

Rapid

Review



NORTH AMERICAN
OBSERVATORY
on Health Systems and Policies

COVID-19 Case and Contact Tracing: Policy Learning from International Comparisons

A Rapid Review Prepared for Toronto Public Health

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May 2020

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Suggested citation:

Bhatia, D., Morales-Vazquez, M., Song, K., Roerig, M., Allin, S., & Marchildon, G. (2020). COVID-19 Case and Contact Tracing: Policy Learning from International Comparisons. Toronto: North American Observatory on Health Systems and Policies. *Rapid Review* (No.25).

Acknowledgements:

We are grateful for the time and insights provided by the local experts in the six selected jurisdictions. We also gratefully acknowledge Victoria Haldane for assistance with recruitment and data collection, and Patrick Farrell for editing and production support.

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Introduction and Background

An outbreak of pneumonia of unknown origin in Wuhan City, China, in late December 2019, was traced to a viral agent named Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), with the associated disease named COVID-19 (1). The World Health Organization (WHO) declared the outbreak a Public Health Emergency of International Concern on January 30, 2020 (2) and classified it as a pandemic on March 11, 2020 (3). As of May 9, 2020, there were 210 countries and territories affected by COVID-19, with 3,855,812 total reported cases and 265,862 deaths, including 65,399 cases and 4,471 deaths in Canada (4). To disrupt the chain of viral transmission and prevent health system capacity overload, governments around the world have adopted varying levels of restrictive public health measures, including border closures, stay-at-home orders, community-wide physical distancing, movement restrictions, and suspensions of non-essential services. The Government of Ontario, Canada, implemented such measures under a Declaration of Emergency on March 17, 2020 (5).

Some jurisdictions saw sustained reductions in the numbers of new COVID-19 cases throughout April and May 2020. Governments have therefore started to prepare for easing of restrictive measures. Since the public availability of safe and effective therapeutics and vaccines is months away, a key consideration during the transition process is minimizing a second surge of infections. To mitigate this risk, the WHO has emphasized the importance of robust case finding, testing, and contact tracing capacity (6). On April 27, 2020 the Government of Ontario released its framework document for reopening the province, similarly echoing the need to strengthen public health capacity for rigorous testing, timely contact tracing, and case management (7).

Many jurisdictions have expressed an interest in using technology-driven approaches to facilitate case and contact tracing, which otherwise involves a laborious process of manually identifying and informing contacts of a confirmed case (6). Digital applications (“apps”), installed on an individual’s personal mobile device, can use the phone’s location data and Bluetooth signals to determine (i) whether the individual has come into contact with someone infected with SARS-CoV-2, or (ii) which individuals the infected person has come into contact with and potentially exposed. However, many concerns have been raised regarding the use of these tools, including imprecision in detecting contacts and distances, vulnerability to fraud and misuse, privacy and safety issues, issues of liberty and agency, and low public uptake (8). It has also been suggested that such approaches may only be effective if 40-70% of the population actively use them (6). The effectiveness of contact tracing strategies is further complicated by the reality that many mild symptomatic cases are advised to self-isolate without diagnostic confirmation, as well as the possibility of asymptomatic viral transmission, as studies have estimated that anywhere between 5-80% of COVID-19 cases in the community may not present symptoms and potentially remain undiagnosed (9).

In this rapid review, we sought to understand how select jurisdictions have been able to contain the COVID-19 pandemic and begin transitioning to more relaxed public health measures through the use of testing, case management, and contact tracing. We are particularly interested in the role of digital contact tracing tools. The results of this rapid review will provide detailed information and evidence (as of May 2020) that may help inform COVID-19 recovery strategies.

Methods

We undertook six rapid jurisdictional case studies, involving an environmental scan of the literature and interviews with local experts. Case-study design allows detailed exploration of the underlying mechanisms of identified phenomena to address the “how” and “why” research questions (10). Multiple case-studies are considered to be more robust than single case-studies, because they enable replication of findings (10). Individual jurisdictions were selected based on the following criteria: evidence of (i) containment of COVID-19 spread which has been sustained until late April 2020 based on a declining incidence of new cases (6), (ii) gradual easing of large-scale public health restrictions, (iii) use of new technologies for case/contact management, and (iv) sufficient availability of public and academic information, as well as ability to reach local experts for consultation.

Environmental Scan

We performed a review of academic and grey literature to describe the testing and case/contact tracing approaches to contain COVID-19 that were implemented in the jurisdictions of interest. This involved targeted and iterative searches of existing COVID-19 evidence repositories (e.g., the European Observatory COVID-19 Health System Response Monitor, McMaster Health Forum’s COVID-END, Johns Hopkins Coronavirus Resource Center), bibliographic databases/search engines such as MEDLINE and Google Scholar, and websites of key organizations, including each jurisdiction’s health ministry and public health units, as well as global health bodies, such as the WHO, the World Bank, and the Organization for Economic Cooperation and Development. A standardized case report form was developed to facilitate data extraction.

Expert consultations

The literature scan was supplemented by consultations with 13 individuals with expertise on the COVID-19 response in one of the six selected jurisdictions. The interviews sought to gain insight into some of the contextual factors and stakeholder perspectives related to testing and case/contact tracing that played a role in containing the COVID-19 epidemic and enabled the relaxation of public health measures. The full list of interview questions is available in **Appendix A**. Local experts were recruited among the NAO network members. The list of local experts, including their affiliations and qualifications, is available in **Appendix B**. The results of all six case studies were reviewed by the local experts to triangulate findings.

Limitations

Literature searches and interviews with local experts were conducted between May 4-May 11, 2020 based on the information available at that time. Given the dynamic and evolving nature of the COVID-19 pandemic, there is a possibility that information may have changed since the time of writing. Further, since much of the pertinent information was only available in the form of press releases, news articles, and technical reports, and unpublished research, there is a possibility of some error related to these non-peer reviewed resources. Due to the expedited nature of this review (1.5 weeks), we acknowledge there may be additional jurisdictions meeting our case criteria that we could not explore and it is possible that we did not identify all the documents relevant to our objectives. Our review focuses on testing, case management, and contact tracing methods only, and did not seek to explore other public health or government actions that may contribute to the containment of COVID-19.

Analytic Overview

We conducted rapid case studies to learn how Israel, Singapore, Iceland, Germany, Taiwan, and South Korea contained the COVID-19 epidemic through rigorous testing, case management and contact tracing. While successes in containment relate, in part, to contextual factors, including population density, population characteristics, and geography, these countries' COVID-19 response strategies may hold important lessons for Canada. In **Box 1**, we present the step-by-step processes by which the selected jurisdictions implemented contact tracing. Subsequently, we describe the practices for testing, contact tracing, and isolating cases, that have been highlighted in the literature and by local experts as particularly effective. In **Box 2**, we provide an overview of the contextual factors that were described as enabling the effective implementation of the jurisdictions' COVID-19 response. Finally, at the end of the analytic section, we provide a tabular summary of testing and contact tracing practices in each jurisdiction. For further detail, please refer to **Appendix C** to view the complete results of the case studies, including testing and contact tracing criteria, processes, capacity, responsible parties, and timelines. Please see **Appendix D** for a summary of the features of digital approaches to contact tracing.

Box 1. Step-by-step contact tracing processes across selected jurisdictions

GERMANY

1. Local public health unit registers a positive SARS-CoV-2 test result.
2. Contact tracing team within the public health unit calls the infected individual to communicate test results and inquire about any contacts that occurred in the 2 days preceding symptom onset. Use of digital tools to support contact tracing is not currently widespread in Germany, though an app is in development (see **Appendices C and D**).
3. Contacts are called by contact tracers, informed of exposure, and advised to quarantine for 14 days.
4. Contacts' symptoms are monitored through regular calls from contact tracers; if symptoms develop or worsen, individuals are advised to call a health office or hotline to determine whether a test may be warranted.
5. If individuals are unable to leave their house, public health units or outreach teams of ambulatory physicians may perform the test at the individual's home.
6. Local approaches vary. Some cities use "corona taxis", in which healthcare providers visit confirmed cases in their homes to monitor their symptoms, perform medical exams, and escalate management if necessary (i.e., transfer the patient to the hospital).
7. Voluntary smartwatch app "Corona Data Donation", released in early April, allows cases to record their symptoms alongside other biometrics; when aggregated at zip code level, these data may help identify outbreak "hotspots" (see **Appendices C and D**).

ICELAND

1. Contact tracing team in the Department of Civil Protection, National Commissioner of Icelandic Police, receives test results from the National University Hospital in Reykjavík (central sample processing lab).
2. Contact tracers call the infected individual to obtain a 14-day history before symptoms onset.
3. If some contacts are unknown, police records, travel records, open source info (e.g., social media), or employer of the infected individual (if available) are used or contacted.
4. Voluntary app "Rakning C-19" tracks the user's 14-day GPS history; upon COVID-19 diagnosis, user may submit these data to the contact tracing team to help identify unknown contacts (see **Appendices C and D**).
5. Contacts are instructed to immediately quarantine for 14 days.
6. Time to trace all contacts: 8 hours since index case diagnosis in March; 2 hours in May.
7. Contacts' symptoms monitored with regular calls from contact tracers; if symptoms develop, individuals are advised to call primary care clinic or helpline to determine if test is warranted.
8. If diagnosed, individuals isolate at home. Those unable to safely do so may book a hotel room.

Box 1. Step-by-step contact tracing processes across selected jurisdictions (continued)**ISRAEL**

1. Contact tracing teams in district-level Health Bureaus of the Ministry of Health call the infected individual to obtain 14-day history.
2. De-identified listing and map of all locations that infected individuals have visited in the past 14 days, with corresponding times, are posted publicly on the Ministry of Health website.
3. Shin Bet secret services' cellphone tracking apparatus was involved in March to enable exposure notifications via SMS (**Appendices C and D**).
4. Voluntary app "HaMagen" cross-references the user's 14-day GPS history with location history of confirmed cases and notifies users of possible exposure (see **Appendices C and D**).
5. Contacts (identified by contact tracers or self-identified) must quarantine for 14 days and submit an online report to the Ministry of Health.
6. If contacts develop symptoms, they are advised to call their HMO clinic/hotline, Ministry of Health hotline, or EMS hotline.
7. The hotline operator screens the caller for COVID-19 epidemiological or clinical criteria; if criteria are met, individual transferred to COVID-19 hotline manned by EMS dispatchers, Ministry of Health staff, or HMO personnel.
8. Contacts' symptoms monitored with regular calls; a paramedic or HMO personnel may be dispatched to the individual's home to administer a test, if deemed warranted by a physician.
9. Initially, all diagnosed cases were isolated in hospitals, regardless of symptom severity (until mid-March). Currently, mild cases isolate at home or in "Corona hotels" rented by the Ministry of Health. All severe cases or those with concurrent medical issues are taken to hospitals.

SINGAPORE

1. Contact tracing starts at the hospital, where tests are performed; healthcare worker interviews the infected patient about their 14-day history.
2. An "activity map" is produced and submitted by the hospital to the Ministry of Health.
3. Contact tracing team at the Ministry of Health verifies the map by calling the patient and their family/friends, and reviewing transport records; full activity map is charted within 24 hours of index case diagnosis.
4. If contacts are unknown, contact tracers review the activity maps of other confirmed cases and flag linkages as "hypotheses".
5. Hypotheses are then "proven" or "disproven" through phone interviews with the other cases and field investigations (e.g., street surveys, review of CCTV footage); to obtain these data, Singapore Police Force may be engaged.
6. Voluntary app, "TraceTogether", records anonymized identifiers of nearby phones over 21 days via Bluetooth; upon diagnosis, user may submit these data to contact tracing team to help identify unknown contacts (see **Appendices C and D**).
7. SafeEntry QR code check-in/check-out system added to public venues in early May to enable identification of contacts should an outbreak occur (see **Appendices C and D**).
8. Identified contacts are called by contact tracers and screened for symptoms. Those who are asymptomatic are advised to quarantine for 14 days (from the time of exposure).
9. Symptoms and quarantine adherence are monitored via regular calls from Ministry of Health officials.
10. Contacts that report symptoms are treated as "suspect cases" and may be transported to a hospital for testing.
11. Time to trace all contacts: 48 hours since index case diagnosis.
12. Cases and contacts may quarantine/isolate at home or in government facilities. Only the most severe cases are admitted to hospitals.

SOUTH KOREA

1. In cases of widespread transmission, local (rather than central) epidemiological investigation teams perform contact tracing.
2. Investigation phase: obtain information through patient, family, and physician interview to identify transmission route.
3. Risk assessment phase: the collected information is verified and supplemented by other sources (medical records, cellular GPS data, credit card transactions, CCTV footage).
4. Contacts are classified by risk status (close vs. casual contact).
5. Contacts are then reached by the epidemiological team, informed of their exposure, and counseled regarding next steps (quarantine and symptom monitoring).
6. Through collaboration with the Ministry of Land, Infrastructure and Transport, Ministry of Science, National Police Agency, Credit Finance Association of Korea, and 3 telecommunication and 22 credit card companies, the Korean Centre for Disease Control and Prevention developed a COVID-19 data platform, drawing on real-time GPS, cellphone, credit card transaction, CCTV information to perform spatio-temporal analyses to chart the infected individual's epidemiological history. This automated approach allows public health officials to rapidly verify patient reporting and identify infection clusters.
7. This approach reduced the 24-hour manual contact analysis to a 10-minute automated one.

TAIWAN

1. The NHI database was a key method of contact tracing in Taiwan. The database contains complete health history, underlying health conditions, recent progression of symptoms, treatments, and hospitalization related to respiratory syndromes.
2. The NHI database was enriched with patients' 14-day travel history using customs and immigration data from the National Immigration Agency. All hospitals, clinics, and pharmacies in Taiwan have access to patients' travel histories.
3. The NHI-based centralized Taiwan Health Cloud program generates automatic surveillance reports for infectious diseases using hospital electronic medical records.

Acronyms: global positioning system, GPS; short message service, SMS; Health Maintenance Organization, HMO; emergency medical services, EMS; closed circuit television, CCTV; National Health Insurance, NHI

Summary of Best Practices

Community-based management of mild cases

Primary and community-based care can play an important role in triaging cases with few or mild symptoms. Such an approach serves a number of functions in the context of an outbreak – first, it offloads case management from hospitals thereby reducing the risk of in-hospital exposure; second, it prioritizes certain individuals for diagnostic testing, as testing of all mild symptomatic cases may not be possible; and third, it allows providers to closely monitor mild or suspected cases and promptly escalate and refer them for testing and acute care treatment, if necessary.

Triage in primary care clinics

Singapore and Taiwan adapted their primary care systems for epidemic responsiveness following the 2003 SARS-CoV-1 outbreak; both systems were also acknowledged for playing a role in successfully containing the 2009 H1N1 outbreak. Singapore's Public Health Preparedness Clinics (PHPCs) were designated as the first point of contact for individuals with any symptoms of an acute respiratory infection. After a physician examination, patients are advised to return to the clinics for possible referral for diagnostic testing if their symptoms do not resolve within five days (11,12). Singapore's Ministry of Health announced the gradual re-activation of the country's 900 PHPCs in mid-February 2020, shortly after the first documentation of community-linked SARS-CoV-2 cases (13). During non-emergency times PHPCs function as regular primary care clinics and polyclinics, and their clinicians and staff undergo periodic Ministry of Health training to stay up-to-date with emergency outbreak protocols (14). In Taiwan's tiered primary care system, Community Healthcare Groups Prepared Clinic (CHGPCs) handle patients with fever, upper respiratory symptoms, or possible SARS-CoV-2 infections. CHGPCs have government-supplied protective equipment for staff and can assist patients in self-isolation through videoconferencing. Suspected COVID-19 cases can be escalated by CHGPCs to the next tier, the Community Screening Station (CSS), in which diagnostic testing can be administered and patients can be further dichotomized into those needing same-tier or higher-tier treatment and care (15).

Telephone hotlines and home-based testing

Jurisdictions such as Germany, Israel, Iceland, and South Korea have established dedicated non-emergency hotlines and home-based testing to manage cases outside the hospital. These hotlines encourage patients with mild symptoms or those without symptoms but history of contact with a confirmed case to self-identify to enable closer monitoring in the community setting. In Germany, the operator from the non-emergency medical service decides whether the individual needs to be tested and discusses the next steps (16). Local public health offices and/or outreach teams of ambulatory physicians may then be dispatched to test individuals for SARS-CoV-2 in their homes if they are unable to leave the house or if they have had direct contact with a confirmed COVID-19 case. In Israel, individuals calling the emergency hotline for non-emergency medical reasons and meeting the epidemiological or clinical criteria for COVID-19 were transferred to the COVID-19 hotline, staffed by paramedics and other healthcare personnel, including Ministry of Health representatives. Upon confirmation of possible exposure, individuals were instructed to quarantine at home for 14 days, with frequent phone-calls from paramedics to monitor symptoms. If the symptoms resembled COVID-19, a physician would decide whether to dispatch a paramedic to the individual's home to test them for SARS-CoV-2 (17). By early May, 88,272

Israelis were tested in their homes (18). While home-based testing was not discussed in the Iceland context, individuals presenting with symptoms of any severity are encouraged to contact their primary care clinic or call a designated helpline to determine whether a SARS-CoV-2 test is warranted, based on physician judgment (19). In South Korea, a 24/7 hotline can be used to report symptoms during quarantine if a smartphone app is unavailable (20), to receive diagnosis if an app user is suspected to have been infected (21), or to find the location of all the available testing centers (22,23).

Drive-through testing facilities

The majority of the selected jurisdictions sought to make SARS-CoV-2 testing more widely accessible in the community to expand testing capacity and reduce hospital traffic, with drive-through testing facilities being a popular approach. For example, Israel's emergency medical service responsible for handling the outbreak at the beginning of the epidemic, set up four stationary testing centers in major metropolitan areas, as well as eight drive-through testing centers mid-March, about a month after the outbreak started (17). Non-quarantined individuals were directed to these centers to undergo testing (17), with 96,065 Israelis tested in drive-through facilities by early May (18). South Korea turned all of its district-level public health clinics into local testing centers, with a total of 592 testing centers present across all 9 provinces on May 21, 2020, including 58 drive-through facilities in 7 provinces (24). Similarly, in Iceland, sample collection was performed by primary care clinics outside their facilities, on a drive-through basis (25).

Selection of populations for testing

Testing in asymptomatic groups

Testing asymptomatic individuals for SARS-CoV-2 is not widespread in part due to risks of false negative results soon after exposure (19,26). Population-based testing surveys may provide key insight regarding the prevalence of the virus (polymerase chain reaction, PCR testing) or immunity to the virus (serologic testing) in the community. These data may be particularly informative when planning to ease large-scale public health restrictions, as they indicate the effectiveness of containment efforts and the estimated size of a possible second wave of the infection. The recent experiences in Iceland, Israel, and Germany are notable examples.

In late March 2020, Iceland conducted the largest study to-date that compared SARS-CoV-2 testing in symptomatic and asymptomatic population-based samples. The study was sponsored by Iceland's biotechnology company deCODE Genetics–Amgen, in collaboration with the Directorate of Health and Landspítali University Hospital. Two population-based samples were recruited – one involving self-identified healthy individuals that registered online, and the other involving healthy individuals identified by sending text messages to random phone numbers. In total, 13,080 mild symptomatic or asymptomatic individuals and 9,199 symptomatic individuals were tested. The prevalence of positive SARS-CoV-2 test results in the healthy population-based samples was close to 1%, while in the symptomatic group, it was 23%. The rate of infection remained stable over time, suggesting that public health containment efforts may have been effective (27).

In advance of lifting its large-scale public health restrictions, Israel's Ministry of Health announced on May 5, 2020 that it was planning to survey 100,000 healthy and asymptomatic Israelis for SARS-CoV-2 antibodies using serological blood tests, in order to determine the community prevalence of SARS-CoV-2 immunity. This will be the largest study of its kind and the findings will inform planning and give an

indication of the possible size of the second wave of SARS-CoV-2 infections in Israel. Researchers suggest that should a second wave of infections occur, a 10% prevalence of immunity to the virus may result in 2,300 individuals needing intensive care, which is well within Israel's health system capacity. However, a prevalence of 1% may result in 12,000 people needing intensive care, which significantly exceeds health system capacity. Another large serological testing study is also currently underway in Germany, with a representative sample of 15,000 individuals to be tested across 150 locations. The first results are expected in June 2020 (28). In Iceland, serological testing is limited to individuals presenting for regular blood draws, although the scale of operation in this setting is less clear (19).

Mass testing in special populations

Although Singapore was initially successful at containing COVID-19 without large-scale restrictions, in early April a new surge of cases in migrant worker dormitories began driving the number of cases back up. This culminated in the April 7, 2020 announcement of “circuit breaker” measures, including closures of workplaces and entry restrictions on outbreak “hotspots” (29–31). Prior to the circuit breaker period, migrant workers were tested in the same fashion as the general population (i.e., through identification of symptomatic individuals); however, more widespread testing was adopted during the circuit breaker period. Nearly 3,000 migrant workers living in the dormitories were being tested daily by the end of April, amounting to over 21,000 individuals. Dormitories with higher documented infection rates were prioritized. Migrant workers presenting with symptoms of acute respiratory infection are isolated and tested immediately, along with their roommates (32). Singapore's government also deployed specialized teams, composed of Civil Defense Force officers, security officers, and other staff in the public service, to facilitate rapid triaging, case finding, and contact tracing in the dormitories (33). Similar efforts were implemented in Singapore's residential care home facilities in order to test all 30,000 care home staff and residents, regardless of the presence of respiratory symptoms or history of possible exposure (34,35). The testing of all residential care home staff and residents was completed by May 8, 2020, with one positive result among staff (although some test results were pending at the time of this rapid review's preparation) (35). Following this one-time test, all staff and residents will continue to be tested periodically, at two-week intervals (35).

In Israel, it has been noted that testing rates among marginalized groups, particularly migrant populations, have been markedly low due to a lack of insurance coverage, fear of losing employment, and, among undocumented individuals, fear that their status will be disclosed to immigration authorities (36). The Sourasky Medical Center (Ichilov Hospital) in south Tel Aviv implemented a special testing point for hard-to-reach populations. According to recent reporting, 332 asylum seekers, foreign workers, and precariously housed individuals have been tested for SARS-CoV-2 there. The infection rate in these populations was found to be similar to that in the Israeli population at large (approximately 3%), suggesting that there has been no COVID-19 outbreak among the selected marginalized groups in Tel Aviv (37). Non-governmental organizations, such as Physicians for Human Rights and the Levinsky Clinic (a clinic specializing in sexually transmitted infections), were involved in recruiting from these hard-to-reach groups. According to local experts, after the initial announcement of Israel's forthcoming exit strategy, the Ministry of Health stated that all children in schools and all individuals visiting Israel's health plans' clinics would be systematically tested for SARS-CoV-2. However, it is unclear whether this measure has been, or is in the process of being, implemented. A similar notice was made in Germany, where the

government recommends that irrespective of symptoms, all individuals presenting to health facilities be tested for SARS-CoV-2 (28).

Maintaining surveillance and contact tracing capacity

As evidenced in **Box 1**, the selected jurisdictions often relied on traditional contact tracing approaches, in which contacts are identified through a thorough review of available data. Below, we outline some key factors that have been described as contributory to effective contact tracing.

Mounting an early response

Most of the selected jurisdictions began implementing public health measures before the first imported case was detected, which enabled them to coordinate multiple sectors of government for a proactive response. For instance, when the WHO was notified on December 31, 2019, of pneumonia of unknown cause in Wuhan, China, Taiwanese officials began surveillance measures by screening passengers flying directly from Wuhan to Taiwan for symptoms (38). Further, Taiwan's National Health Command Center, acting as the operational command point during public health emergencies, was activated on January 20, 2020 to address the COVID-19 outbreak – one day before Taiwan's first confirmed case (39). Iceland convened a meeting between the National Security Council, the Ministry of Health, and the country's Chief Epidemiologist shortly after the WHO declaration of a state of emergency on January 30, 2020, and nearly a month before its first case on February 28, 2020. Furthermore, testing for SARS-CoV-2 among symptomatic international travellers began in Iceland on January 31, 2020 (27,40).

Similarly, according to local experts, following the WHO emergency declaration and long before its first imported case on February 21, 2020, Israel summoned its epidemiological investigation team to begin assembling information, coming up with case definitions, and writing protocols for handling cases when they emerge. The country also engaged the Ministry of Defense and the Ministry of Foreign Affairs to handle the epidemic domestically and abroad. The Singapore government set up a Multi-Ministry Taskforce to direct a whole-of-government response to ramp up preventive measures and contain the virus on the same day as its first imported case was confirmed, on January 23, 2020 (41). Finally, in mid-January – prior to its first confirmed case on January 20, 2020, the South Korean government held its meeting on leveraging the emergency authority of the Korean Centers for Disease Control and Prevention to produce diagnostic tests. This enabled the country to begin approving test kit production in early February and increasing the number of tests from approximately 3,000 to 18,000 per day by March (22).

Human resource capacity for contact tracing

Although manual contact tracing is the preferred approach, it is very resource intensive and capacities may rapidly become overwhelmed. Human resource capacity for contact tracing in most of the selected jurisdictions was achieved through redeployment of employees and volunteers across governmental sectors. In Singapore, Ministry of Health epidemiologists and communicable disease experts train and supervise contact tracing teams, composed of medical residents and Civil Defense officers, among others. There were fifty teams of 10 trained contact tracers in February, at the outset of the epidemic. By late March, the number of teams increased to seventy (700 contact tracers in total). There are three contact tracing teams on duty during any single shift, and there are two contact tracing shifts per day (42). In late April, it was reported that Germany's goal was to have one team of five contact tracers per 20,000

inhabitants (amounting to a total of 21,000 contact tracers). To meet this goal, the Ministry of Health facilitated the transfer of public employees from other departments and financed placements of medical students. Soldiers and officials of the armed forces were also engaged to help in the most affected areas (28). In Iceland, contact tracing is carried out by the Department of Civil Protection and Emergency Management within the National Commissioner of Icelandic Police (40,43). A contact tracing team was assembled shortly after the country was put on high alert in early March (44). At the outset, the team was comprised of six individuals – two detectives, two criminologists, and two medical workers. This team of contact tracers was later expanded to 52 individuals, including civil servants, medical workers, and students (45).

Local experts from Iceland emphasized that good communication, listening, and rapport-building skills are essential for conducting contact tracing. Conversations with potential contacts may be difficult in part due to people feeling ashamed, particularly if they have had many contacts since exposure. Icelandic experts further noted that their contact tracing team’s “motto” has been to ensure that people “feel better on in the end of the call, than in the beginning.” This is echoed in the reporting on contact tracers in Germany, with one contact tracer remarking “It’s about taking away people’s fears and informing them very clearly what they can do,” (46).

Effectiveness of contact tracing

It may not be possible to directly attribute containment of the COVID-19 epidemic to any single public health measure. Nonetheless, four of the selected jurisdictions – Singapore, Iceland, Taiwan, and South Korea – did not impose a national lockdown at the outset of the outbreak, which indicates at least partial effectiveness of contact tracing approaches. For instance, throughout the six consecutive days leading up to May 1, 2020, Taiwan had zero new COVID-19 cases (47). As discussed earlier, Singapore was initially successful in containing the outbreak without a lockdown, but an outbreak among migrant worker dormitories drove the number of cases up in April, leading to the temporary circuit breaker period. Most recently, the number of new cases in Singapore has dropped to an average of 12 per day (48). In South Korea, the daily average of new cases was 9 between April 26, 2020 and May 9, 2020 (49).

Iceland presents compelling evidence supporting the effectiveness of rigorous contact tracing. Each of the country’s 1,799 cases confirmed up to May 6, 2020 has been identified as either imported or community-linked (50). As of May 12, 2020, a total of 19,694 individuals have completed a 14-day quarantine, while 564 were still in quarantine and 18 were in isolation (51). Most notably, 57% of individuals eventually diagnosed with COVID-19 were already in quarantine at the time of diagnosis, suggesting that contact tracing accurately identified and limited further transmission from a significant proportion of individuals exposed to the virus (50).

Tiered quarantine and isolation facilities

The availability of high-capacity government quarantine and isolation facilities also may have had a role in containing the outbreak in the selected jurisdictions, particularly in high density areas. Specialized facilities may lead to increased quarantine and isolation adherence, particularly among marginally housed individuals. Further, tiered facilities ensured that hospital beds were reserved for the most severe COVID-19 cases, while keeping the mild and moderate cases in the community. In Israel, all diagnosed COVID-19 cases were taken to hospitals for isolation, regardless of disease severity at the outset of the epidemic. As

of the end of March 2020, mild cases could choose to isolate at home or in designated hotels, temporarily rented by the Ministry of Health to service COVID-19 isolation purposes. In late April, there were 99 government-approved quarantine facilities across 17 cities/towns for individuals without a permanent residence in South Korea; 1,021 rooms out of 3,368 were occupied on April 26, 2020 (52).

Singapore has also made notable advances in creating quarantine and isolation bed capacity. Individuals who are unable to safely self-isolate at home while awaiting test results for SARS-CoV-2 are directed to Swab Isolation Facilities (repurposed hotels with a 4,000-bed capacity). Those with severe symptoms or concurrent health conditions are immediately transferred to hospitals (53). A number of hotels, university hostels, and convention centers have been temporarily converted into quarantine facilities, with capacities of 500-10,000 beds. By the end of June, capacity is expected to further increase to 20,000 beds (53). Upon being diagnosed with COVID-19, patients may remain in the hospital, be admitted to the Intensive Care Unit (ICU), or be discharged to lower-level facilities for isolation, treatment, and recovery (53). Finally, in residential care settings, to further reduce the risk of exposure among staff and residents, staff are in the process of moving to designated on-site accommodation facilities or hotels until the public health restrictions are lifted (34).

Digital contact tracing approaches

In this section, we highlight the most common digital approaches used to support or enhance contact tracing, which involve smartphone apps using global positioning systems (GPS) or Bluetooth data, as well as linked data and cloud-based technologies. For a full discussion of the technological approaches employed in each jurisdiction and a cross-jurisdictional comparison, please see **Appendices C and D**.

Global positioning system smartphone apps

Israel and Iceland have developed contact tracing smartphone apps using GPS technology, though the implementation and features of the two apps are different. Israel's app, called HaMagen, serves to notify the user of whether they have frequented a location within the same time window as a confirmed COVID-19 case. To do this, the app unilaterally downloads the Ministry of Health data on recently confirmed cases and compares it against the user's 14-day GPS history. When users are notified of potential exposure, they are provided with instructions on quarantine and next steps, including self-reporting to the Ministry of Health and where to inquire about testing (54,55). Iceland's app, called Rakning C-19, serves to track the user's 14-day GPS location data so that, should the user be diagnosed with COVID-19, their location history could be used to identify any potential contacts whose identity is not known to the infected person. Upon COVID-19 diagnosis, contact tracers at the Department of Civil Protection and Emergency Management request the user to consent to secure transfer of their data to Department servers (56,57).

Both apps can be viewed as supplementary to contact tracing efforts, with HaMagen helping individuals recognize their own risk of exposure and with Rakning C-19 helping contact tracers identify unknown contacts. Icelandic experts noted that the relevance of their app for contact tracing may become more salient as restrictive measures are lifted. The use of both apps is voluntary. Interestingly, the uptake of Rakning C-19 has been substantially higher than that of HaMagen (38% vs. 17% of the population) (58,59). The high uptake of Rakning C-19 may, in part, be explained by the promotional messaging chosen by Icelandic officials, emphasizing communal thinking and the role of individuals in supporting COVID-19 containment (56). Public trust may also play a role, as Iceland's COVID-19 response has been primarily led

by civil servants and scientific experts (44,45). Conversely, Israel's experience with Shin Bet security services' cellphone surveillance (see **Appendices C and D** for details), which was highly contested by civil rights groups, may have primed the public to lean against technology-based contact tracing approaches. To potentially improve uptake, it was reported on May 5, 2020 that Israel was expected to launch a new version of HaMagen, equipped with Bluetooth capabilities (59).

Bluetooth smartphone apps

Singapore was the first major developer of a Bluetooth-based contact tracing app, TraceTogether. This app operates by using wireless Bluetooth technology to measure proximity and duration of an encounter between two nearby smartphones over time (60,61). Upon installing TraceTogether, the user submits their mobile number to the Ministry of Health's centralized secure server. Using its private key, the server generates a temporary identifier for each submitted phone number (62,63). When near another TraceTogether user, the smartphones exchange their time-linked anonymized temporary identifiers, which are then stored locally for 21 days on a rolling basis. If an individual is eventually diagnosed with COVID-19, contact tracers would request their consent to access their TraceTogether Bluetooth data to decrypt the phone numbers of the potential contacts (64,65). Singapore's open source protocol, BlueTrace, is publicly available for review and use. Germany has been considering using a similar app to support its contact tracing efforts. However, the use of a centralized server has been controversial in Germany, due to stricter privacy laws and the vulnerability of centralized servers to security breaches. In late April, Germany announced its support for the decentralized approach, favoured by Google and Apple, and is preparing to launch the app in June 2020. Roughly 20% of Singapore's population have downloaded the TraceTogether app (66). Low uptake may be, in part, explained by accounts of poor functionality of TraceTogether on the iOS interface, as the app cannot run in the background and drains the smartphone's battery rapidly (67). Although Bluetooth is considered to be a less invasive approach to contact tracing than GPS or cellphone data, privacy concerns persist among the public (67).

Big data and cloud-based technologies

Through sophisticated digitization of health system records and linkage across multiple databases, South Korea and Taiwan were able to partially automate their contact tracing approaches. The Korean Centers for Disease Control and Prevention collaborated with the National Police Agency, Ministry of Science, Ministry of Land, Infrastructure and Transport, Credit Finance Association, three mobile carriers, and 22 credit card companies (68) to develop a cloud-based COVID-19 open data hub, producing almost real-time (10 minutes) spatio-temporal analysis of epidemiologically-relevant data (69). Data inputs include GPS location, mobile networks, and credit card transaction information. Existing digitized infrastructure for research and development of public services enabled the creation and linkage of this hub (70). Taiwan's government implemented a National Health Insurance (NHI) centralized Health Cloud program in 2014 (71). The NHI database contains electronic medical record information, such as complete health history, underlying health conditions, recent progression of symptoms, treatments, and hospitalization related to respiratory syndrome (72). The NHI database was enriched with patients' 14-day travel history using customs and immigration data from the National Immigration Agency. All hospitals, clinics, and pharmacies in Taiwan have access to patients' travel histories (38,72). The Health Cloud program is then able to generate automatic surveillance reports for infectious diseases using these linked data (71).

Box 2. Contextual factors enabling effective implementation of containment efforts

Emergency preparedness: Prior large-scale fatal events catalyzed the development essential legislation, public health infrastructure, and pathways for a whole-of-government pandemic response. *Iceland* frequently experiences natural disasters; as such, the Department of Civil Protection and Emergency Management in the police force has often been deployed for crisis management. *Iceland's* pandemic preparedness plan (previously updated in 2016) formalized the involvement of Civil Protection for contact tracing. Since the 2015 Middle East Respiratory Syndrome (MERS) outbreak, *South Korea* amended the Infectious Disease Control Act to allow timely of identification and movement information of confirmed and suspected cases, increased its public health workforce, and developed the Emergency Use Authorization, which allows for fast-track approval of the supply chains. This allowed *South Korea* to mass distribute COVID-19 test kits across nearly all test centers by late January 2020. *Singapore's* Public Health Preparedness Clinics (PHPCs) were implemented following the 2003 SARS-CoV-1 outbreak. These clinics act as the first point of contact and triage centers for potential cases in the community, that way allowing for close monitoring of mild cases, offloading case management from hospitals, and creating an escalation pathway. *Taiwan* developed a similar network of tiered Community Healthcare Groups Prepared Clinics (CHGPCs) after the 2003 SARS-CoV-1 outbreak. The clinics serve a similar function to *Singapore's* PHPCs.

Cross-sectoral collaboration: Local experts often emphasized the importance of an “all hands on deck” approach. In *Israel*, the immediate involvement of the Ministry of Defense and the Ministry of Foreign Affairs, facilitated the domestic and foreign management of the COVID-19 crisis. *Singapore* established a Multi-Agency Task Force on the same day as the WHO declared a public health emergency; this facilitated redeployment and training of personnel to increase the capacity of the country's contact tracing apparatus. Similarly, *Iceland* convened a meeting between the National Security Council, the Ministry of Health, and the Chief Epidemiologist to plan the country's response shortly after the WHO emergency declaration. A multi-sectoral collaboration also enabled *South Korea's* Centers for Disease Control and Prevention to develop an automated “big data” contact tracing platform. Further, the establishment of a central disaster and safety countermeasure with Ministry of the Interior and Safety and local task forces enabled the emergency message system to alert the Korean public of new cases in their proximity.

Local public health units: As technology is currently viewed as supplementary, thorough manual contact tracing remains essential. Local public health units have been described as essential for implementing contact tracing protocols, maintaining the number of cases within a manageable range, and building a rapport with the community. The latter is particularly important as good communication skills have been highlighted as key for effective contact tracing. In *Israel*, contact tracing teams were situated within district-level Health Bureaus (an extension of the Ministry of Health), which allowed them access to COVID-19 test results. *Germany* has a similar structure, which allowed local public health units to develop innovative ways of connecting with patients and performing symptom checks. In *Israel*, *Germany*, and *South Korea*, local public health units also facilitated scaling up of testing capacity.

Science-focused strategic communication: *Iceland's* transparent and expert-driven communication strategy has been highlighted as a key enabling factor, leading to the public's cooperation with containment and contact tracing methods. The country's daily press briefings were primarily led by civil servants and scientists involved in the COVID-19 response, in whom the public trust was substantially higher, compared with political leaders. *Germany's* Chancellor Angela Merkel has also been acknowledged for centering scientific expertise when addressing the public about the country's COVID-19 strategy.

As mentioned in the Limitations section, the following **non-modifiable contextual factors** may also explain the selected jurisdictions' performance with regard to containing COVID-19:

- Isolated geography (*Iceland*, *Israel*, *Singapore*)
- Low population density (*Iceland*)
- Low-risk characteristics of the susceptible population (*Singapore*)
- Less restrictive privacy regulations (*Taiwan*, *South Korea*)
- Large-scale restrictions, i.e., “lockdown” (*Germany*, *Israel*)

Conclusions

In this rapid review, we sought to understand how selected jurisdictions – Israel, Singapore, Iceland, Germany, Taiwan, and South Korea – have been able to contain the COVID-19 epidemic through testing and contact tracing, enabling their transition to more relaxed public health measures. We inferred a number of best practices that appeared to improve the effectiveness of testing and contact tracing in each jurisdiction, as well as contextual enabling factors.

Best practices:

1. **Community-based management of mild cases:** primary care clinics may be particularly well equipped to handle intake, triage, and monitoring of mild and suspected cases. Telephone hotlines and home-based testing may similarly facilitate triaging, while reducing the risk of exposure. Drive-through testing facilities may help scale up the testing process in the community.
2. **Population-based testing of mild or asymptomatic groups** may provide key insight regarding the prevalence of the virus or immunity to the virus in the community. These data are informative for plans to ease large-scale public health restrictions, as they indicate the effectiveness of containment efforts and the estimated size of a possible second wave of infection.
3. **Mass testing in special populations**, including hard-to-reach groups or those residing in dense congregational settings (e.g., dormitories, long-term care homes), may help uncover infection clusters.
4. **Tiered quarantine and isolation facilities:** the availability of government-sanctioned high-capacity quarantine and isolation facilities throughout the disease process, from testing to recovery, may lead to increased quarantine and isolation adherence, and offload case management from hospitals.
5. **High surveillance and contact tracing capacity:** well-trained, and adequately staffed contact tracing teams are crucial for mounting a proactive pandemic response.
6. **Digital contact tracing approaches:** Bluetooth, GPS, and cloud-based technologies may serve as useful tools for supporting contact tracing, particularly in densely populated areas where not all contacts may be known to the infected individual. However, due to privacy and usability concerns, digital contact tracing tools may best serve as supplementary measures to traditional contact tracing. This approach has been recommended by the WHO (6,8,73).

Enabling factors:

1. **Emergency preparedness:** pre-existing pandemic or natural disaster emergency infrastructure facilitates a rapid whole-of-government response.
2. **Cross-sectoral collaboration:** an “all hands on deck” approach facilitates a rapid and comprehensive response and supports human resource/redeployment needs for contact tracing.
3. **Local public health units** are essential for implementing contact tracing protocols, maintaining the number of cases within a manageable range, building rapport with the community, and piloting new outreach approaches (e.g., home-based testing or symptom monitoring).
4. **Science-focused strategic communication:** transparent, evidence-informed public communication, delivered by experts, builds public trust and may facilitate public cooperation with contact tracing strategies.

Case Study Summaries

GERMANY	
Date of first case	January 28, 2020
	Total cases/deaths 168,551 cases / 7,369 deaths (total population of over 83 million)
Party responsible for testing and contact tracing	Robert Koch Institute (RKI) oversight, including guidelines and recommendations; contact tracing implemented through 375 local public health units.
Testing criteria	<p>Laboratory testing is recommended for individuals with:</p> <ol style="list-style-type: none"> Acute respiratory tract infection and history of close contact with a confirmed or probable case in 14 days prior to symptom onset Clinical or radiologic characteristics of viral pneumonia in the context of increased number of pneumonias in care facilities or hospitals Clinical or radiologic characteristics of viral pneumonia with no indication of any other cause, and no contact with a confirmed case Acute respiratory tract infection and (a) history of medical-related activities, (b) a pre-existing medical condition, or (c) no known risk factors <p>German residents are encouraged to immediately, irrespective of symptoms, contact their health office, get in touch with a doctor or call the non-emergency medical service, and stay at home if they have contact with a person with confirmed SARS-CoV-2 infection. The operator from the non-emergency medical service decides whether testing is warranted and discusses the next steps.</p>
Testing capacity	<p>Daily testing: <i>End of April</i>: 141,815 tests per day or 860,494 tests per week; <i>May 13</i>: 157,150 tests per day or 1,038,223 tests per week</p> <p>Total tested: 3,147,771 tests have been performed in Germany by May 13</p> <p>PCR test processing: 134 laboratories of university hospitals, research institutions, and clinical and outpatient settings were equipped for processing samples on May 13</p> <p>Testing capacity: has both been increasing with the regard to the number of laboratories equipped to process the tests and the number of tests processed per laboratory</p>
Contact definition	There are three categories of contact with specific follow-up instructions for each. Broadly, close contacts are defined as: (a) speaking to the confirmed case for at least 15 minutes, or (b) being coughed or sneezed on at a time when the confirmed case was infectious (i.e., 2 days before symptom onset).
Contact tracing and case management process	<ol style="list-style-type: none"> Local public health unit registers a positive SARS-CoV-2 test result Contact tracing team situated within the public health unit calls the infected individual to communicate test results and inquire about any contacts that occurred in the 2 days preceding symptom onset Due to strict privacy laws, the use of digital tools to support contact tracing is not widespread; SORMAS app is used by public health units to contact exposed individuals in Berlin; Corona App (Bluetooth exposure notification app) is in development (see Appendices C and D for detail) Contacts are called by contact tracers and informed of exposure. Contacts are classified into 3 categories, depending on the nature of exposure. Recommendations vary depending on contact category, but generally, they are advised to quarantine for 14 days Contacts' symptoms are monitored through regular calls from contact tracers; if symptoms develop or worsen, individuals are advised to call a health office or a non-emergency medical service hotline to determine whether a test may be warranted If individuals are unable to leave the house, public health units or outreach teams of ambulatory physicians may dispatch a healthcare worker to perform the diagnostic test at the individual's home Some cities use "corona taxis", in which healthcare providers and medical students visit confirmed cases in their homes to monitor their symptoms, perform a medical exam, and escalate management if necessary (i.e., transfer the patient to the hospital) <ul style="list-style-type: none"> Voluntary smartwatch app "Corona Data Donation", released in early April, allows cases to record their symptoms alongside other biometrics; when aggregated at zip code level, these data may help identify "hotspots" (see Appendices C and D for detail)
Contact tracing capacity	<p>Germany's goal is to have a team of 5 contact tracers per 20,000 inhabitants (amounting to 21,000 individuals nationally).</p> <p>To meet this capacity goal, medical students, healthcare workers, and public employees from other areas of the bureaucracy have been redeployed into contact tracing teams, with additional assistance from the armed forces in the most affected areas</p>
Effectiveness of contact tracing	Germany's viral basic reproduction factor (R0) was estimated to be at 0.76 on May 5. This change may not be attributed to testing and contact tracing alone, as Germany implemented border closures and large-scale restrictions throughout early to mid-March.

ICELAND	
Date of first case	February 28, 2020
Total cases/deaths	1,801 cases / 10 deaths (total population of over 360,000)
Party responsible for testing and contact tracing	Department of Civil Protection and Emergency Management (National Commissioner of Icelandic Police) in collaboration with Directorate of Health and Chief Epidemiologist, mandated by the Minister of Health
Testing criteria	<ul style="list-style-type: none"> Those presenting with symptoms (any severity) should contact their primary care clinic or call a designated helpline to determine whether a test is warranted, based on physician judgment Healthcare workers and persons whose medical history may put them at risk of experiencing more severe symptoms are prioritized for testing
Testing capacity	<p>Daily testing: Outbreak peak (March-April): 1,000 tests per day; Current: 500 tests per day</p> <p>Total tested: 51,663 tests completed (141,931 tests per million individuals)</p> <p>Location: Tests done outside primary care clinics on a drive-through basis</p> <p>PCR test processing: 1 central lab (National University Hospital in Reykjavik, NUHI)</p> <p>Test results turnaround time: 24 hours</p>
Contact definition	Individuals that, within the 14 days preceding diagnosis, have been within 1-2 meters of: (a) a symptomatic person, or (b) a confirmed case.
Contact tracing and case management process	<ol style="list-style-type: none"> Contact tracing team within Civil Protection Dep't receives test results from NUHI Contact tracers call the infected individual to administer a questionnaire re: 14-day history before symptoms onset (dates, locations, individuals contacted) For unknown contacts, use: police records, travel records, open source info (e.g., social media), employer of the patient (if relevant/available) Voluntary app "Rakning C-19", released in early April, tracks the user's 14-day GPS history; upon COVID-19 diagnosis, user may submit these data to the contact tracing team to supplement efforts to identify unknown contacts (see Appendices C and D for detail) Contacts are instructed to quarantine for 14 days immediately Time to trace all contacts: 8 hours (March); 2 hours (May) Contacts' symptoms monitored with regular calls from the contact tracers; if symptoms develop, individuals advised to call primary care clinic or helpline to determine if test is warranted If diagnosed, individuals isolate primarily at home. Those unable to isolate safely at home may book a hotel room. Hotels also available for foreign workers and marginally housed individuals
Contact tracing capacity	<ul style="list-style-type: none"> Early March: team of 6 individuals (detectives, criminologists, healthcare workers) Current (May): 52 individuals (civil servants, healthcare workers, students)
Effectiveness of contact tracing	<ul style="list-style-type: none"> May 6: each of 1,799 cases confirmed up to that point identified as either imported or community-linked May 12: 19,694 individuals have completed a 14-day quarantine, 564 were in quarantine, 18 were in isolation, and 1 was hospitalized (no ICU). 57% of individuals eventually diagnosed with COVID-19 were already undergoing quarantine at the time of diagnosis.

ISRAEL	
Date of first case	February 21, 2020
	Total cases/deaths 16,444 cases / 245 deaths (total population of over 9 million)
Party responsible for testing and contact tracing	Testing: centralized through Magen David Adom (MDA), national EMS service (February); Testing later de-centralized through 4 national HMOs (Kupat Holim or "sick funds") Contact tracing: district-level Health Bureaus of the Ministry of Health (7 districts)
Testing criteria	Eligibility for testing is decided by physicians. Symptomatic individuals may be eligible if they: <ul style="list-style-type: none"> • Had close contact or were in the same location as a confirmed contact in the past 14 days • Have travelled to Israel from abroad in the past 14 days • Have a severe health condition Mass testing in special groups: <ol style="list-style-type: none"> a) Healthcare workers in some hospitals; b) Elderly individuals in long-term care (LTC). c) Marginalized groups (asylum seekers, foreign workers, houseless individuals, ultra-orthodox communities, Arab communities) in urban centers as recruited by NGOs, e.g., Physicians for Human Rights, Levinsky clinic (clinic for STIs)
Testing capacity	<ul style="list-style-type: none"> • Daily testing: <i>Outbreak peak (April)</i>: 10,000 tests per day; <i>Current</i>: 8,000 tests per day • Locations: Tests done at home, HMO clinics, 4 stationary units (metropolitan areas), 8 drive-through facilities (for non-quarantined individuals). MDA is staffed with 2,500 salaried workers and 24,000 volunteers. • Total tested: 245,460 individuals tested, with 96,065 in drive-through facilities, 88,272 in their homes, and 61,123 in LTC • PCR test processing: 1 lab (National Virology Laboratory at Sheba Medical Center) in early March; 17 labs in late March; further increased since HMO involvement in testing • Processing capacity increased through repurposing of existing research and hospital labs and recruiting and training lab technicians
Contact definition	Contact with individual with diagnosed COVID-19 within 2 meters of distance for at least 15 minutes.
Contact tracing and case management process	<ol style="list-style-type: none"> 1. Ministry of Health has a record of all individuals that have a COVID-19 diagnosis 2. Contact tracing teams in district-level Health Bureaus of the Ministry of Health call the infected individual to administer a questionnaire re: 14-day history (dates, locations, individuals contacted) 3. De-identified listing and map of all locations that infected individuals have visited in the past 14 days, with times, are posted publicly on the Ministry of Health website 4. As contact tracing capacity became strained with increasing number of cases, Shin Bet secret services' cellphone tracking apparatus was involved in March to notify individuals of exposure (see Appendices C and D for details) 5. Voluntary app "HaMagen", released in late March, cross-references the user's 14-day GPS history with the location history of confirmed cases and notifies users of possible exposure (see Appendices C and D for details) 6. Contacts (identified by contact tracers or self-identified) are instructed to quarantine for 14 days immediately and to submit an online report to the Ministry of Health 7. If contacts develop symptoms, they are advised to call their HMO clinic/hotline, the Ministry of Health hotline, or the MDA emergency hotline 8. The hotline operator screens the caller for epidemiological or clinical criteria consistent with COVID-19; if criteria are met, the individual is transferred to MDA's COVID-19 hotline, manned by EMS dispatchers, Ministry of Health staff, or HMO personnel 9. Contacts' symptoms monitored with regular calls; a paramedic may be dispatched to the individual's home to administer a test, if deemed warranted by a physician 10. Mid-March: all diagnosed cases isolated in hospitals, regardless of symptom severity; Current: mild cases isolate at home or in "Corona hotels" rented by the Ministry of Health. Those in LTC quarantine in designated LTC units while awaiting test results. All severe cases or those with concurrent medical issues are taken to hospitals
Contact tracing capacity	In emergency times, Health Bureaus can recruit nurses from district-level mother and child centers to aid contact tracing.
Effectiveness of contact tracing	<ul style="list-style-type: none"> • Late April to early May: daily number of new cases consistently fell below 100 and number of those recovered has surpassed the number of those actively ill • May 6: Infection rate in Jerusalem, which experienced the highest burden of COVID-19, dropped from a mid-April high of 23 cases per 10,000 people to 15 per 10,000 • These changes may not be attributed to testing and contact tracing alone, as Israel implemented border closures and large-scale restrictions throughout early to mid March

SINGAPORE	
Date of first case	January 23, 2020
	Total cases/deaths 21,707 cases / 20 deaths (total population of over 5.6 million)
Party responsible for testing and contact tracing	<ul style="list-style-type: none"> Ministry of Health responsible for testing and contact tracing, in close collaboration with hospitals, Certis security (private auxiliary police force), Singapore Police Force, and Singapore Civil Defense Force Multi-Ministry Taskforce created to manage COVID-19 oversees these processes
Testing criteria	<p>The following individuals are prioritized for testing:</p> <ol style="list-style-type: none"> Those diagnosed with pneumonia Those with symptoms of acute respiratory infection and/or: (i) history of close contact with a confirmed COVID-19 case, and/or (ii) recent travel history <p>All individuals experiencing respiratory symptoms of any severity are advised to visit a primary care physician for close monitoring; if symptoms do not resolve after 5 days, individuals may be referred for further investigation and possible testing. Singapore's 900 Public Health Preparedness Clinics (PHPCs) are the first point of contact for symptomatic persons. PHPCs are regular primary care practices whose clinicians and staff are trained in emergency outbreak protocols; this function of the clinics is activated during public health emergencies.</p> <p>Mass testing in special groups:</p> <ol style="list-style-type: none"> All 30,000 adult residential care home staff and residents (housing the elderly, houseless individuals, and those with disabilities) Residents of foreign worker dormitories. As of late April, 21,000 individuals were tested (3,000 individuals per day or 6,500 individuals per 100,000)
Testing capacity	<ul style="list-style-type: none"> Daily testing: Early April: 2,900 tests per day; Current (late April to early May): 8,000 tests per day; By June/July, test rate expected to increase to 40,000 tests per day Total tested: 2,100 per 100,000 persons tested Locations: Tests done in acute care hospitals and the National Centre for Infectious Diseases (NCID) PCR processing: tests processed in laboratories within public hospitals and the National Public Health Laboratory in NCID. The Multi-Ministry Taskforce scaled up processing capacity by repurposing private and research laboratories While awaiting test results, individuals are advised to self-isolate in their homes. Those unable to safely isolate at home are directed to Swab Isolation Facilities (repurposed hotels with 4,000 bed capacity). Those with severe symptoms or concurrent health conditions are isolated in hospitals.
Contact definition	Contact with individual with diagnosed COVID-19 within 2 meters of distance for 30 minutes or more.
Contact tracing and case management process	<ol style="list-style-type: none"> Contact tracing starts at the hospital: healthcare worker interviews the patient with COVID-19 about their history up to 14 days before symptoms (locations, dates, times, individuals contacted) An "activity map" is produced and submitted by the hospital to the Ministry of Health Contact tracing team at the Ministry of Health verifies the map by calling the patient and their family/ friends, and reviewing transport records; full activity map is charted within 24 hours of diagnosis For unknown contacts, contact tracers review the activity maps of other confirmed cases and flag linkages as "hypotheses" Hypotheses are then "proven" or "disproven" through phone interviews with the other cases and field investigations (e.g., street surveys, review of CCTV footage), which may involve engagement of the Police Force Voluntary app, "TraceTogether", released late March, records anonymized identifiers of nearby phones over 21 days via Bluetooth; upon diagnosis, user may submit these data to the contact tracing team to supplement efforts to identify unknown contacts (see Appendices C and D for detail) SafeEntry QR code check-in/check-out system added to public venues in early May to enable identification of contacts in case of an outbreak (see Appendices C and D for detail) Identified contacts are called and screened for symptoms. Those who are asymptomatic are advised to quarantine for 14 days (from the time of exposure) Symptoms and quarantine adherence are monitored via regular calls from Ministry of Health official Contacts with symptoms are treated as "suspect cases" and may be transported to hospital for testing Time to trace all contacts: 48 hours after patient diagnosis Depending on symptom severity and medical history, cases and contacts may quarantine/isolate at home or at government facilities. Only the most severe cases are admitted to hospitals
Contact tracing capacity	<ul style="list-style-type: none"> Ministry of Health epidemiologists and communicable disease experts train and supervise contact tracing teams, composed of redeployed personnel (e.g., medical residents, volunteers from other departments, Civil Defense officers)

	<ul style="list-style-type: none"> February: 5 teams of 10 contact tracers (500 individuals) Late March: 7 teams of 10 contact tracers (700 individuals) There are 3 contact tracing teams on duty during any single shift, and 2 contact tracing shifts per day April 21: To facilitate rapid triaging, case finding, and contact tracing within foreign worker dormitories, on Taskforce has deployed Forward Assurance and Support Teams (FAST Teams) Hotels, university hostels, and convention centers converted to quarantine facilities (500–10,000 bed capacity); by end of June, capacity expected increase to 20,000 beds Over 200 Certis security services officers deployed to quarantine facilities to assist with check in and check out processes and monitor adherence
Effectiveness of contact tracing	<ul style="list-style-type: none"> Contact tracing was the primary method of containment in Singapore until early April, when the number of cases began increasing due to outbreaks in foreign worker dormitories, at which point large-scale “circuit breaker” restrictions were imposed May 2: average number of new cases was 12 per day

SOUTH KOREA	
Date of first case	January 20, 2020 Total cases/deaths 10,936 cases / 258 deaths (total population of over 51.6 million)
Party responsible for testing and contact tracing	Korean Centers for Disease Control and Prevention (KCDC) within the Ministry of Health and Welfare
Testing criteria	<ul style="list-style-type: none"> Patients classified as suspected cases and Patients Under Investigation (PUI) may get testing: Suspected cases are those at high-risk of having been in close contact with a confirmed patient, who developed symptoms within 14 days of contact PUIs include those suspected to be a case due to (i) pneumonia of unknown causes, (ii) a fever or respiratory symptoms that occurred within 14 days of traveling to a country with local COVID-19 transmission, or (iii) an epidemiological link to the collective outbreak of COVID-19 in Korea and presence of symptoms
Testing capacity	<ul style="list-style-type: none"> Daily testing: <i>February</i>: 3,000 tests per day; <i>March</i>: 18,000 tests per day Total tested: 680,890 tests completed, 569 active testing centers across all 9 provinces and 55 drive-through testing facilities in 7 out of 9 provinces (May) Capacity increase attributed to the increase in diagnostic reagent companies approved by the government under emergency use authorization (5 companies approved); under the authorization, tests were distributed not only to the 18 public health labs, but also private labs (which previously needed a lengthy authorization process). By late January, nearly 200 laboratories, 600 testing centers, and numerous private clinics had access to the government-approved test kits
Contact definition	Close contact with a confirmed case, who developed symptoms within 14 days of contact.
Contact tracing and case management process	<ol style="list-style-type: none"> In cases of widespread transmission, local (rather than central) epidemiological investigation teams perform contact tracing Investigation phase: obtain information through patient, family, and physician interview to identify transmission route Risk assessment phase: the collected information is verified and supplemented by other sources (medical records, cellular GPS data, credit card transactions, CCTV footage) Contacts are classified by risk status (close vs. casual contact) Contacts are then reached by the epidemiological team, informed of their exposure, and counseled regarding next steps (self-quarantine and symptom monitoring) Through collaboration with the Ministry of Land, Infrastructure and Transport, Ministry of Science, National Police Agency, Credit Finance Association of Korea, 3 telecommunication and 22 credit card companies, the Korean Centre for Disease Control and Prevention developed a COVID-19 data platform; this system draws on real-time GPS, mobile, and credit card transaction information to perform a spatio-temporal analysis to chart the infected individual's epidemiological history. This automated “big data” approach allows to rapidly verify patient reporting and identify infection clusters. This approach reduced the 24-hour manual contact analysis to a 10-minute automated one.
Contact tracing capacity	Not discussed
Effectiveness of contact tracing	The number of new cases in South Korea stayed primarily in the single digits between mid-April and early May. Given its proximity to high-incidence settings and a lack of a widespread lockdown, the decrease in cases can likely be attributed to the country's effective testing and contact tracing practices.

TAIWAN	
Date of first case	January 21, 2020
Total cases/deaths	440 cases / 6 deaths (total population of nearly 24 million)
Party responsible for testing and contact tracing	Taiwan Centers for Disease Control (CDC) in coordination with the National Health Command Center
Testing criteria	<p>All suspected cases are tested, defined as individuals who were in close contact with a symptomatic confirmed case within 14 days prior to symptom onset, and who present one or more of the following:</p> <ul style="list-style-type: none"> • Fever ($\geq 38^{\circ}\text{C}$) or symptoms of acute respiratory tract infection • Abnormal sense of smell or taste, or diarrhea of unknown etiology • Community-acquired pneumonia highly suspected to be COVID-19 by doctors <p>High-risk groups identified for increased surveillance:</p> <ol style="list-style-type: none"> a) the elderly b) individuals with comorbidities. <p>The first point of contact and triage center for mild symptomatic cases is the network of Community Healthcare Groups Prepared Clinics (CHGPC). These clinics do not perform testing, but determine whether testing is warranted.</p>
Testing capacity	April 7: CDC announced establishment of a national testing network of 34 laboratories to expand testing capacity and reduce waiting times for test results. This resulted in a testing rate of 3,800 tests per day in different settings across Taiwan.
Contact definition	<ul style="list-style-type: none"> • Individual that had close (less than 2 meters) face-to-face contact for more than 15 minutes with a confirmed COVID-19 case before they received a diagnosis • In healthcare settings, contacts are medical staff, hospital workers, or other patients that had close contact (less than 2 meters) with a confirmed case for a longer duration than required, without protective equipment
Contact tracing and case management process	<ol style="list-style-type: none"> 1. The National Health Insurance (NHI) database was a key method of contact tracing in Taiwan. The database contains complete health history, underlying health conditions, recent progression of symptoms, treatments, and hospitalization related to respiratory syndrome 2. The NHI Cloud was enriched with patients' 14-day travel history using the Customs and Immigration data of the National Immigration Agency. All hospitals, clinics, and pharmacies in Taiwan have access to patients' travel histories 3. The NHI-based centralized Taiwan Health Cloud program generates automatic surveillance reports for infectious diseases using hospital electronic medical records
Contact tracing capacity	Not discussed
Effectiveness of contact tracing	<ul style="list-style-type: none"> • Despite its proximity to high-incidence settings and a lack of a national lockdown, Taiwan achieved the lowest incidence of COVID-19 cases per capita globally by late March • May 1: Taiwan achieved a rate of zero new cases in six consecutive days

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Appendix A: Expert Interview Guide

1. How was case/contact tracing deployed in your jurisdiction as part of the COVID-19 strategy?
 - a. Prompts:
 - i. Contact tracing methods (e.g., patient interviews, medical records, insurance billings, credit card records, media advisories)
 - ii. Level of government involvement in leading contact tracing
2. Was contact tracing seen as effective in containing the COVID-19 epidemic?
 - a. Prompts:
 - i. Why or why not?
 - ii. What criteria or key evidence determine effectiveness?
3. What other public health approaches are needed alongside contact tracing to effectively contain COVID-19 spread?
4. How was technology used to support case/contact tracing approaches?
 - a. Prompts:
 - i. What technologies were used? (e.g., GPS, Bluetooth)
 - ii. What role did technology take?
 - iii. What was the uptake of technology-based tracing?
 - iv. Were there any challenges in maintaining public support for contact tracing?
5. Were technological tools and/or the necessary infrastructure already in place or was it developed specifically to support the COVID-19 response?
 - a. Prompts:
 - i. If in place, how come? (e.g., response to prior outbreaks)
 - ii. If developed for COVID-19 response, who was tasked with developing these approaches? How long did this take?
6. What privacy concerns were considered when developing technological tools for case/contact tracing? How were they addressed?
 - a. Prompts:
 - i. How much identifying vs. anonymous information was collected?
 - ii. Were these efforts supported by any changes to legislation?
7. What resources are required to support case and contact tracing?
 - a. Prompts:
 - i. Staff capacity (e.g., hiring new personnel and/or training voluntary personnel)
 - ii. Technological capability (e.g., IT infrastructure)
 - iii. Funding/costs
8. What has been the approach to testing for COVID-19 in your jurisdiction?
 - a. Prompts:
 - i. What are the required criteria to undergo testing? (e.g., testing of symptomatic individuals, mild symptomatic or asymptomatic contacts, asymptomatic community testing, targeted/high-risk testing)
 - ii. How long did it take to scale up testing?
 - iii. How accessible was testing? (e.g., number of tests available, testing criteria, availability of physical facilities and trained personnel to perform testing, and laboratory capacity for processing of samples)
 - iv. How many tests have been done?
 - v. Level of government involvement in leading testing

Appendix B: List of Local Experts

Local Expert	Affiliation	Jurisdiction	Interview Date
Dr. Moriah Ellen <i>Senior Lecturer & Assistant Professor</i>	Department of Health Systems Management, School of Public Health, Ben-Gurion University of the Negev, Israel Institute of Health Policy, Management and Evaluation, University of Toronto, Canada	Israel	May 4, 2020
Dr. Odeya Cohen <i>Head of Master's Program in Emergency Medicine</i>	Department of Health Systems Management, School of Public Health, Ben-Gurion University of the Negev, Israel	Israel	May 4, 2020
Dr. Nadav Davidovitch <i>Director of Public Health</i>	Department of Health Systems Management, School of Public Health, Ben-Gurion University of the Negev, Israel	Israel	May 4, 2020
Ms. Ruth Waitzberg <i>Research Scholar & PhD Fellow</i>	The Smokler Center for Health Policy Research, Myers-JDC-Brookdale Institute, Israel Department of Health Systems Management, School of Public Health, Faculty of Health Sciences, Ben-Gurion University of the Negev, Israel Department of Health Care Management, Faculty of Economics & Management, Technical University Berlin, Germany	Israel & Germany	May 4, 2020
Ms. Tsung-Mei Cheng <i>Health Policy Research Analyst</i>	Woodrow Wilson School of Public & International Affairs, Princeton University, United States	Taiwan	May 4, 2020
Ms. Juliane Winkelmann <i>Research Fellow</i>	Department of Health Care Management, Faculty of Economics & Management, Technical University Berlin, Germany	Germany	May 5, 2020
Mr. Friedhelm Schnitzler <i>Senior Health Policy Advisor</i>	International Health Management Consulting, Germany	South Korea & Germany	May 5, 2020
<i>Anonymous</i>		South Korea	May 5, 2020
<i>Anonymous</i>		Singapore	May 6, 2020
<i>Anonymous</i>		Singapore	May 7, 2020
Dr. Chin Huat Jason Yap <i>Director of Public Health Translation Programme, Programme Director of the National Preventive Medicine Residency Programme & Associate Professor</i>	Saw Swee Hock School of Public Health, National University of Singapore, Singapore	Singapore	May 10, 2020
Dr. Sigurbjörg Sigurgeirsdóttir <i>Associate Professor of Public Policy and Governance</i>	Department of Political Science, University of Iceland, Iceland	Iceland	May 11, 2020
Mr. Ævar Pálmi Pálmason <i>Head of the Contact Tracing Team & Superintendent</i>	Criminal Investigations, Reykjavik Metropolitan Police, Iceland	Iceland	May 11, 2020

Appendix C: Case Studies

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Appendix C1: Germany

Setting overview and COVID-19 timeline

The first case of COVID-19 was diagnosed in Germany on January 28, 2020 in an individual who had contact with a Chinese citizen in a work meeting (74). As the number of confirmed cases increased to 7,156, and SARS-CoV-2 infections spread to the 16 federal states, the risk assessment of COVID-19 in Germany was changed to “high,” with lockdown implemented on March 17, 2020 (75). Between January 28 and May 9, 2020, there have been 168,551 confirmed COVID-19 cases and 7,369 deaths in Germany overall (for a total population of over 83 million) (4). On April 15, 2020, given the controlled number of new infections and a low mortality rate, the federal government announced its plan to carefully relax some of the lockdown measures, while extending self-isolation measures until May 3, 2020. Some schools opened on May 4, 2020 in low-risk areas. There is a plan to provide emergency day care services for some groups, including single parents that have to return to work. Large events, including religious services, will continue to be prohibited until August 31, 2020. The federal government and health authorities highly recommend wearing masks on public transport and in shops. As of April 17, 2020, the federal states started announcing their measures to ease the lockdown restrictions (76). According to a local expert, Germany’s viral basic reproduction factor (R_0) was estimated to be at 0.76 on May 5, 2020.

Testing

In Germany, the Robert Koch Institute (RKI) is the government’s central institution overseeing COVID-19 testing, case management, and contact tracing (77).

Eligibility criteria

As of April 22, 2020, laboratory testing is recommended for individuals with (i) an acute respiratory tract infection and history of close contact with a confirmed or probable COVID-19 case in the 14 days prior to symptom onset, (ii) clinical or radiologic characteristics of viral pneumonia in the context of increased number of pneumonias in care facilities or hospitals, (iii) clinical or radiologic characteristics of viral pneumonia with no indication of any other cause, and no contact with a confirmed COVID-19 case, or (iv) an acute respiratory tract infection and (a) activity in care, medical practice, or hospital, (b) a pre-existing medical condition, or (c) no known risk factors (28).

Testing capacity

To quantify the number of laboratory tests that are being performed in Germany, the RKI launched an online national survey, in which the 200 laboratories of university hospitals, research institutions, and clinical and outpatient laboratories can register the number of tests conducted. The RKI collates this information in a weekly basis (78). Testing capacity has both been increasing with the regard to the number of laboratories equipped to process the tests and the number of tests processed per laboratory. This increased testing capacity has allowed to test individuals with mild respiratory symptoms. As of the end of April, the testing capacity was 141,815 tests per day or 860,494 tests per week. By May 13, 2020, test capacity was further increased to 157,150 tests per day or 1,038,223 polymerase chain reaction (PCR) tests per week, performed by 134 laboratories. Further, by that point, a total of 3,147,771 tests had been performed in Germany, of which 197,101 were positive (28).

Testing in special groups

With the anticipated lifting of isolation measures, testing is planned to be conducted two to three times per week among healthcare providers caring for individuals with COVID-19 or working at intensive care units (ICU), geriatrics or cancer departments, as of April 20, 2020. In addition, irrespective of symptoms, all individuals visiting health facilities are recommended to be tested (28).

Asymptomatic and/or serologic testing

German residents are encouraged to immediately, irrespective of symptoms, contact their health office, get in touch with a physician, or call the non-emergency medical service, and stay at home if they have contact with a person with confirmed SARS-CoV-2 infection (28). The operator from the non-emergency medical service decides whether testing is warranted, arranges the test (if required), and discusses the next steps (16). According to key informants, individuals are unable to obtain a test unless cleared by the operator (or another healthcare worker). On-call consultations with the non-emergency medical service have increased throughout the COVID-19 pandemic in Germany (28).

On April 8, 2020, voluntary COVID-19 antibody testing has begun to be offered to healthcare providers in the Charité hospital in Berlin. On April 9, 2020, RKI announced the start of a large antibody study aimed at better assessing SARS-CoV-2 infection rates. There are three serological tests involved in this study: (1) samples of 5,000 blood donors will be examined every 14 days (early April), (2) antibody tests will be conducted in a representative sample of 2,000 people in each of four areas that have experienced large outbreaks, and (3) a representative study of 15,000 individuals will be carried out across 150 locations in Germany as of mid-May (first results expected in June 2020) (28).

Case management and contact tracing

Contact tracing and case management in Germany is overseen by the RKI, which issues guidelines and recommendations, and is implemented through the country's 375 public health units (28). These units are recognized to play a central role in community surveillance and in keeping the number of infections manageable. All individuals who have tested positive for SARS-CoV-2 are registered by the public health units. These individuals are then called by contact tracers, who inform them of their diagnosis and question them regarding their contacts in the two days preceding symptom onset, which is the time when the individual is considered to be most infectious. Contacts are then advised by the contact tracers to quarantine for 14 days, though the precise instructions vary by the contact classification (three groups, explained below). They are also instructed to monitor their health and to call a health office or the non-emergency medical service hotline to determine whether testing is warranted, should symptoms develop. Contact tracers also continue to contact these individuals by phone to inquire about changes to their symptoms. If a contact is eventually diagnosed with COVID-19, contact tracers begin tracing their chain of transmission. Currently, contact tracing in Germany has been reported to focus on disrupting the chains of infection from the confirmed case to others ("forward" tracing), rather than to identify the source of infection ("backward" tracing) (46). To enable public health units to trace all contacts, on May 5, 2020, local experts advised that the goal was to get to under 1,000 new infections per day in Germany.

Asymptomatic individuals may also self-identify if they meet exposure criteria by calling the non-emergency medical service, as discussed above. Public health units and/or outreach teams of ambulatory physicians test persons with COVID-19 symptoms at home if they are not able to leave the house or if they have had direct contact with a confirmed COVID-19 case. Tested individuals awaiting results are advised

to self-isolate (stay home, avoid contact within 2 meters, respect hand hygiene, and use a mask) in the meantime. Local initiatives in case management and outreach vary. For example, in the city of Heidelberg, healthcare providers and medical students visit diagnosed individuals at their homes, in “corona taxis”, to monitor their symptoms and take medical measurements (e.g., check oxygen levels, temperature) to determine whether they should be promptly taken to a hospital (28).

Contacts are defined as individuals that had physical contact with a person who was confirmed to be a positive case of COVID-19 within two days of this individual exhibiting symptoms. The RKI classifies contacts into three categories according to the risk of infection and provides follow-up recommendations for each category (79).

1. In category I (*higher risk of infection*), the contact with a COVID-19 case may happen one of three ways: (i) cumulative face-to-face contact for at least 15 minutes, (ii) direct contact with secretions or body fluids (particularly respiratory secretions), and (iii) health personnel in contact with the case in less than two meters without personal protective equipment (PPE). Individuals in this category are registered by name and telephone number and are informed about possible disease courses and transmission risk. These contacts should also self-isolate at home for 14 days, reduce contact with other people, and maintain hygiene measures. The health department conducts daily health surveillance of category I contacts, and requests individuals to daily register any symptoms, their body temperature (taken twice a day), general activities, and contact with other people, if any, during the self-isolation period.
2. In category II (*lower risk of infection*), the contact with a COVID-19 case may happen in either of two ways: (i) cumulative face-to-face contact for less than 15 minutes, and (ii) health personnel who were in the same room as the confirmed COVID-19 case (more than two meters apart) without the use of adequate PPE. These individuals are only requested to reduce their contact with other people and to maintain hygiene measures in and outside the household.
3. In category III (*health personnel*), the contact with a COVID-19 case may happen in either of two ways: (i) approach within two meters apart from the case, wearing adequate PPE, and (ii) approach with more than two meters apart from the case without direct exposure to secretions and aerosol. Recommendations for these individuals include improved awareness and training about PPE, immediate release from work in case of unspecific general symptoms, interviews with other employees about possible exposure to contact, and daily self-monitoring and reporting of symptoms. If the contact person, at any category of risk, manifests any symptoms within the 14 days of self-isolation, they should contact the health department immediately for further diagnostic clarification and discussion of the next steps (79).

To enable Germany’s Public Health Service (ÖGD) to have at least one contact tracing team of five people per 20,000 inhabitants (amounting to nearly 21,000 people nationally), the Minister of Health announced a personnel increase in public health offices and the use of digital tools on April 20, 2020 (46). Public employees from other areas of the bureaucracy have been transferred to help with COVID-19 contact tracing. Furthermore, soldiers and officials in the armed forces have been assigned to help in the most affected areas. The Ministry of Health is financing training for medical students to support health authorities in tracking contact persons, developing documentation, and registering data (28).

Digital contact tracing approaches

Corona App

Given the constraints of manual contact tracing, Germany has joined many other jurisdictions in expressing an interest in developing a contact tracing app that may be used to notify individuals of potential exposure. In early April, the federal government announced its collaboration in the Pan-European Privacy-Preserving Proximity Tracing Initiative (PEPP-PT), a team of more than 130 members across eight European countries, in which the RKI and the Fraunhofer Heinrich Hertz Institute in Germany are involved (80,81). PEPP-PT is an open source contact tracing protocol, using Bluetooth technology. The technology works by creating anonymous device identifiers that cannot be linked to the user's identity or personal data. The identifiers are assigned by and stored on a centralized server (hosted by the health authority), which is the only entity that can decrypt the identifiers using a private key. The proximity and duration of contact between two phones using the app is then estimated by measuring Bluetooth signals. The anonymous identifiers of the close contact surrounding phones are recorded in the encrypted proximity history stored locally on the device. The anonymous proximity history cannot be viewed by anyone, including the phone users themselves. Events in the proximity history are automatically deleted when these are older than the established epidemiological time period (14 days). If the user is eventually diagnosed with COVID-19, health authorities may contact them to request their consent to send an in-app alert to notify the users recorded in their proximity who may be at risk of exposure (81).

Although the PEPP-PT protocol has been designed to comply with privacy regulations and its open source code could be freely inspected by national cyber security and data protection agencies (81), concerns have been raised around the protocol's reliance on a centralized server (82). An alternative protocol, Decentralized Privacy-Preserving Proximity Tracing (DP-3T), has been proposed in Switzerland and subsequently favoured by Google and Apple. DP-3T is also an open source protocol for contact tracing that uses Bluetooth technology. Its distinction from PEPP-PT, however, is that it uses a decentralized approach, in which the user's device locally assigns and stores the anonymous identifiers for the devices it encounters. This means that upon diagnosis, the user's device is responsible for contact matching and sending the notification to other users. Nonetheless, the decentralized approach has also raised concerns, as United States private mobile device companies would have the control of user data, rather than German health authorities (83,84). On April 26, 2020, Germany announced its support of the decentralized approach (85). According to local experts, the app is expected to launch in June 2020.

Corona Data Donation app

The app was launched on April 7, 2020, published by the RKI and developed in collaboration with Thryve (a company specialized in digital health). The Corona Data Donation app is linked to fitness wristbands and other smartwatches to collect data about COVID-19-related symptoms. Specifically, the app collects user sex, age (five-year categories), weight (five-kilogram categories), height (five-centimeter categories), sleeping behaviour, heart rate, body temperature, and zip code (86). The app recognizes symptoms that are associated with COVID-19. The data collected allows the development of maps to illustrate the spread of potentially infected people at the zip code level. As of May 6, 2020, over 6,509,000 people have been reported to be using the app (87). As the code of the app is not available on an open source basis, some concerns have arisen related to the inability to check the app for security and data protection. Nevertheless, the RKI has declared that identifying data, such as names (uses pseudo-names) or addresses, are not being collected (82). Furthermore, the RKI has noted that both data collection and

processing are subject to strict data protection guidelines and have been checked under data protection law. Users can also view, manage, and delete their data at any time. Although the app does not alert users about potential infection with COVID-19 (not designed for contact tracing), it can be used to identify “hotspots” of COVID-19 to inform the implementation of measures and policies (88).

SORMAS

Since April 20, 2020, the public health office in one of Berlin’s districts began using the software app SORMAS ("Surveillance, Outbreak Response Management and Analysis System") to enhance contact tracing. SORMAS uses an open source code, which was developed at the Helmholtz Centre for Infection Research, in collaboration with national and international partners, as part of the response to the Ebola virus outbreak in West Africa in 2014. SORMAS is still used for contact tracing in some countries, including Nigeria and Ghana. The app is used to manage cases and contact individuals who may have been exposed to high-risk areas. SORMAS is only used by health centers, laboratories, and health authorities, and is available to them at no cost (28,89).

Appendix C2: Iceland

Setting overview and COVID-19 timeline

On the heels of the WHO declaration of the state of emergency on January 30, 2020, Iceland convened a meeting between the National Security Council, the Ministry of Health, and the Chief Epidemiologist. The Department of Civil Protection and Emergency Management Coordination Centre was subsequently evoked to handle the outbreak response, in accordance with the national pandemic preparedness plan.¹ The first imported case of COVID-19 was confirmed in Iceland on February 28, 2020. The first two community-linked cases were documented on March 6, 2020 and traced to contact with infected individuals that had recently travelled to Northern Italy. This triggered Iceland's Chief Epidemiologist and the National Commissioner of the Icelandic Police's Department of Civil Protection and Emergency Management to declare the highest level of alert (emergency phase) on March 6, 2020. On March 19, 2020, Icelandic authorities designated all countries as high-risk and all Icelandic citizens and residents returning from abroad were advised to self-quarantine for 14 days. Incremental business closures, school closures, and restrictions on public gatherings were announced between March 22 and 24, 2020 (44). As of May 9, 2020, there have been 1,801 confirmed COVID-19 diagnoses and 10 deaths in Iceland overall (for a total population of 364,134) (4). The peak of the epidemic was reached between late March and early April, and steadily decreased afterwards, with the daily number of new SARS-CoV-2 infections consistently staying in the single digits between April 19 and early May (90). On April 14, 2020, the Ministry of Health, together with the Ministry of Justice and the Prime Minister's Office, announced that starting on May 4, 2020, certain restrictive measures will be gradually lifted, with businesses, schools, and universities resuming activity (91). A mandatory 14-day quarantine for any international arrivals, introduced on April 24, 2020, remains in place until at least May 15, 2020 to reduce the risk of new imported cases (92). Overall, the focus of Iceland's strategy to containing COVID-19 has been on evidence-based public health measures, such as comprehensive testing, isolation, aggressive contact tracing, and timely quarantine, rather than larger-scale restrictions (44).

Testing

Eligibility criteria

Testing for SARS-CoV-2 began in Iceland on January 31, 2020, prior to the identification of the first imported case. This included symptomatic individuals returning from abroad and/or symptomatic individuals that have been in contact with a confirmed COVID-19 case within the 14 days preceding symptom onset (27,40). As the epidemic evolved, testing criteria were opened to symptomatic individuals, regardless of their travel or exposure history. Currently, individuals presenting with symptoms of any severity are encouraged to contact their primary care clinic or call a designated helpline to determine whether a test is warranted, based on physician judgment (19). Healthcare workers and persons whose medical history may put them at risk of experiencing more severe symptoms are prioritized for diagnostic testing (25).

¹ National plan, outlining the responsibilities of the involved government departments, the alert system, and the appropriate escalation of restrictions. The plan has most recently been updated on March 5, 2020 (see: Icelandic Pandemic Influenza Preparedness Plan. (Issue 2, 2016). Chief Epidemiologist of Iceland. Available at: https://www.landlaeknir.is/servlet/file/store93/item31657/29%209%202016_Abtract-influenza%20pandemic%20preparedness%20-%20Iceland.pdf. Last accessed: May 12, 2020).

Testing capacity

In early to mid March, Iceland's SARS-CoV-2 testing rate was approximately 400 tests per day. At the height of the outbreak from late March to mid-April, the rate increased to over 1,000 tests per day. Throughout late April and early May, the rate decreased to about 500 tests per day (93). By early May, a total of 51,663 tests have been performed, amounting to 141,931 tests per million inhabitants (50).

Sample collection for SARS-CoV-2 tests is typically performed outside primary care clinics on a drive-through basis. The collected samples are processed by one central laboratory within the Department of Microbiology at the National University Hospital (NUHI) in Reykjavik. The turnaround time for diagnostic results was reported to be about 24 hours (25). Individuals are advised to stay in home isolation while awaiting test results (19). Iceland's testing and processing capacity has been deemed to be sufficient (25).

Testing in special groups

Beyond the focus on testing symptomatic individuals, prioritization of individuals at risk of more severe symptoms (i.e., those with medical comorbidities), and healthcare workers, we did not retrieve any evidence of targeted efforts among special populations.

Asymptomatic and/or serologic testing

Although SARS-CoV-2 testing was primarily conducted among symptomatic individuals, Iceland conducted the largest study to date comparing testing in symptomatic and asymptomatic population-based samples, under the sponsorship of Iceland's biotechnology company deCODE Genetics–Amgen, in collaboration with the Directorate of Health and Landspítali University Hospital. All adult residents of Iceland who were symptom-free or had mild symptoms of the common cold, which was prevalent during this season, were eligible to register online between March 13 and April 1, 2020 to undergo population-based testing (10,797 tested). To validate this recruitment strategy, another population-based sample was recruited between April 1 to 4, 2020, through random text message invitations (2,283 individuals tested). Testing was carried out in Reykjavik. The prevalence of positive SARS-CoV-2 results in the two population-based groups was close to 1% (compared with 23% in the symptomatic group). The rate of infection remained stable over time, suggesting that public health containment efforts may have been effective (27). Although 43% of individuals did not report any symptoms at the time of testing (27), Icelandic health authorities do not currently recommend routinely testing asymptomatic individuals, as the test is more likely to return false negative results (19).

Serologic antibody testing is underway in Iceland and tests are being validated for their ability to accurately detect any evidence of immunity. Serologic testing is not widespread and Iceland's Chief Epidemiologist is asking individuals that are undergoing blood draws to donate a separate sample for this purpose. This is not considered to be a research project and patients may refuse. However, patients are unable to independently request to undergo a serologic test (19).

Case management and contact tracing

The contact tracing operation in Iceland is carried out by the Department of Civil Protection and Emergency Management within the National Commissioner of Icelandic Police, in collaboration with the Directorate of Health and the Chief Epidemiologist, as mandated by the Minister of Health (40,43). The contact tracing team, situated in the Department of Civil Protection and Emergency Management, was assembled shortly after the country was put on high alert in early March (44). At the outset, the team was

comprised of six individuals – two detectives, two criminologists, and two medical workers (nurse & psychologist). This multidisciplinary team of contact tracers was subsequently expanded to 52 individuals. Contact tracers use traditional investigative methods for reaching close contacts of diagnosed COVID-19 patients. Upon receipt of laboratory results confirming diagnosis from NUHI, contact tracers call the infected individual to administer a questionnaire, which asks in detail about the individual’s whereabouts in the 14 days preceding symptom onset, including dates, locations, and any individuals they have interacted with that may meet the definition of a close contact. If contacts are not known to the cases, additional tools used to identify possible contacts of the infected person include police records, travel records, and social media. Contacts are then phoned by the contact tracers and instructed to quarantine immediately for 14 days (45). Most recently, it has been reported that it takes approximately two hours from the time of diagnosis to identify all contacts of an infected person.

Iceland’s health authorities define close contacts as those that have been within 1-2 meters of a symptomatic individual or an individual with a confirmed SARS-CoV-2 infection. Exposure must have occurred in the 14 days preceding diagnosis. These conditions may differ for healthcare workers, who are able to mitigate their exposure risk through the use of personal protective equipment (19).

Iceland’s contact tracing efforts are widely regarded as effective. For instance, according to government communication dated May 6, 2020, each of the 1,799 cases confirmed up to that point has been identified as being either imported or community-linked (where 342 or 19% were imported and the rest were transmitted locally) (50). Further, as of May 12, 2020, a total of 19,694 individuals have completed a 14-day quarantine, 564 were still in quarantine, 18 were in isolation, and 1 was hospitalized, with none in the ICU (51). Most notably, 57% of individuals eventually diagnosed with COVID-19 were already undergoing quarantine at the time of diagnosis, suggesting that contact tracing accurately identified and limited further transmission from a significant proportion of individuals exposed to the virus (50).

Digital contact tracing approaches

Rakning C-19 smartphone app

On April 2, 2020, the Iceland government released a contact tracing smartphone app called “Rakning C-19” (44). The app was a joint venture of the Directorate of Health and the Department of Civil Protection and Emergency Management, who collaborated with software developers in Iceland (56). The Directorate of Health is the designated data controller (57). The app operates by running in the background and saving the user’s global positioning system (GPS) location several times per day. Only the location data from the past 14 days is saved, on a rolling basis, and stored locally on the smartphone device. Upon installing the app, the user provides their phone number, which is stored on secure servers hosted by Sensa², and allows the app to access the phone’s location data. No location data prior to app installation is collected or stored. If the user is eventually diagnosed with COVID-19, the contact tracing team in the Department of Civil Protection and Emergency Management may contact the user through the app to request access to Rakning C-19 data. The data will only be sent securely to the contact tracing team’s database if the user provides consent. If the user is Icelandic, they will be asked to also provide their national identification number to ascertain their identity (56,57). The location data transmitted to the contact tracing team will be deleted from the database 14 days after they were uploaded by the user (57). The app code has been

² Sensa is an information technology company based in Reykjavík, specializing in Cloud services (see Sensa website [Icelandic]. Available at: <https://sensa.is/>. Last accessed: May 12, 2020).

approved by the Icelandic Data Protection Authority. Although the code is not currently available on an open source basis, it may become so in the future.

Rakning C-19 is freely available for download on the iOS App Store and Google Play Store and operates on an opt-in basis, meaning that its installation and use are voluntary. The app was downloaded by over 120,000 individuals within the first week of its release and on May 11, 2020 (94), it was reported to have been installed by 38% of Iceland's population (58). The high uptake of the app may be, in part, explained by the messaging chosen by Icelandic officials to promote it. Specifically, official communication encouraging app use emphasizes communal thinking and the role of individuals in supporting COVID-19 containment with wording like "Join the Tracing Team!" and "Contagion is a community affair" (56). Public trust may also play a role, as Iceland's COVID-19 response is primarily being led by civil servants and scientific experts, over political leaders (44,45). Although the app data have been useful in some contact tracing investigations, the app is viewed as a supplementary tool to aid manual contact tracing, rather than replace it (58). Nonetheless, as Iceland begins to ease its restrictive measures in the coming weeks, the reliance on app data may become more salient. App use may also consequently become mandatory or more enforced, although concrete plans for this have yet to be set out.

Appendix C3: Israel

Setting overview and COVID-19 timeline

The first case of COVID-19 diagnosed in Israel was on February 21, 2020 from an individual returning from quarantine on the Diamond Princess cruise ship in Japan (95). As the number of cases climbed to 677, the Israeli government announced a national state of emergency and lockdown on March 19, 2020 (96). Between February 21 and May 9, 2020, there have been 16,444 confirmed COVID-19 cases and 245 deaths in Israel overall (for a total population of over 9 million) (4). Between late April and early May 2020, the daily number of new cases was documented to consistently fall below 100 and the number of individuals that have recovered from the disease has surpassed the number of those actively ill. Notably, the city of Jerusalem, which experienced the highest burden of COVID-19 cases, saw its infection rate drop from a mid-April high of 23 cases per 10,000 people to 15 per 10,000 on May 6, 2020 (97).

In light of early signs of COVID-19 containment, on April 19, 2020, the Israeli cabinet approved relief of some restrictions of activity, including conditional re-opening of certain schools and businesses, as well as conditional allowance of some congregational activities in limited numbers (98). Conditional re-openings of additional businesses, including in-person mental health services, restaurant take-away and delivery services, cosmetic services, national parks, malls, and gyms, among others, were announced on a rolling basis between April 25, 2020 and May 7, 2020 (99,100). Conditions for re-opening (termed “purple badge” conditions) included the wearing of facemasks, adherence to strict hygiene rules and maintenance of hand-sanitizing stations, screening of patrons for COVID-19 symptoms and measurement of their temperature, and regulation of customer entry and site occupancy. Workplaces must self-identify as meeting these conditions and must appoint an individual within their organization as the one accountable for monitoring and achieving compliance with “purple badge” requirements (101).

There is, nonetheless, an understanding that a resurgence in new infections may occur as restrictions are gradually lifted. Indeed, the Israeli government has stated that the easing of restrictions may be put on hold should the daily rate of new infections exceed 100 cases in the community or 200 in “hotspots”, should the infection doubling rate return to 10 days, or should the number of patients in serious condition reach 250 (excluding retirement homes or other areas designated as outbreak “hotspots”) (102). Currently, most restrictions are expected to be lifted by June 2020 (101).

Testing

In Israel’s initial COVID-19 response, testing, case management, and contact tracing efforts were led by Magen David Adom (MDA) – the national emergency medical services (EMS) organization (17,36,103). The MDA is staffed with 2,500 salaried workers and 24,000 volunteers. According to the local experts, the testing system has since been de-centralized and moved to Israel’s four Health Maintenance Organizations (HMOs)³ and associated clinics. Further, in anticipation of the potential second wave of infections, there is currently (end of May 2020) a new initiative in which testing, contact tracing, and case

³ Coverage for health services in Israel is supplied by four Health Maintenance Organizations (HMOs; also referred to as Kupat Holim or “sick funds” in Hebrew), which are regional semi-public insurance organizations: Clalit, Maccabi, Meuhedet, and Leumit. Healthcare in Israel is universal and Israeli residents are required to be registered with one of the four HMOs by law (see: National Insurance Institute of Israel. Registration for a Health Maintenance Organization. Available at: <https://www.btl.gov.il/English%20Homepage/Insurance/Health%20Insurance/Registration/Pages/default.aspx>. Last accessed: May 7, 2020).

management would be consolidated into a larger overarching center, reporting directly to the Director General of the Ministry of Health. This initiative has not yet been implemented and is only under discussion.

Eligibility criteria

Testing criteria have evolved as the epidemic progressed from imported to community-acquired cases. In early February, only symptomatic individuals travelling from China, and later, Italy, were tested, with some tests administered by MDA at the airports. Currently, symptomatic individuals are eligible for COVID-19 testing if they had close contact or were in the same location as a confirmed case, if they have travelled to Israel from abroad in the past 14 days, or if they have a severe health condition (36).

Testing capacity

To expand case management and testing capacity, on March 17, 2020, the MDA established four stationary testing centers in major metropolitan areas, as well as eight drive-through testing centers. Non-quarantined individuals were directed to these centers to undergo testing. These centers used QR codes to identify patients and manage flow (17). According to the MDA data reported on May 5, 2020, a total of 245,460 Israelis have been sampled by MDA teams, with 96,065 individuals tested at drive-through facilities, 88,272 tested in their homes, and 61,123 tested in LTC (18). Between April 1 and May 7, 2020, Israel was reported to perform an average of 8,000-10,000 diagnostic tests per day (104).

Only one lab (the National Virology Laboratory at Sheba Medical Center) was equipped to perform PCR analyses to process COVID-19 diagnostic tests at the outset of the outbreak. The Ministry of Health has since sought to expand testing capacity by purchasing new devices, repurposing existing research and hospital laboratories, and recruiting and training laboratory technicians. There were 17 laboratories authorized by the Ministry of Health to process COVID-19 diagnostic tests as of March 17 (36). According to the local experts, this number has been exceeded further in May 2020, due to the involvement of Israel's four HMOs in overseeing the testing system.

Testing in special groups

Some hospitals have been reported to periodically test their staff (36). Previously, it has been noted that testing rates among marginalized groups, particularly migrant populations, have been considerably low due to a lack of insurance coverage, fear of losing employment, and, among undocumented individuals, fear that their status will be disclosed to immigration authorities (36). As such, the Sourasky Medical Center (Ichilov Hospital) in south Tel Aviv implemented a special testing point for hard-to-reach populations between early April and May 6, 2020. According to recent reporting, 332 asylum seekers, foreign workers, and houseless individuals were tested there for SARS-CoV-2. The SARS-CoV-2 infection rate among these populations was found to be similar to that in the Israeli population at large (with approximately 3% testing positive), suggesting that there has been no COVID-19 outbreak among these selected marginalized groups in Tel Aviv (37). Non-governmental organizations, such as Physicians for Human Rights and the Levinsky clinic (clinic for sexually transmitted infections), were involved in recruiting from hard-to-reach groups. According to local experts, other hard-to-reach populations targeted by these special efforts have included Arab populations and ultra-orthodox communities.

In addition, according to local experts, after the initial announcement of Israel's forthcoming exit strategy, the Ministry of Health stated that all children in schools and all individuals visiting Israel's health plans' clinics would be systematically tested for SARS-CoV-2. However, it is unclear whether this measure has

been, or is in the process of, being implemented. Finally, the move of the testing system to the HMOs has made testing more available for institutionalized elderly and healthcare workers.

Asymptomatic and/or serologic testing

In advance of lifting of large-scale public health restrictions, Israel's Ministry of Health announced on May 5, 2020 that it is planning to survey 100,000 healthy and asymptomatic Israelis for SARS-CoV-2 antibodies using serological blood tests, in order to determine the community prevalence of SARS-CoV-2 immunity. This will be the largest study of its kind and the findings will give an indication of the possible size of the second wave of SARS-CoV-2 infections in Israel and inform planning. Researchers suggest that should a second wave of infections occur, a 10% prevalence of immunity to the virus may result in 2,300 individuals needing intensive care, which is well within Israel's health system capacity. However, a prevalence of 1% may result in 12,000 people needing intensive care, which significantly exceeds health system capacity. Israel obtained 2.4 million antibody tests from suppliers from the United States and Italy, at the cost of nearly \$40 million. Testing will be conducted at clinics run by Israel's HMOs (105).

Case management and contact tracing

Israel's response centered on prevention even before its first case was identified. Following WHO's January 30, 2020 announcement regarding the public health threat of COVID-19, Israel summoned its epidemiological investigation team (known by the acronym "Tsatam" in Hebrew), which began assembling information, coming up with case definitions, and writing protocols for handling cases when they emerge. The country also used an "all hands on deck" approach, engaging the Ministry of Defense and the Ministry of Foreign Affairs to handle the epidemic domestically and abroad. As Israeli nationals began returning from the known outbreak clusters abroad, such as the Princess Diamond ship in Japan, they were put into mandatory quarantine for 14 days immediately following their arrival in Israel.

The National Medical Emergency Dispatch Center (NMEDC) oversees MDA dispatch. In late January 2020, the Ministry of Health instructed the MDA to prepare to respond to possible cases of SARS-CoV-2 infection. On February 23, 2020, the MDA expanded NMEDC to establish a specialized COVID-19 call center, manned by EMS dispatchers and representatives from the Ministry of Health. The MDA-run COVID-19 call center has been reported to receive an average of 6,000 calls per day, with 120,000 calls per day at the height of the outbreak (17,106). Individuals who contacted NMEDC and met the epidemiological or clinical criteria for COVID-19 were transferred to the COVID-19 call center.

The epidemiological investigation teams in each district's Health Bureau (there are seven districts in Israel overall)⁴ perform manual contact tracing. Health Bureaus are considered to be local extensions of the Ministry of Health, responsible for local implementation of public health policies and protocols. Upon receipt of laboratory test results, members of the epidemiological investigation team at the Health Bureau call the confirmed cases to obtain their 14-day history. Potential contacts are then called by the team and instructed to quarantine for 14 days. Contacts receive frequent calls from contact tracers or MDA paramedics to monitor symptoms. If contacts develop symptoms, they are advised to call their HMO clinic, HMO hotline, or the 101 MDA Emergency Services hotline to inquire whether testing may be appropriate. If the symptoms resemble COVID-19, a physician would decide whether to dispatch a paramedic to the

⁴ See: State of Israel Ministry of Health (2020). Health Bureaus. Available at: <https://www.health.gov.il/English/MinistryUnits/LB/Pages/default.aspx>. Last accessed: May 20, 2020

individual's home to test them for SARS-CoV-2 (17).

Self-identification of exposure is possible due to the Ministry of Health's webpage, providing a searchable de-identified listing and map of all locations that individuals with confirmed diagnoses have visited in the past 14 days, including visit dates and time-windows.⁵ These listings are updated everyday. Each announcement is accompanied by instructions to enter home quarantine and send an online report to the Ministry (using a linked template form) for any persons that have visited the specified locations at the identified times. Individuals also have the option to call the centralized Ministry of Health hotline or the hotline for one of Israel's four HMOs, in place of the online form.

Until mid-March 2020, all diagnosed COVID-19 cases were taken to hospitals for isolation, regardless of disease severity. As of the end of March 2020, those with mild cases could choose to isolate at home or in designated hotels that were temporarily rented by the Ministry of Health to service COVID-19 isolation. In case of bed shortages, mild cases were instructed to self-isolate at home, with regular follow-up from healthcare providers. Long-term care (LTC) residents presenting with COVID-19 symptoms were immediately tested and moved to quarantine in designated COVID-19 units within the LTC facility until diagnostic confirmation. Positive cases with severe concurrent medical issues were transferred to hospitals, while mild cases were transferred to designated hotels, similar to cases diagnosed outside of LTCs. All COVID-19 patient transfers were performed using dedicated negative-pressure hooded beds (17,103,107).

Digital contact tracing approaches

Shin Bet security service cellphone tracking

On March 15, 2020, bypassing parliamentary approval, the Israeli government enacted emergency measures to allow the Shin Bet, Israel's security agency (also known by the acronym Shabak), to repurpose its mass surveillance protocols for COVID-19 contact tracing (108,109). This program involves using cellphone location records and other digital information available to the Shin Bet, such as credit card data, to identify individuals that have been within two meters, for 10 minutes or more, of confirmed COVID-19 cases in the 14 days prior to that case's diagnosis (110). Contacts are then notified of potential exposure and instructed to self-quarantine via an SMS message sent to their phone (111).

This measure has been highly criticized by civil rights groups, as all civilians with cellphones are subject to the program without the ability to opt out. Following a number of petitions from advocacy organizations, including the Israeli Public Health Physicians Association, Israel's High Court of Justice announced that Shin Bet's surveillance program would be frozen on March 21, 2020, unless the government sought parliamentary (the Knesset) oversight. In addition, the Attorney General's restrictions placed on the Shin Bet, such as ensuring that collected surveillance data were transferred directly to the Ministry of Health and not stored, became binding by court order (112). On April 26, 2020, the Court ruled that the Shin Bet's surveillance program would only be extended further if a formal legislative process was initiated. The eventual legislation would also have to "allow journalists the right to protect their sources by preventing their cell phone data from being handed over to the Shin Bet," with exceptions reviewed on a case-by-case basis (113). On May 5, 2020, the Shin Bet surveillance program was extended by a parliamentary panel until May 26, 2020. The proposed legislation is expected to become available for public comment

⁵ See: State of Israel Ministry of Health (2020). Locating corona virus exposure sites. Available at: <https://coronaupdates.health.gov.il/corona-updates/grid/place>. Last accessed: May 20, 2020.

within two weeks of the extension approval, after which it will be submitted to the parliament. According to the most recent data submitted to the parliament, Shin Bet's surveillance program has detected over 5,500 (34%) of Israel's total COVID-19 cases (59).

HaMagen smartphone app

On March 22, 2020, Israel's Ministry of Health launched a contact tracing smartphone app called "HaMagen" (Hebrew for "The Shield") (54,55). HaMagen aims to identify "contacts between diagnosed patients and people who came in contact with them in the 14 days prior to the patient's diagnosis of the disease," (55). The app operates by using the smartphone owner's 14-day GPS history and comparing it to the epidemiological history of confirmed COVID-19 patients available in the Ministry of Health records. If the app user was found to have frequented the same location as a confirmed case within the same time window, they are considered to be a contact and are sent an alert with instructions to quarantine at home and to contact the Ministry. As GPS works best outside, there have been concerns regarding the app's precision in measuring distances and therefore, determining contacts (8). As such, users that received an alert of potential exposure are encouraged to cross-reference this information with the Ministry of Health website or to call the Ministry hotline.

If the user is diagnosed with COVID-19, HaMagen also allows them to retrace their movement in the 14 days leading up to their diagnosis (including locations, dates, and times). With the user's permission, this information is then used by the Ministry of Health to notify individuals that may have been the user's contacts (114). Upon installing the app, the user must give the app permission to use their smartphone's GPS history and wireless networks. GPS data collection begins at the time of installation, unless the user also permits HaMagen to sync with their Google location tracing information, which may provide the user's location history in the 14 days prior to app installation (if Google GPS history has been on). The user GPS information is only stored in the internal memory of their smartphone and not relayed to the Ministry of Health servers or other entities for storage (114). The app regularly cross-references the user's locations to those reported from the Ministry of Health's cloud record of COVID-19 cases, which ensures unilateral movement comparisons within the device (115). Internet access (cellular or WiFi) is required to download and compare the Ministry of Health files.

HaMagen was developed in Israel under the direction of the Ministry of Health by private partners, including the Tel Aviv-based technology start-up, GlobeKeeper.⁶ Developers used an open source code to create the app (54). HaMagen has been tested by staff from the Israel National Cyber Directorate, security specialists from the commercial and civil sectors and passed architectural checks, code reviews, and PT (breach checks) (116). HaMagen is freely available for download on the iOS App Store and Google Play Store and operates on an opt-in basis, meaning that its installation and use are voluntary. On April 1, 2020, it was reported that an estimated of 1.5 million Israeli residents have downloaded the app, amounting to about 17% of the total population. To improve uptake and location accuracy, at the time of writing, a new version was expected to launch in May to improve uptake and location accuracy through Bluetooth capabilities. The new version aimed to reach at least four million users (44% population coverage) (59).

⁶ This technology company is known for developing secure strategic and tactical communication protocols for law enforcement, military, government, first responder, and other agencies, including a "virtual command platform," which "replaces walkie-talkies with smart phones using their capabilities like GPS, Bluetooth and WiFi to measure distances between objects in real-time," (54) (see: GlobeKeeper website. Available at: <https://www.globekeeper.com/>. Last accessed: May 6, 2020).

Appendix C4: Singapore

Setting overview and COVID-19 timeline

Singapore confirmed its first imported COVID-19 case on January 23, 2020 in an individual travelling from Wuhan, China (41). On the same day, the Singapore government set up a Multi-Ministry Taskforce to direct a whole-of-government response to ramp up preventive measures and contain the virus (41). First cases of community transmission were identified on February 4, 2020 among individuals that have been in close contact with travellers from China (117). Between January 23 and May 9, 2020, there were 21,707 confirmed COVID-19 cases and 20 deaths in Singapore overall (for a total population of over 5.6 million) (4). Given Singapore's robust existing public health infrastructure – a legacy of prior pandemics⁷ – the country's overall approach to containing COVID-19 has focused on aggressive contact tracing and quarantine, rather than large-scale restrictions. This approach appeared to be effective in containing community spread until early April 2020, when a surge of cases was documented in foreign worker dormitories. On April 5, 2020, the Ministry of Health designated foreign worker dormitories as isolation areas (13) and on April 7, 2020, the Singapore parliament passed the COVID (Temporary Measures) Act, which included large-scale "circuit breaker" measures, such as closures of workplaces, greater monitoring of adherence to physical distancing, and imposing of entry restrictions on outbreak "hotspots" (29–31). These measures were renewed by the Multi-Ministry Taskforce on April 21, 2020 (30,33). On May 2, 2020, the Multi-Ministry Taskforce announced that the circuit breaker period will end on June 1, 2020, after which, Singapore will begin to gradually resume economic activity (48,118). In the first week of the circuit breaker period (April 7-13, 2020), there was an average of 40 new cases per day (33), while in the week preceding May 2, 2020, the number of new cases dropped to an average of 12 per day (48).

Testing

In Singapore, testing and contact tracing are overseen by the Ministry of Health. Testing is performed in acute care hospitals and the National Centre for Infectious Diseases (NCID).

Eligibility criteria

Individuals diagnosed with pneumonia or those with symptoms of acute respiratory infection and: (i) history of close contact with a confirmed COVID-19 case, and/or (ii) recent travel history, may be eligible to undergo SARS-CoV-2 testing, upon physician recommendation. All individuals experiencing respiratory symptoms of any severity are advised to visit a primary care physician for close monitoring – if symptoms do not resolve after five days, these individuals may be referred for further investigation and possible SARS-CoV-2 testing, which is administered free of charge (32).

Testing capacity

In early April, the SARS-CoV-2 testing rate in Singapore was 2,900 tests per day. PCR processing of samples was primarily performed in laboratories within public hospitals. The Multi-Ministry Taskforce scaled up processing capacity by repurposing private and research laboratories. As of late April, the testing rate has

⁷ Singapore's Ministry of Health has devised a pandemic response plan as a result of the country's experiences with the 2003 SARS-CoV-1 and 2009 H1N1 outbreaks (see: Ministry of Health Singapore [2014, April]. MoH Pandemic Readiness and Response Plan for Influenza and Other Acute Respiratory Diseases. Available at: <https://www.moh.gov.sg/diseases-updates/being-prepared-for-a-pandemic>. Last accessed: May 11, 2020).

increased to an average of 8,000 tests per day, with a total of about 2,100 per 100,000 persons tested (32). Experts report that the testing rate is expected to further increase to 40,000 tests per day by June or July 2020. While awaiting test results, individuals are advised to self-isolate in their homes. Those unable to safely do so are directed to Swab Isolation Facilities, which include temporarily repurposed hotels with a current capacity of 4,000 beds. Those with severe symptoms or concurrent health conditions are immediately referred to hospitals (53).

Testing in special groups

The Multi-Ministry Taskforce announced that the Ministry of Health, the Ministry of Social and Family Development, and the Agency for Integrated Care will perform SARS-CoV-2 testing among all 30,000 residential care home staff and residents (including nursing homes, welfare homes, sheltered homes, and adult disability homes) between April 29–May 2, 2020 (34,35). Prior to this announcement, testing was done only in symptomatic residents and staff. The Taskforce also announced that to further reduce the risk of exposure, staff would be moved to designated on-site accommodation facilities or hotels for the duration of the circuit breaker period (34). In the Ministry of Health May 8, 2020 announcement, 3,000 staff were reported to be in the process of moving (35). The testing of all nursing home staff was completed by May 8, 2020, with all but one individual testing negative. All residents cared for by that staff have tested negative and have been quarantined. The testing of both staff and residents in all other types of residential care homes was completed by May 8, 2020, with no positive results (although some test results are still pending) (35). Following this one-time test, all staff and residents will continue to be tested periodically, at two-week intervals. Symptomatic individuals will be tested immediately (35).

A similar comprehensive testing approach has been undertaken in foreign worker dormitories. In its April 27, 2020 announcement, the Ministry of Health noted that nearly 3,000 migrant workers living in the dormitories have been tested on a daily basis, amounting to a total of over 21,000 individuals (i.e., testing rate of 6,500 per 100,000). Dormitories with higher documented infection rates have been prioritized and experts have expressed concerns regarding the Ministry's capacity to scale up testing to all dormitories. Migrant workers presenting with acute respiratory infection symptoms are isolated and tested immediately, along with their roommates (32). To facilitate rapid triaging, case finding, and contact tracing within the dormitories, on April 21, 2020, the Taskforce has deployed Forward Assurance and Support Teams (FAST Teams) to support the dormitories (33).

Asymptomatic and/or serologic testing

Due to temporary lockdown measures and low incidence of new cases in the general population, community-based asymptomatic testing is considered to be of lower priority compared to mass testing of high-risk groups, such as those in residential care settings and migrant worker dormitories. Extensive contact tracing (described in detail below), is currently the primary means for containing the infection in the community (119).

Case management and contact tracing

On February 14, 2020, shortly after the first community cases were documented, the Ministry of Health announced gradual re-activation of the country's 900 Public Health Preparedness Clinics (PHPCs) (13). These clinics were established during the 2003 SARS-CoV-1 outbreak and were subsequently activated

during the 2009 H1N1 epidemic and the haze events.⁸ PHPCs were designated to be the first point of contact for individuals with respiratory symptoms. Consultation and treatment fees at PHPCs are subsidized, with Singapore citizens and permanent residents paying \$5–10 out-of-pocket. Patients may also obtain a five-day sick leave from the clinic doctors; if symptoms do not resolve within five days, patients are advised to return to the clinics for further investigation (11,12). At that point, physicians may determine that SARS-CoV-2 testing is necessary and refer the individual to an acute care hospital or NCID for testing and management. The PHPC infrastructure allowed to closely monitor and triage potential cases of mild infection in the community, while offloading case management from hospitals and preventing hospital-acquired infections (120). During peace times, PHPCs function as regular primary care clinics and polyclinics and their clinicians and staff undergo periodic Ministry of Health training to stay up-to-date with emergency outbreak protocols (14).

At the outset of the epidemic, all patients with COVID-19 were taken to the NCID – a 330-bed facility specifically designed to handle large-scale infectious disease outbreaks, with the largest number of isolation rooms among Singapore hospitals and the embedded National Public Health Laboratory, which processes the swab samples collected during SARS-CoV-2 testing. As the number of cases increased throughout February 2020, NCID collaborated with other public hospitals to accommodate more severe COVID-19 cases and transfer out patients admitted for reasons other than COVID-19 (121).

The Ministry of Health oversees the contact tracing operation in Singapore, in close collaboration with hospitals, Certis security officers⁹, the Singapore Police Force, and the Singapore Civil Defence Force. Contact tracing starts at the hospital, when an individual is admitted with a confirmed COVID-19 infection. A healthcare worker caring for the patient typically interviews the patient shortly after their diagnosis regarding their movement history (including locations, dates, and time-windows) and any individuals they had close contact with up to 14 days prior to symptom onset. Close physical contact is defined as being within two meters of the infected person for 30 minutes or more. This information is used to produce a detailed “activity map”, which is then submitted by the hospital to the Ministry of Health (42).

The Ministry of Health epidemiologists and communicable disease experts train and supervise contact tracing teams, composed of redeployed personnel (e.g., medical residents, volunteers from other Ministry departments, and Civil Defense officers). There were fifty teams of 10 trained contact tracers in February, at the outset of the epidemic. By late March, the number of teams increased to seventy (700 contact tracers in total). There are three contact tracing teams on duty during any single shift, and there are two contact tracing shifts per day (42). Broadly, contact tracers aim to perform both “forward” (i.e., who the index patient may have infected) and “backward” (i.e., who the index patient may have been infected by) tracing.

⁸ Large-scale air pollution due to forest fires in the neighbouring regions of Singapore, such as Indonesia, brought about by winds (see: The Straits Times (2019, September 16). Hazy one moment, clear the next: haze in Singapore is at mercy of the winds. Available at: <https://www.straitstimes.com/singapore/environment/hazy-one-moment-clear-the-next-when-will-singapore-experience-haze>. Last accessed: June 1, 2020).

⁹ The largest private auxiliary police force (over 6,000 employees), authorized to provide armed security services to individuals and governmental/non-governmental actors in Singapore. The group originated as a guard and escort unit under the Singapore Police Force and was turned into a statutory board, named Commercial & Industrial Security Corporation (CISCO), in 1972 (see: AsiaOne News (2007, September 13). CISCO renamed Certis CISCO. Available at: <https://www.asiaone.com/News/AsiaOne+News/Singapore/Story/A1Story20070913-25338.html>. Last accessed: May 11, 2020).

Contact tracers verify the provided activity map by phoning the patient, the patient’s family and friends, and by reviewing transport and airline records; the full activity map is charted within 24 hours of patient diagnosis. Contact tracers then proceed to phone the identified contacts and screen them for symptoms (within 48 hours of the index patient’s diagnosis). If the contact is not experiencing any symptoms, they are advised to quarantine for 14 days, starting from exposure (time of contact with the infected individual), either at a government facility or at home. A number of hotels, university hostels, and convention centers have been temporarily converted for quarantine purposes, with capacities of 500–10,000 beds. By the end of June, capacity is expected to be further increased to 20,000 beds (53). Over 200 Certis officers have been deployed to these facilities to assist with check-in and check-out processes and monitor adherence. Individuals quarantined at home receive regular phone checks from a Ministry of Health official to monitor their adherence to quarantine orders and any changes in their symptoms. Contacts with symptoms are treated as “suspect cases” and are transported via a designated ambulance to COVID-19 hospital wards, where they are tested for the virus (42). Depending on the severity of symptoms and patient history, patients may remain in the hospital, be admitted to the Intensive Care Unit (ICU), or be discharged to lower-level facilities for isolation, treatment, and recovery (e.g., variously named Community Care Facilities, Community Isolation Facilities, or Community Recovery Facilities) (53).

To identify individuals that could not be reached, contact tracers review the activity maps of confirmed cases and flag any linkages as “hypotheses.” These hypotheses are then “proven” or “disproven” through phone interviews with confirmed cases and field investigations, which may include street surveys and frame-by-frame reviews of closed-circuit television (CCTV) footage from public areas. The Singapore Police Force has a designated unit that keeps regular contact with contact tracers at the Ministry of Health. The Police Force supports contact tracing by, for example, providing access to their own databases and tools, such as CCTV cameras (42).

Digital contact tracing approaches

TraceTogether smartphone app

On March 20, 2020, Singapore’s Ministry of Health launched the contact tracing smartphone app called “TraceTogether” (64,122). TraceTogether operates by using wireless Bluetooth technology to measure proximity and duration of an encounter between two smartphones over time. Specifically, the app uses Bluetooth Relative Signal Strength Indicator (RSSI) to infer proximity and successive communications to infer duration (60,61). Upon installing the app, the user submits their mobile number to the Ministry of Health’s secure server. Using its private key, the server generates a temporary unique ID, which is periodically refreshed, for each submitted phone number (62,63). When near another TraceTogether user, the smartphones exchange their anonymized temporary IDs, which are then stored locally (on each smartphone) for 21 days on a rolling basis, along with the estimated proximity and duration of the encounter. To detect each other, both smartphones must have the TraceTogether app downloaded and Bluetooth must be enabled. The app does not collect any geolocation information and does not relay any data externally, without the user’s permission (60).

If an individual is eventually diagnosed with COVID-19, contact tracers would request their consent to access their TraceTogether Bluetooth data. These data would then be decrypted by the Ministry of Health using their private key to reveal the phone numbers associated with the stored temporary IDs of the devices whose proximity and duration information matches the definition of close contact. Contact tracers would then call these numbers and follow the usual contact tracing protocol, detailed above (62,63).

TraceTogether is described as a “mobile application developed to support existing nationwide efforts to combat COVID-19, by enabling community-driven contact tracing,” (123). It is therefore viewed as a supplementary approach to manual contact tracing, rather than as its replacement. TraceTogether may be particularly useful when the confirmed case does not personally know every individual they have been in close and extended contact with (64,65).

TraceTogether was developed by the Government Digital Services team at the Government Technology Agency of Singapore (GovTech)¹⁰, in collaboration with the Ministry of Health. The app was built on the open-source BlueTrace protocol, which is accessible on the global software development website, GitHub (124). TraceTogether is freely available for download on the iOS App Store and Google Play Store and operates on an opt-in basis, meaning that its installation and use are voluntary. In late March, it was reported that about 13% of Singapore’s population have downloaded the TraceTogether app (66). Presently (May 2020), the app has been installed by 20% of the population, according to the local experts. Low uptake may be, in part, explained by accounts of poor functionality of TraceTogether on the iOS interface, as the app cannot run in the background and drains the smartphone’s battery rapidly (67). Although Bluetooth is considered to be a less invasive approach to contact tracing than approaches using GPS or cellphone data, privacy concerns persist among the public (67). In addition, despite high penetrance of smartphones among Singaporeans, the app may be challenging to use for individuals that are less tech-savvy, such as the elderly. Finally, though Bluetooth has been reported to work well both indoors and outdoors, not all phones may be equipped with Bluetooth capabilities (8).

SafeEntry system

On May 9, 2020, the Ministry of Health announced that all businesses and services that have resumed economic activity should implement the SafeEntry system by May 12, 2020 (125). SafeEntry was developed and is overseen by Singapore’s GovTech (126,127). It is described as a “national digital check-in and check-out system that logs the names, NRIC/FINs¹¹ and mobile numbers of individuals visiting hotspots, workplaces of essential services, as well as selected public venues to facilitate contact tracing efforts” (128). Specifically, SafeEntry operates by having visitors either scan the QR code displayed at the venue entry/exit points using their smartphone or by having the venue staff scan the visitors’ identification cards that have a barcode (e.g., NRIC, driver’s licence, student pass, work permit) (128). By recording the dates of visit, time-windows of visit, and visitor identities in high-density public areas, SafeEntry is anticipated to help supplement manual contact tracing efforts in case of an outbreak, particularly given the forthcoming easing of circuit breaker measures (126). This system is mandatory for all venues in which individuals would be in close proximity with one another for a prolonged period of time or in enclosed and/or high-traffic spaces. As of May 9, 2020, there were 16,000 venues in which SafeEntry has already been deployed (125). It is expected that SafeEntry will be rolled out in offices and factories, schools, healthcare facilities, community care facilities, supermarkets, malls, hotels, and taxis, among other spaces (126).

¹⁰ GovTech is a Singapore government agency that develops technology-driven approaches to governance. The agency was created by the Smart Nation and Digital Government Group (SNDGG), situated in the Prime Minister’s Office, as part of Singapore’s Smart Nation initiative (see: GovTech Singapore website. Available at: <https://www.tech.gov.sg/who-we-are/our-role/>. Last accessed: May 10, 2020).

¹¹ Personnel identifiers used by the Singapore Payroll System, where National Registration Identification Card (NRIC) is used among Singapore citizens and Foreign Identification Number (FIN) is used among permanent residents of Singapore.

Appendix C5: South Korea

Setting overview and COVID-19 timeline

The first case was reported in South Korea on January 20, 2020. The country declared the “highest” level of disease alert on February 23, 2020 upon a sudden increase of new cases caused by an outbreak at a religious gathering that accounted for 73% of the total domestic cases as of March 1, 2020 (52). However, the number of daily cases started declining after 909 cases reported on February 29, 2020. As of May 11, 2020, there have been 10,936 confirmed cases with a total of 258 deaths (for a total population of over 51.6 million), and 1,008 individuals in either hospitalization or quarantine; there was a weekly average of 19 new cases from May 6 to May 12 (68). The heightened sense of alertness towards infectious diseases had been instilled in Koreans following the Middle East Respiratory Syndrome (MERS) outbreak in 2015, which lacked robust health security measures (20,129). This led to legislative measures¹² and administrative restructuring¹³; both proving to be instrumental in the timely COVID-19 response of the current government and its ability to utilize technology for contact tracing and testing (20).

Testing

The Ministry of Health and Welfare (MOHW) plays a central role in health system policy planning and implementation. Korean Centers for Disease Control and Prevention (KCDC) is a specialized body of MOHW. The subnational governments are given the decentralized managerial autonomy of public health facilities. Testing quality of each center is maintained by quality assurance by KCDC and academic experts (KCDC).

According to an informant, all district-level public health clinics turned into the local testing centers within a week following the central announcement. The existing health workers were assigned new roles as testing officers and external medical volunteers were recruited to provide additional support at the testing centers. Staff from the district government office filled the need for additional non-medical human resources. The MOH and KCDC issued training guidelines, now in their 17th version, which have been implemented by local governments. Fast compliance of the local governments to the central decision was crucial in the re-purposing of the health facilities and staff to respond with enough testing capacity.

Eligibility Criteria

As per KCDC guidelines, patients classified as suspected cases and Patients Under Investigation (PUI) may get testing (21). Suspected cases refer to individuals identified as high-risk of having been in close contact with a confirmed patient and have developed symptoms within 14 days of coming into contact with a confirmed patient (22). PUIs include individuals who are suspected to be a case as per doctor’s diagnosis due to pneumonia of unknown causes, who develop a fever or other respiratory symptoms within 14 days of traveling to a country with local COVID-19 transmission, and a person with an epidemiological link to the collective outbreak of COVID-19 in Korea and develops symptoms (130). All symptomatic passengers

¹² Namely, the *Infectious Disease Control and Prevention Act* (IDCPA) and Emergency Use Authorization (EUA).

¹³ Administrative restructuring was of central disaster and safety countermeasures of MOHW with Ministry of the Interior and Safety (MOIS) alongside the central disease control of KCDC and its nationwide local government task forces (20).

from abroad must get diagnostic testing at the airport (130,131). Post-mortem tests are conducted if the deceased had pneumonia or possible epidemiological links with a confirmed case (22).

Testing capacity

As of May 21, there were 592 testing centers across the country covering all nine provinces (132), 96% (n = 569) of which are equipped to collect samples (133). There were 55 drive-through testing centers in 7 out of 9 provinces (134). As of May 11, a total of 680,890 diagnostic tests had been done: 653,624 (96.0%) were negative, 10,936 (1.6%) were positive, and 16,330 (2.4%) were pending results (68). The test takes about six hours but tested individuals usually get results 1-2 days following the test (130). Walk-in stations consist of a single booth to separate the patient and provider, either in a negative pressure booth (patients inside) or positive pressure booth (providers inside) (21). Sample collection takes 10 minutes in the negative pressure booth due to cleaning and sterilizing measures, but only takes one minute in the positive pressure booth (21). However, at the time of interview, a local expert stated that the government had not endorsed the walk-in model due to hygiene reasons although these centers were found at private clinics.

There are 5 diagnostic reagent companies that have been approved by the government under emergency use authorization (EUA)¹⁴: KogeneBiotech, Seegene, Solgent, SD Biosensor, and Biosewoom (20). As more companies were approved in mid-February, the maximum number of tests per day increased six-fold in about one month from approximately 3,000 in early-February to 18,000 as of mid-March (22). According to a local expert, once the test kits made by the industry partner were approved, they were distributed not only to all 18 public health laboratories but also to the private laboratories that previously required a lengthy authorization process – this step was bypassed under EUA; by late-January, almost 200 laboratories, 600 testing centers, and numerous private clinics had access to the government-approved test kits.

Asymptomatic and/or serologic testing

Some asymptomatic incoming passengers will receive diagnostic testing at the airport or within a certain time period of their arrival. In every case, self-quarantine for 14-days and the installation of an appropriate app is required. Table 1 outlines the procedures for all incoming asymptomatic passengers (130,131).

¹⁴ Under the EUA, the CDC director holds the authority to operationalize the fast-track approval of the supply chains from resource mobilization, manufacturing to mass distribution.

Table 1. Procedures for incoming asymptomatic passengers (as of April 13, 2020)

Incoming Passengers		Procedure
Koreans	Europe or US	<ul style="list-style-type: none"> Self-quarantine for 14-days, install the Self-Quarantine Safety Protection App Diagnostic testing at a health center within three days upon arrival
	other than Europe or US	<ul style="list-style-type: none"> Self-quarantine for 14-days, install the Self-Quarantine Safety Protection App Diagnostic test if any symptom appears
Foreign Nationals (Long-term)	Europe	<ul style="list-style-type: none"> Diagnostic test at airport; Self-quarantine for 14-days, install the Self-Quarantine Safety Protection App
	US	<ul style="list-style-type: none"> Self-quarantine for 14-days, install the Self-Quarantine Safety Protection App Diagnostic test within three days upon arrival
	other than Europe or US	<ul style="list-style-type: none"> Self-quarantine for 14-days, install the Self-Quarantine Safety Protection App Diagnostic test if any symptom appears
Foreign Nationals (Short-term)	Europe	<ul style="list-style-type: none"> Diagnostic test at airport; Quarantine for 14-days at facilities, install a self health check mobile app ("Self-Diagnosis App")
	non-European countries, including US	<ul style="list-style-type: none"> Quarantine for 14-days at facilities, install a self health check mobile app ("Self-Diagnosis App"); Diagnostic test if any symptom appears
	Exempted from quarantine at facilities (Diplomat, Government officials)	<ul style="list-style-type: none"> Diagnostic test at airport and wait for results at temporary testing facility; If negative, active surveillance for 14-days via self health check mobile app

Case management and contact tracing

In cases of widespread transmission, local epidemiological investigation teams perform contact tracing. In the investigation phase, the team obtains information through patient, family, and physician interview to identify transmission route. The health authority classifies confirmed cases into four groups based on the severity of symptoms, from mild, moderate, severe, and extremely severe. All except mild cases are immediately hospitalized until full recovery; mild cases are placed under self-quarantine for 14 days (22). An amendment to the IDCPA in 2015 grants MOHW and KCDC authority to collect specific types of personal data related to identification and movement of the confirmed and suspected cases in efforts to prevent the infectious disease outbreaks at the expense of personal privacy infringement (135), which overrides certain measures under the *Personal Information Protection Act of 2011* (129). The specific types of information collected include name, resident registration number, address, phone number, prescriptions and medical records, immigration control records, and information prescribed by Presidential Decree for monitoring the movement paths (135), such as mobile phone location data, CCTV footages, transit pass records, and card transactions (129). Movement information is collected from police records, while the rest of the information is gathered from public and medical institutions, and corporations. The collected information can then be shared with the heads of the relevant government agencies, the National Health Insurance Corporation, the Health Insurance Review and Assessment Service, and other organizations that are involved in infection control (124).

Contacts are classified by risk status between close and casual contact. They are then given a notice from the Health Service to be informed of self-quarantine guidelines (22). Similarly, inbound travellers that had negative results are also given the quarantine guidelines. For example, short-term stay foreigners should be in self-quarantine at a government-approved living facility for 14 days; Koreans and long-term stay foreigners are released to go home to be in self-quarantine for 14 days (130).

From late January to late March, the epidemiological analysis of cases was manually done by the trained officials, which usually took about 24 hours (20). Access to personal information had to be written and managed in handwriting, which also required substantial coordination between the organizations. The de-identified travel route information was disclosed publicly until April 12 (136).

Under the IDCPA, the public has the right to be informed about the outbreak status by the government disclosure of necessary information (20). Until mid-April, the MOHW website disclosed the case information, including their path, medical institutions, number of contacts, sex, nationality and age (136). However, certain local governments provided even finer details, such as the names of shops and restaurants the cases visited (129). Through MOIS, local governments send out emergency text messages through cellular broadcasting service to all mobiles in their catchment area so residents can check if they have been in an overlapping area of a confirmed patient (21). On a few occasions, these details led to stigmatized re-identification of cases and closure of businesses. In early to mid-March, shortly after the National Human Rights Commission issued a recommendation for revision, KCDC established guidelines for the local governments (129). As of April 12, 2020, with the exception of sex and age, the MOHW has halted disclosing most of information, such as the movement path of the cases on their website. As of May 21, 2020, no case-level information was found on the MOHW website; instead, the details of the most recent outbreaks were shown, including the address, date of exposure and status of disinfection (136).

The 24/7 hotline (“1339 Call Center”) is available (23,137) in Korean, English, and Chinese (21) It can be used to report the symptoms during quarantine if a smartphone app is unavailable (20), to receive a diagnosis if an app user is suspected to have been infected (21), or to find the location of all the available testing centers (23), which are also listed on the MOHW website or other COVID-19 designated apps (22).

Digital contract tracing approaches

Self-health check app (“Self-Diagnosis App”)

The Self-health check app monitors symptoms of inbound travellers while providing prompt medical advice by connecting users directly to the call center and social media channels. The app was launched on February 12, 2020 intended for travellers from China but has since been expanded to all travelers as of April 1, 2020. The app must be downloaded upon their arrival at the airport and is used to submit personal information (e.g., passport information, name, address, etc.) for quarantine. Daily reporting is sent to public health clinics for the 14-day quarantine period (21).

Self-quarantine safety app

Those under self-quarantine must report their symptoms twice daily using the self-quarantine safety app.¹⁵ The app is available in three languages (Korean, English, Chinese) and, in addition to self-reporting,

¹⁵ If a smartphone is unavailable or inaccessible, phone call services are also available for symptom reporting.

it also requires users to provide location information to ensure self-quarantine measures are followed (21). Health authorities can monitor the GPS location of those under self-quarantine (135). The location data is transferred from the mobile carriers to the police and ultimately to KCDC and local governments. Downloading the app is voluntary for those living in Korea, but mandatory for all inbound travellers, including Korean nationals (21). The self-reported data is transferred to a complementary app of an assigned case officer from the MOIS and local governments who monitors daily reporting and location data. If symptoms are reported, the users are contacted by the designated case officers to find the nearest testing center to get tested. The app also has an alarm feature that sets off when users venture out from the designated quarantine areas and case officers are notified when data is not entered. Leaving the quarantine area with or without the GPS-monitored cellphone may result in fines up to 10 million won or imprisonment for up to one year (20).

Epidemiological Investigation Support System

The COVID-19 Epidemiological Investigation Support system was launched on March 26, 2020 following a 10-day pilot operation (21). KCDC operationalizes the system by coordinating with the National Police Agency, Ministry of Science, Ministry of Land, Infrastructure and Transport, Credit Finance Association, three mobile carriers, and 22 credit card companies (68). The automated system, which uses a cloud-based open data hub, provides an almost real-time (within 10 minutes) epidemiological analysis of cases to the authorized epidemiological investigators (69). Existing technology systems facilitated the development of South Korea's tracing methods: the Advancement of Smart Quarantine Information System used the overseas roaming data to identify inbound travellers from high-risk areas and monitor them during the incubation period (20); and an open data hub called "Smart City Portal" for the R&D purpose of improving various sector developments (70). The system allows for multi-agency coordination under a central platform and maximizes the efficiency of tracing (21).

Appendix C6: Taiwan

Setting overview and COVID-19 timeline

Taiwan confirmed its first imported COVID-19 case on January 21, 2020, in an individual returning from Wuhan, China (138). Despite its proximity to mainland China and other high-incidence countries, Taiwan has managed to maintain a reduced number of COVID-19 infections and deaths, amounting to the lowest incidence of cases per capita globally (8). Taiwan's success could be, in part, explained by Taiwan's timely and proactive response from the very beginning of the outbreak. For instance, when the WHO was notified on December 31, 2019, of pneumonia of unknown cause in Wuhan, China, Taiwanese officials began surveillance measures by screening passengers flying directly from Wuhan to Taiwan for symptoms (38). In 2004, following the 2003 SARS-CoV-1 outbreak, the Taiwanese government and the Taiwan Centers for Disease Control (CDC) established the National Health Command Center (CECC), which acts as the operational command point during public health emergencies and informs decision-making. The NHCC was activated by the CDC on January 20, 2020, to address the COVID-19 outbreak (39). Unlike many other countries, Taiwan did not adopt lockdown measures to contain COVID-19. Between January 21, 2020 and May 9, 2020, there have been 440 confirmed COVID-19 cases and 6 deaths in Taiwan overall (for a total population of nearly 24 million) (139,140). As the number of new infections has been decreasing in Taiwan, achieving zero new cases in six consecutive days by May 1, 2020, some isolation restrictions have started to be lifted. On May 8, 2020, Taiwanese citizens that have been staying in Hubei province were permitted to fly back to Taiwan on commercial flights. Some sporting events have also resumed, allowing a restricted number of spectators (47).

Testing

In Taiwan, testing, case management, and contact tracing are overseen by the Taiwan Centers for Disease Control in coordination with the National Health Command Center.

Eligibility criteria

Testing guidelines for SARS-CoV-2 in Taiwan, updated on April 12, 2020, recommend testing all suspected cases. Suspected cases are individuals who were in close contact with a symptomatic confirmed case within 14 days prior to symptom onset, and who also present one or more of the following: (i) fever (≥ 38 °C) or symptoms of acute respiratory tract infection, (ii) abnormal sense of smell or taste, or diarrhea of unknown etiology, or (iii) community-acquired pneumonia highly suspected to be COVID-19 by doctors (141). Additionally, since February 12, 2020 it is mandatory to test all the individuals who reported upper respiratory infections from January 31 and tested negative (142).

Testing capacity

On April 7, 2020, the CDC announced the establishment of a national testing network of 34 laboratories to expand testing capacity and reduce waiting times for test results as part of one of the strategies of the CECC. The increased testing allows for 3,800 tests per day in different settings across Taiwan (143,144).

Identification and testing of new individuals are based on the Taiwanese four-tier primary healthcare network of community healthcare groups prepared clinics (CHGPCs) (introduced after the 2003 SARS-CoV-1 outbreak) and community screening stations (CSSs). Individuals go to tier 1 walk-in clinics for assessment of general symptoms and other health issues, a person is referred to the next tier if suspected with COVID-

19. In tier 2, clinics that voluntarily joined the CHGPC program, assess patients with fever, cough, upper respiratory symptoms, or possible COVID-19 cases. Although CHGPC clinics do not test for COVID-19, these provide treatment for suspected cases, recommend isolation, monitor isolated individuals with calls, and refer suspected cases to the next tier. Tier 3 consists of CSSs, which are community health centers, regional hospitals, and other volunteer clinics equipped with x-ray devices that test and quarantine possible cases referred from CHGPC. CSSs also refer confirmed cases to the next tier. Tier 4 are hubs of medical centers and designated hospitals that treat referred confirmed cases from the CSSs. These hubs also test suspected cases (15).

Testing in special groups

Since February 16, 2020, suspected cases for COVID-19 are actively identified in the health centers by meeting the clinical criteria in the National Health Insurance (NHI)¹⁶ database (143). Specific high-risk groups for COVID-19 infection are mentioned in the guidelines for closer surveillance and case identification, including older people and individuals with comorbidities (cardiovascular, renal, hepatic, or neurological diseases; diabetes mellitus; chronic lung diseases like asthma, immunocompromised individuals requiring long-term treatment, and pregnant women) (145,146).

Asymptomatic and/or serologic testing

Asymptomatic individuals are not being tested in Taiwan.

Case management and contact tracing

A contact is defined as an individual who had a close face-to-face approach, without PPE, for more than 15 minutes with a confirmed COVID-19 case before the latter received the test results. In health settings, contacts are medical staff, hospital workers, or other patients who have close proximity (less than 2 meters) without PPE with a confirmed case during a longer time than required (147).

At the beginning of the COVID-19 outbreak, the CDC in Taiwan quickly updated and improved the infection control practices and strategies established during the 2003 SARS epidemic (72). The CECC has published measures to follow up on persons at risk of infection, which are classified into three groups. First, the individuals who had contact with confirmed cases of COVID-19, receive a home isolation notice and local health authorities ensure isolation by monitoring the individuals twice a day. These individuals must stay at home (or designated location) for 14 days. Second, people with travel history, receive a home quarantine notice and the local civil affairs bureau or borough chief ensure quarantine by monitoring the individuals once or twice a day. These individuals must stay at home (or designated location) for 14 days. Both individuals who had contact with a confirmed case and individuals with travel history are penalized under the Communicable Disease Control Act and forcibly placed at home if they do not adhere to the mandated self-isolation or quarantine. Besides, these individuals must take an additional 7-day period of self-health management after self-isolation or quarantine. Third, suspected cases who tested negative, should take 14 days of self-health management and central/local health authorities ensure that individuals adhere to the measures. Self-health management involves reducing time in public spaces,

¹⁶ National Health Insurance program (NHI) is mandatory for citizens and foreigners living in Taiwan for more than six months (see: Tsung-Mei Cheng. The Commonwealth Fund. The Taiwan Health Care System. International Health Care System Profiles. Available at: <https://international.commonwealthfund.org/countries/taiwan/>)

adopting hygiene measures, testing body temperature twice a day, using a mask in public, and avoiding public transport. There is no enforcement of isolation or penalization for these individuals (148,149).

Digital contact tracing approaches

Throughout the COVID-19 epidemic, case and contact tracing in Taiwan have been conducted along with the use of already existent or updated technologic resources.

Use of Big Data

In 2014, the federal government implemented the NHI centralized Taiwan Health Cloud program which generates automatic surveillance reports for infectious diseases using hospital electronic medical records (EMRs) (71). On January 27, 2020, the NHI centralized Health Cloud database was supplemented and merged, into “big data”, with the patients’ past 14-day travel history from the Customs and Immigration data of the National Immigration Agency, that process was completed in one day (38,72). On February 18, the government announced that all hospitals, clinics, and pharmacies in Taiwan would have access to patients’ travel histories (38). Big data has allowed the identification of suspected cases and contacts. The NHI system flags medical records of patients with a travel history so that health staff can easily identify them when these individuals have a medical appointment. Then, health staff proceed as recommended by the CECC. Also, all confirmed and suspected contacts are added to the NHI database. Since the NHI patient records in the cloud include complete health history, underlying health conditions, recent progression of symptoms, treatments, and hospitalization related to respiratory syndrome, the Big Data helps identifying high-risk patients and contacts (72).

Entry Quarantine System

To help monitoring people with a travel history, the Entry Quarantine System was launched on February 14, 2020 (38). With this system, travelers flying to Taiwan had to complete a health declaration survey in a surveillance poll when arriving at Taiwan’s airports. Travelers with mobile phone numbers provided by telecom operators in Taiwan are able to complete the health declaration survey using their phones to accelerate immigration clearance. The mobile form consists in scanning a QR code, filling out the health declaration form, and upon arrival in Taiwan users receive a health declaration pass via SMS to show to the surveillance personnel (143). Information requested in the COVID-19 health declaration included passport number, name, nationality, flight number, presence of specific symptoms in past 14 days (fever, cough, runny nose, limb weakness), personal mobile phone number, landline, and address of home/hotel where the individual will be in mandatory quarantine (150). If travelers in Taiwan do not have a local mobile landline, they should apply for a SIM card at the airport and health staff will dial the phone number on-site to ensure it is valid and the person is always reachable. Those arriving at Taoyuan International Airport receive a mobile phone designated for isolation and quarantine follow-up and tracking (151). People arriving to Taiwan have enforced quarantine and monitoring according to the CECC recommendations (148,149).

Electronic security monitoring system

In collaboration with Taiwanese telecom companies, the CECC developed an electronic security monitoring system to enforce quarantine and self-isolation. This system tracks the location of people subject to home quarantine or self-isolation using the GPS on their mobile phones. The phone signal is

monitored, so when an individual leaves the designated quarantine site the signal moves from the closest antenna tower and both the individual and the civil affair bureau worker will receive an SMS notification. The responsible worker and the police will check the person's location immediately, and those who are not in their quarantine location are fined and returned by force (143). To ensure that the phone has not been left behind while leaving the quarantine site, officials call individuals up to twice a day for monitoring of symptoms (152). To alleviate the burden of the enforced self-isolation and quarantine, staff wearing PPE could conduct home visits, arrange meal deliveries, and bring essential supplies to persons living alone (148). Besides, people in quarantine or self-isolation receive a daily subsidy of \$1,000 NT (approximately \$47.21 CAD) for 14 days (153).

Police cloud

The National Police Agency (NPA) introduced the "home quarantine" identity searching function into the already existent M-police system to strictly track individuals who infringe self-isolation or quarantine (154). The M-police system is the Police Cloud Computing Plan that integrates databases from six nationwide organizations to help with criminal investigations. The M-police system contains information of people, vehicles, criminal cases, places, photos, and videos (155). The NPA also conducts inspections in opened venues and uses an M-Police small computer to query the identity of each person and identify individuals interrupting their self-isolation or quarantine (156,157).

The COVID-19 containment methods adopted by the Taiwan government have been debated worldwide, especially regarding privacy concerns. Despite the CDC Act⁷¹ and the COVID-19 Special Act⁷² authorising the Taiwanese government to impose quarantine, isolation care, and other necessary measures to address the COVID-19 epidemic, monitoring multiple sources of data, disclosing names and phone numbers, and collecting and tracking mobile data could be of concern (158). In addition, the use of Big Data NHI system data has been restricted exclusively to addressing the COVID-19 epidemic, and health records or other personal information are not available to anyone outside of the health system (72). Some Taiwanese citizens agree with the enforced quarantine and other strict measures as long as these can help combat the epidemic and maintain the public health. However, not all citizens agree with the imposed measures and perceive the strategy as intrusive (152).

Appendix D: Summary of Contact Tracing Approaches

Table D1: Summary of digital contact tracing approaches across jurisdictions

Jurisdiction	Name	Launch date	Device	Tech	Data collected	Data access	Data period	Data storage	Developer	Open source protocol	Mandatory/voluntary	Uptake	Action
Germany	Corona app	June 2020 (expected)	Smartphone (iOS + Android)	Bluetooth, Google/Apple	Time-linked temporary anon'd IDs of nearby phones, self-reported dx	User only	Unclear	Local (on device)	HA + private partner	Yes (DP-3T)	Voluntary installation for user	NA (need 50% pop'n)	In-app exposure alert
Germany	Corona Data Donation app	April 7, 2020	Fitness wristbands/ smartwatches (iOS + Android)	App algorithms	User-assigned pseudonym, app recognized COVID-19 related symptoms, postcode	User + HA	10 years (can be deleted by the user)	HA server + Local (on device)	HA + private partner	Unclear	Voluntary installation for user	8% of pop'n	No user alert, data transferred constantly, with consent
Germany	SORMAS	April 20, 2020	Smartphone (iOS + Android)	Software	Dx, symptoms hx of patients in clinics	HA + other partners	Unclear	HA server	HA + other partners	Yes	Voluntarily for clinics	One district in Berlin	No user alert, identification of cases and contacts
Iceland	Rakning C-19	April 2, 2020	Smartphone (iOS + Android)	GPS	User phone number, device location hx	User + HA with consent, if user dx	14 days (destroyed on rolling basis)	HA server: user phone number Local (on device): device location hx	HA + private partner	No	Voluntary installation for user	38% of pop'n	No user alert, data transferred if dx, with consent
Israel	Shin Bet cellphone tracking	March 15, 2020	Cellphone	Unclear	Device location, credit card records	User + HA	14 days (unclear if destroyed)	HA	Shin Bet security service	No	Mandatory for user, no installation	Unclear	SMS exposure alert, self-quarantine, self-report to HA
Israel	HaMagen	March 22, 2020	Smartphone (iOS + Android)	GPS	Device location hx	User only	14 days (destroyed on rolling basis)	Local (on device)	HA + private partner	Yes	Voluntary installation for user	17% of pop'n	In-app exposure alert, self-quarantine, self-report to HA
Singapore	TraceTogether	March 20, 2020	Smartphone (iOS + Android)	Bluetooth	User phone number, time-linked temporary anon'd IDs of nearby phones	User + HA with consent, if user dx	21 days (destroyed on rolling basis)	HA server: user phone number Local (on device): anon'd IDs	HA + GovTech	Yes (BlueTrace)	Voluntary installation for user	13% of pop'n	No user alert, data transferred if dx, with consent

Singapore	SafeEntry	May 9-12, 2020	Smartphone or gov't ID card with barcode	QR code or gov't ID card with barcode	User name, NRIC/FIN, user phone number	HA	Unclear	HA	HA + GovTech	Unclear	Mandatory for venues, no user installation	16,000 venues (rollout ongoing)	No user alert
South Korea	Epidemiological Investigation Support System	March 26, 2020	NA	Cloud	GPS, mobile information, credit card transaction history	Health authorities	Unclear	Secured server/cloud	Ministry of Land, Infrastructure and Transport	Unclear	Mandatory	NA	No user alert
South Korea	Self-health check app	February 12, 2020	Smartphones (iOS + Android)	Unclear	Self-report symptoms	User + public health authorities	14 days	Unclear	Unclear	Unclear	Mandatory	Unclear	No user alert
South Korea	Self-quarantine safety protection	March 20, 2020	Smartphones (iOS + Android)	GPS	Self-report symptoms, individual location information	User + public health authorities	14 days	Unclear	Ministry of the Interior and Safety	Unclear	Mandatory for in-bound travellers (incl. Korean nationals) and voluntary for Korean residents	91.4% of quarantined individuals	No user alert
Taiwan	Big Data	January 27, 2020	NA	Health Cloud	Dx, symptoms hx, travel history, full health records	HA + health settings + pharmacies	Unclear	National centralized health cloud/server	HA	Unclear	Mandatory	100% pop'n	Flag health records or high-risk patients
Taiwan	Entry Quarantine System	February 14, 2020	Smartphones (iOS + Android)	Online survey and SMS	Passport number, name, nationality, flight number, symptoms hx, phone number, landline, and address of quarantine location	HA	Unclear	HA	HA	Unclear	Mandatory	All incoming travelers	No user alert, data transferred to the Health Cloud
Taiwan	Electronic security monitoring system	February 14, 2020	Smartphones (iOS + Android)	GPS	Individual location information	HA + National Police Agency	Unclear	HA server	HA	Unclear	Mandatory	All individualism quarantine or self-isolation	Alert user and police authorities if quarantine is interrupted
Taiwan	Police cloud	February 14, 2020	NA	Police cloud	Information for criminal investigation (individual hx, places, photos, videos, vehicles)	National Police Agency (NPA)	Unclear	NPA cloud (M-cloud)	Unclear	Unclear	Mandatory	All individualism quarantine or self-isolation	No user alert, complements electronic security monitoring system

List of abbreviations: HA (Health Authority); GPS (global positioning system); NA (not applicable); dx (COVID-19 diagnosis); hx (history)

