizations—for Washington (Washington State Department of Health, 2020e). The Washington State Department of Health

has a COVID-19 dashboard that includes a COVID-like illness hospitalization chart that shows the number of COVID-like illness hospitalizations occurring each week (Washington State Coronavirus Response, 2020). The Washington State COVID-tracking dashboard provides a summary of CLI hospitalization trends, with about a two-week delay (Washington State Coronavirus Response, 2020). *The Atlantic*'s COVID tracking project also captures hospitalizations by state, but for Washington it lacks historical numbers (*The Atlantic* COVID Tracking Project, "Our Data," 2020). The University of Minnesota COVID-19 hospitalization tracking tool includes both current and cumulative hospitalization rates for Washington (University of Minnesota, Carlson School of Management, 2020a, 2020b; Washington State Department of Health, 2020b).

Reporting

Washington started to report CLI hospitalizations on May 5. While this may still include hospitalizations where the patient is not tested or tests negative, this strategy aims to identify more CLI patients and patients diagnosed with any type of coronavirus and to remove visits in which the patient was instead diagnosed with influenza. Thus, the reported number and percentage of CLI hospitalizations increased (Washington State Coronavirus Response, 2020). Not all facilities reported hospitalizations, with 96 percent of facilities reporting hospitalizations retrospectively and 84 percent having identified hospitalizations prospectively as of April 28. Due to variation in the number of hospitals reporting, counts of hospitalizations have not been directly comparable from day to day (Washington State Coronavirus Response, 2020). However, as of May 16, the Department of Health reports that 100 percent of acute care hospitals have reported retrospective hospitalizations that occurred since January and are identifying hospitalizations prospectively (Ghose, 2020b). Hospitals have been reporting daily COVID-19 and CLI cases to the state.

COVID-19 Mortality and Excess Mortality

One of the first reported cases of COVID-19 death in the United States was in Washington State on February 29, 2020, in a care center where eventually dozens of people died (CDC, 2020b), although earlier deaths were later reported in California (Bush, 2020). Collection of mortality data was initially slow. From the time the outbreak was discovered, it took nine days, during which 18 residents died, for an outside medical team to visit the site of the first death (Sun, 2020).

Of confirmed cases, 5.5 percent had died as of May 15 (Kirschman, 2020). The CDC analyzed mortality data to determine the number of excess mortality, or those above what are expected based on historical data, while accounting for state reporting lags. Excess mortality included deaths from COVID-19 and other factors, such as fewer people seeking treatment for other illnesses during the pandemic. It seemed the pandemic has not greatly slowed reporting,

although data from more recent weeks was less complete. The state's weekly excess mortality reached a peak of 90 during the week ending April 11, about 7 percent more than the CDC estimated. This difference may reflect delays in reporting and data processing.

Deaths may be reported by health care providers, medical examiners and coroners, local health departments, and others before being included in the statewide count. States often lag in reporting deaths because they are often first reported to the local health department and then the state Department of Health (Washington State Coronavirus Response, 2020). As of April 14, the CDC included probable deaths with confirmed deaths (Yan et al., 2020). A probable case or death is defined based on a combination of evidence from clinical, epidemiologic or serological testing, or vital records, but not a confirmatory laboratory RNA testing (Yourish et al., 2020). Thus, the numbers for Washington, which reports probable cases and confirmed deaths separately, may increase as past data are revised.

Conclusion

- Since the first reported COVID-19 case in the U.S. occurred in Washington in late January, the state gradually expanded its testing criteria to reflect changing CDC guidelines.
- Amidst a shortage of supplies, testing later ramped up to include drive-through testing and antibody testing.
- Reported numbers and percentages of tests have been affected by variation in laboratory results and swabbing techniques and separate reporting of probable cases and confirmed cases.
- The state currently reports cumulative cases of hospitalizations, keeps recovered cases, and includes CLI cases.
- Initially, not all hospitals reported rates retrospectively. Now hospitals report daily confirmed and CLI cases to the state.
- The CDC includes probable deaths along with confirmed deaths as of mid-April, which may increase past numbers for Washington as they are revised.
- Excess mortality includes those from COVID-19 and other factors.
- There may be delays in reporting deaths as health care providers, medical examiners, and local health departments are notified before inclusion in the statewide count.
- Based on the timeline of pandemic response in Washington State, it appears that measurement of COVID-19 measures has improved over time.

Appendix E. Medical Examiner Roundtable Guide

The RAND Human Subjects Committee (HSPC) has determined that this project is exempt from human subjects oversight. Participation in this roundtable is completely voluntary. Even if you decide to participate now, you may change your mind and stop at any time. You may choose not to answer questions for any reason. We will be taking detailed notes in order to create a word-for-word copy of today's discussion for analysis. You will not be quoted or referenced by name in the notes. We will make every effort to assure that you cannot be identified through the details that you share. The results of this study could be published in an article but would not include any information that would let others know who you are.

We believe the risks to you participating are minimal and that there may be benefits to U.S. communities through understanding COVID-19-related death certification.

Do you have any questions?

Medical Examiner Roundtable Guide

- What federal guidance have you received around certifying COVID-19 deaths?
- Are there state guidelines around certification of COVID-19 deaths in your state?
- What are the processes for certification of COVID-19 deaths in your state?
- What are some challenges in COVID-19 death certification in your state?
- Does your state conduct post-mortem COVID-19 testing? Under what circumstances are those conducted?
    - When did you start post-mortem COVID-19 testing?
    - Are you going back to reclassify prior deaths based on CDC April 14 guidance to include probable COVID-19 deaths?
- Do you count both those that die "of" and "with" COVID-19 as COVID-19 deaths?
- Do you document "probable" COVID-19 in the death certificate? If so, what constitutes a probable COVID-19 death? Do these count towards COVID-19 deaths?
- Do you document co-morbidities (e.g., chronic diseases like diabetes, asthma, or heart disease) as part of COVID-19 death certification?

- What type of additional federal or state guidance would help with the process of COVID-19 death certification?

- Are there other issues around COVID-19 death certification you would like to discuss?

Additional questions if time permits:

- We found references on some state dashboards saying that death certificate lists COVID-19 or an equivalent as the cause of death. What is an "equivalent" death?

- On average, how long does it take for a COVID-19 confirmed or probable death to show up on the state dashboard?
    - How about the CDC provisional counts?
    - How long does it take for an all-cause death to show up in CDC provisional counts?

Appendix F. Summary Findings from the Medical Examiner Roundtable

Table F.1. Medical Examiner Roundtable Themes and Excerpts

Theme	Excerpt
Insufficient post-mortem testing capabilities	"I don't know if all COVID-19 cases are reported to us to begin with . . . many physicians are frustrated and won't put COVID-19 unless there is a swab. But if somebody has a chest x-ray . . . [they] end up writing ARDS [acute respiratory distress syndrome] and don't put COVID-19 on there. So . . . these cases are being missed. They're going out as natural underlying conditions. . . . Those that couldn't have testing or testing was not available at that time." "We had challenges in getting access to [post-mortem] testing. We were at the very bottom of the priority list for this equipment." "What would be helpful is if they could ramp up testing on a federal level, and on a national level. Each county is going to need to ramp up their [post-mortem] testing."
Insufficient personal protective equipment	"There hasn't been efficient use of the Defense Production Act, for PPE so, at the federal level having a real ramp up of industry to get PPE for staff—not just for clinicians, but coroners and mortuary assistants as well. We need to be able to do surveillance of every person that comes through our door to make sure we're safe, and don't have to wait too long if we have an exposure." "[Working for the sheriff coroner] . . . I'm trying to make sure people coming in and out of the building are symptom free, and we are getting PPE to the sheriffs so that they wouldn't get infected and bring this back to the office. . . . I finally got them a gown so that when they go in the house their uniforms were protected. I had to fight hard for that and they got mad at me, like I don't know what I'm doing. They treated me like I'm an agitator."

Insufficient education and variability in certification	"I think we'll see a real wide variation in the quality of the data." "Most deaths have not been certified, so I think that adds variability." "Death certificates are notoriously completed wrong, or not well. They either list every diagnosis they have, or just put cardiac arrest or something." " . . . most medical examiners are not certifying these deaths. Most are being certified by physicians in the hospital. . . . Most medical examiners are certifying for home deaths, and not as much for hospital deaths." "The CDC guideline is pretty specific about what "probable" deaths are. You have to have compelling evidence of death due to COVID-19. They give an example of an elderly woman with an underlying disease who refuses treatment . . . and dies. . . . I think when they say compelling, they mean compelling. There is probably great variation, and people aren't following what the CDC says."
Complex, fragmented reporting systems	"There is some state guideline regarding the use of the word 'possible' or 'probable,' so they say that if this is pending a COVID test, or pending COVID results, this is not proper to use. They don't like 'possible' unless the patient has COVID symptoms and the test comes back negative. We will call them "probable" COVID-19, and that is ok with the vital system." "Most offices are coroners, or sheriff coroners. We're not bringing cases in that are deaths certified by clinicians. I have not seen any guidance from the State Department of Public Health." "Mayors and governors, and victims' families . . . are dealing with clinicians and hospitals that don't do this [death certification] well, or don't do this [death certification] nearly as often." "There is CDC guidance. It's on their website, including what table to submit but again you can't submit it without prior permission. They require you to go through the health department, but most of us know the CDC, so I don't go through the health department first."
Need for transparency in reporting	"We also need some sort of protection so medical examiners are not muzzled. We've had medical examiners with numbers different from what the public health department provided, so they were telling them to stop talking." "All information is being funneled from one source, and I either got no response, or got a response that said "thanks, but no thanks", or "I'm not allowed to talk about this."

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