Optimising Covid-19 'Test and Trace' systems: Early lessons from a comparative analysis of six countries

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Abstract

‘Test and Trace’ systems are key components of national responses to the ongoing Covid-19 pandemic. Each country has its own set of measures for testing Covid-19 cases, finding contacts, and isolating and supporting those affected by the SARS-CoV-2 virus. This article presents early results from a comparative analysis of six countries; Germany, Ireland, Spain, South Africa, South Korea, and the UK. Using evidence from publicly available sources, the paper presents analyses of testing systems in the study countries, using a Find, Test, Trace, Isolate, and Support (FTTIS) framework. The article demonstrates that no single study country has a fully optimised FTTIS system, with lessons to be learned for all from international comparisons. Findings emphasise lessons for the countries studied as well as general lessons of wider relevance on the potential scope of FTTIS systems. In particular, the need for openness and evaluation is emphasised as an integral part of the FTTIS system, to support continual assessment, learning, evolution and international sharing of good practice.

Key words: COVID-19; SARS-CoV-2; rt-PCR; prevention; early detection; public health

Introduction

‘Test and trace’ systems are vital for the rapid control and containment of infectious disease spread. Countries across the globe are building and implementing these systems in response to the ongoing SARS-CoV-2 pandemic. The likelihood of continued SARS-CoV-2 spread, as well as future infectious disease outbreaks, means that it is imperative for countries to learn from one another. Here we report early results from a study of the national testing systems in Germany, Ireland, South Africa, South Korea, Spain, and the UK (hereafter referred to as ‘the study countries.’)

To organise the analysis, a framework outlined by the UK’s Independent Scientific Advisory Group for Emergencies is used.[1] This framework presents five key components of a ‘test and trace’ system that is equipped to effectively control the spread of SARS-CoV-2 (Fig.1).[1] These five elements, Find, Test, Trace, Isolate, Support (‘FTTIS’) provide a systematic basis for comparing national testing systems and elucidating lessons learned for others. Using FTTIS as a framework, the early experiences of a range of countries in establishing test and trace systems can be analysed.

Findings show considerable variation in FTTIS systems across countries, and suggest three lessons for control of SARS-CoV-2: First, as no country has a fully optimised system, all

study countries can benefit from sharing lessons. Second, for many countries, key areas of focus should be on maintaining isolation and quarantine of individuals and providing support measures to ensure adherence to guidelines and wellbeing. Third, that a full system requires an additional evaluation component to enable learning to address the changing challenges of Covid-19 response and share best practice internationally.

Fig 1: Description of the FTTIS framework provided by the UK Independent Scientific Advisory Group for Emergencies in their report *Final Integrated Find, Test, Trace, Isolate, Support Response To The Pandemic* [1]

UK Independent Scientific Advisory Group for Emergencies' FTTIS framework

Find the virus, by encouraging those with symptoms to come forward, while also seeking out asymptomatic carriers.

Test all those suspected of carrying the virus, ensuring that testing is available to all who needed it as quickly and easily as possible.

Trace all who have had a positive test and those they have had close contact with to warn them to avoid infecting others.

Isolate those who are infectious and quarantine those who may be incubating the virus in order to break the chain of infection.

Support all in isolation or quarantine to maximise the chances that they do not infect others, while ensuring their wellbeing.

Materials and methods

This article draws primarily on data from publicly available sources in the study countries, collected between June 1st and August 31st 2020. The project team is composed of researchers from each of the six study countries who are familiar with the local administrative context and/or are fluent/native in the local language. This combination of national knowledge and linguistic fluency allowed the team to use sources that would have been unavailable were the analysis to be English-language only.

To structure and systematise the analysis, the project team used a series of standard questions based around the FTTIS framework. The resulting information was used to construct individual country reports, as well as a shared online spreadsheet for ease of comparison and data validation. Weekly team meetings allowed the country experts to create shared understandings, and enabled standardisation of data collection, and collective discussion of the analysis. The analysis presented here has been informed by these

discussions on the context of the problems experienced in establishing FTTIS for Covid-19 and lessons learned for each country. The Covid-19 pandemic is a dynamic situation, and data presented here reflects the current state of FTTIS systems in August 2020.

Results

Find

Two parallel strategies need to be considered for a comprehensive FTTIS system. A *passive* strategy first ensures that those coming forward with Covid-19 symptoms can access diagnostic tests and have their contacts traced. However, the majority of those infected with SARS-CoV-2 will not display symptoms, or may infect others before symptoms develop.[2] Therefore, an *active* strategy is also needed to hunt for asymptomatic individuals in carefully identified high-risk populations to reduce opportunities for SARS-CoV-2 to spread.

Passive Strategies

Study countries implemented passive strategies for finding and testing possible Covid-19 cases but early in the pandemic, eligibility for testing was often restricted as testing capacity was limited. The experience of Spain provides a cautionary illustration; travel history was initially used as a criterion to restrict access to testing. This led to community transmission *within* Spain being missed for some time, arguably worsening the outbreak.[3] Similarly, in Germany, South Africa, the UK, and Ireland early eligibility for testing included a narrow range of symptoms, which were not representative of those infected with the virus.

In passive case finding, communication is an important part of raising awareness for symptomatic individuals to seek testing. The use of tailored communication strategies for different minority and age groups are necessary to boost uptake of testing.[4] Here a cautionary example is found in England, where some more multicultural areas have experienced relatively high numbers of cases, in part because minorities have not had access to information due to language barriers and limited media use. A more successful case is seen in Germany, however, where the Robert Koch Institute (RKI) issues its guidance in 19 different languages.[5][6]

Digital technologies may enhance passive case finding by disseminating advice on when and how to access testing, while also providing health services with data on trends in epidemic growth and clusters. Digital apps have been deployed in Ireland[7], Germany,[8] and Spain,[9] while South Korea[10] and South Africa[11] have used other forms of mobile communications to provide information to citizens. In the UK, however, mobile apps have not

been adopted in England due to government concern over the ‘confusion’ these may cause,[12] but have been supported by devolved administrations in Scotland, Wales and Northern Ireland.

Active strategies

Active case finding strategies have emerged as testing capacity has increased. In South Africa, community health workers are undertaking door-to-door symptom screening in hotspots and defined vulnerable locations.[13] In the UK, a household survey (including testing) commissioned by the Department of Health and Social Care has identified age groups and professions more likely to be infected e.g. health and social care workers.[14] Regular screening of staff and residents in care homes has now commenced in the UK[15] and also in some regions in Spain.[16]

In Germany there has been debate[17] about the role of screening for Covid-19 because a negative result may provide false reassurance, particularly in pre-symptomatic or sub-clinical individuals. However, current RKI guidelines do recommend the testing of asymptomatic people to control regional outbreaks and the routine use of testing for healthcare staff.[18] Some German regions are implementing routine testing of high-risk groups. This active case finding balances a need to be cautious of negative test results with a need to find less visible cases.

For countries with low incidence of Covid-19, testing at ports of entry and borders has been prioritised. While all travellers entering South Korea are tested and quarantined, Germany does the same only for a selected list of high-risk countries. Travellers to South Korea are also required to use an app to monitor their health and location. Repatriated South African citizens were tested before repatriation and again before release from 21 days’ quarantine.[19] Testing on entry is yet to be established in the UK and Spain. The UK government has tried to balance demands to open up business and leisure travel with reducing imported cases. As a result, quarantine measures for those entering the UK have been stepped up, down, and back up again as case numbers in other countries oscillate.[20] Rapid changes have caused disruption to travellers and associated businesses.

Test

While antibody testing and rapid or close-to-patient diagnostics are now emerging, molecular laboratory tests based on the polymerase chain reaction (PCR) technique have been the standard for managing Covid-19 in study countries. Many laboratories in hospitals, universities, government agencies and commercial organisations have shown the capability

to develop and/or provide diagnostic testing capacity for SARS-CoV-2. The accuracy and utility of these tests depends greatly on the wider context of their use, including procedures for sample collection, sample handling, the robustness of testing processes, and the speed at which results are obtained and communicated.

Sample collection influences the reliability of test results, with the sample site[21] (e.g. upper or lower respiratory tract) and the training of the individual collecting the sample[22] having a marked impact on the sensitivity of the test itself. This means that 'it is difficult to rule out COVID-19 based solely on one negative [test] result.' Guidance in Germany, South Korea, Spain and South Africa[22] recommends collection of both upper respiratory (nasal and oral) and lower respiratory (bronchial sputum) samples where possible. The UK is an outlier, focusing solely on upper respiratory sample collection in the context of its community testing programmes. Moreover, England's National Health Service (NHS) Test and Trace programme has relied heavily on self-collected samples from home collection kits, raising concerns around speed of testing and accuracy of results.[23]

High standards of testing are essential. In most study countries, testing has been undertaken in accredited laboratories with experience of clinical testing for infectious diseases, overseen by a nominated laboratory. Examples include: Charité-Universitätsmedizin Berlin in Germany, the National Virus Reference Laboratory in Ireland, the Centro Nacional de Microbiología in Spain, and the National Health Laboratory Service in South Africa. Professional bodies of pathologists (such as the Korean Society for Laboratory Medicine) may also play a role in oversight or provide training (as the Korea Laboratory Medicine Foundation task force has done). Notably in the UK, the commissioning of new, private, large scale testing in 'Lighthouse Laboratories' has bypassed accreditation and raises quality concerns.[24]

Rapid scale-up of testing, fast turnaround, and prompt reporting are essential for ensuring chains of infection are broken. In all study countries, tests are free to the patient at point of access, which is appropriate as tests for those less likely to become seriously unwell nevertheless serve as a public good, where this testing aids prevention of onward transmission. In most study countries, the rapid scale up in testing (see Table 1 for claimed and proven testing capacity for the study countries) has been achieved through recruiting universities and commercial laboratories into wider pathology laboratory networks. In Ireland, capacity was rapidly expanded partly by repurposing commercial veterinary viral testing capacity, while South Africa scaled up testing by repurposing existing capacity for Tuberculosis testing.[25]

Prompt reporting refers both to notification of test results for tested individuals and the collation and distribution of data to provide strategic oversight of the outbreak response and improvements in the performance of the FTTIS system itself. While performance data are released for the UK and South Africa on the rate of test results returned to individuals within 48 hours, similar data for other study countries are not available. While the centralised nature of data collection as in the UK may aid reporting (some study countries are more federalised), lack of performance data limits the ability to share best practice across contexts. Without accurate data on the performance of these systems, a 'what works?' approach to sharing lessons may be seriously constrained.

Table 1: National testing capacity PCR Testing Capacity for SARS-COV-2

	Stated Test Capacity (Claimed maximum test capacity per week per million capita [dates])	Proven Test Capacity (Highest number of tests recorded per week per million capita [dates])
South Korea (Pop. 52 mil.)	1,346 [End of February] [27]	2,356 [Aug 24th – Aug 30th]
UK (Pop. 67 mil).	36,452 [July 7th – July 13th] [28]	12,985 [July 15th – July 21st]
Ireland (Pop. 5 mil.)	20,408 [Mid-May] [29]	12,523 [April 28th – May 5th]
Germany (Pop. 83 mil.)	14,153 [July 6th – July 12th] [30]	6,342 [July 13th – July 19th]
Spain (Pop. 47 mil.)	13,228 [May 25th – May 31st] [31]	6,748 [April 24th – April 30th]
South Africa (Pop. 58 mil.)	6,057 [June 29th – July 5th] [32]	5,628 [July 5th – July 11th]

Source: Authors' elaboration. Proven test capacity data from OurWorldInData [26]. Stated test capacity data for each country reported in references [27][28][29][30][31][32].

Trace

At the heart of an effective FTTIS system is the capability to rapidly identify and warn all contacts of infected individuals to take action to prevent onward spread of disease, and to

monitor these individuals' wellbeing and compliance. Study countries are using three approaches to contact tracing in their FTTIS systems. These are: decentralised (local), centralised, and digital contact tracing. However, of the study countries, only South Korea has successfully implemented all three approaches so far, in part due to measures taken following the 2015 Middle East Respiratory Syndrome (MERS) outbreak. In other cases, such as in England and Spain, decentralised contact tracing systems established before the pandemic were initially overwhelmed and new centralised measures subsequently sought – neither country has implemented digital contact tracing before August 2020. Features of the study countries contact tracing systems are summarised in Table 2, which includes notable local concerns as reported nationally.[33]

Each of these three layers, centralised, decentralised, and digital are potentially complementary. While digital technologies provide additional gains over manual methods alone, they raise data protection issues that require either avoiding data centralisation or the compromising of data privacy. Centralised contact tracing may be slower and less efficient than decentralised, but allows for the rapid collation and sharing of data for evaluation and learning. Decentralised systems are embedded in their localities and can address complex tracing cases, but the lack of centralisation makes it difficult to share data across contexts and to learn. Moreover, local resources may become rapidly overwhelmed, while centralised resources could be used to provide additional capacity to regional hot spots.

Table 2: Scope of contact tracing systems and key local concerns

Country	Manual Contact tracing	Digital contact tracing	Notification of contacts	Linkage to monitoring of those isolated/ quarantined	Key local concerns
S. Korea[34,35]	By local public health and centralised function	Mobile phone records, card payments, and CCTV allow close contacts to be automatically determined, very rapidly	Can be in person, by phone and by automated system (SMS)	Mobile app used to detect violations as well as to report any symptoms. SMS warnings when GPS detects violations before imposing fines and custodial sanctions	Emergency access to personal data allowed under Data Protection Law (following 2015 MERS outbreak) compromises privacy. Frequent and around-the-clock proximity alerts at risk of being ignored and leading to complacency
UK[4,36,37]	Long est. local authority public	Differs by nation:	Can be in person, by	None	The low effectiveness of new centralised tracing system, which

	health teams. Large, new centralised contact tracing capability needed in England	None in England, Scotland, Wales – but a DP-3T app under development. N. Ireland uses similar app to Ireland	phone and SMS Additionally, by mobile app in NI		is expensive and has been termed 'secretive'. Mobile app delayed by switch from centralised to decentralised approach
Ireland[38,39,40]	A centralised contract tracing operation	Decentralised, Bluetooth mobile phone app launched in June	Can be in person, by phone, SMS or mobile app	Daily reminders by SMS to stay at home for isolation/ quarantine period	There were early technical issues in developing an IT system to coordinate information between laboratories and contact tracers. Phone app did not launch until June 26
German[41,42]	No central contact tracing. Control of contact tracing devolved to state level, and done by local public health teams	Decentralised Bluetooth mobile phone app launched middle of June	Can be in person, by phone, or by app	National guidance suggests daily follow up, but this only occurs in some states	Variable performance by states. Contact tracers have not been appointed in sufficient numbers in some states to avoid the system becoming overwhelmed. Mobile app delayed by switch from centralised to decentralised approach. The app was rapidly downloaded by 20% of the population within four weeks of use, it has been difficult to establish its impact due to its decentralised nature
Spain[43,44]	No national central contact tracing. Tracing devolved to regional state level, and managed in primary care.	A decentralised DP-3T app launched on 10th August 2020	Mainly by phone	Follow up calls for the first 96 hours.	Scarcity of contact tracers has been widely blamed for the serious upsurge of new cases during mid-July.
South Africa[45,46]	Initially National centralised contact tracing by NICD which became decentralised to provincial and district level as community transmission	Mobile phone location data can be used by contact tracers. A smartphone app for contact tracing is currently under development	By phone	Self-monitoring, active telephone monitoring in certain circumstances. If unreachable for more than 24 hours, the district/provincial	Long turnaround time for samples tested in government laboratories. Concerns about adequacy of safeguards to protect personal information.

	became established. The district or provincial outbreak response team is responsible for contact tracing.			team may do a home visit.	

Isolate

Those confirmed as infected with SARS-CoV-2 through a positive test result need to isolate until they are no longer a risk to the public. World Health Organisation (WHO) guidelines on isolation (June 2020) recommend a minimum isolation period of 13 days after symptom onset for symptomatic cases (including at least 3 days without symptoms), and ten days after a positive PCR test for asymptomatic cases. WHO guidelines on contact tracing[47] (May 2020) recommend that contacts of infected individuals should quarantine themselves for a minimum of 14 days, and be followed up daily to allow them to report symptoms.[48]

Of the study countries, only Germany - and particularly only the state of Baden-Wurttemberg[49] - formally requires that *all* of these conditions are followed. The federal government recommends that isolation is checked by daily contact with the local health authorities. Those breaking isolation rules can be charged €500, up to €25,000 for repeat offences and, if a person infects another individual while breaking quarantine, may be sentenced to up to five years in prison.[50] However, enforcement of these laws and monitoring of the isolation varies greatly, with only 45% of local health authorities actively monitoring it.[51]

While fines, detention and jail terms are common enforcement measures in place across all the study countries, monitoring of those in isolation or quarantine varies substantially. In South Korea, individuals are tracked through their mobile phones, with warnings by text message for moving out of strict bounds.[52] In Ireland, legal measures have been put in place, but are not generally enforced, preferring to rely on community spirit for compliance. Contacts receive a daily text message emphasising the importance of isolation and asking about symptoms.[53] In Spain, isolation is checked with telephone interviews with contact tracers but these end after 96 hours from first contact (except in the case of domiciliary support, where evaluation continues until isolation ends).[54] In the UK there appears to be no systematic follow-up of isolating or quarantining individuals, except for travellers returning from designated countries. In South Africa initially, close contacts were monitored by the

national call centre (backed up by home visit by the provincial team if contact became unreachable) for 14 days post last exposure to the confirmed case.[55] However, provincial teams were rapidly overwhelmed and home visits have been replaced by self-monitoring except in certain circumstances.[56] This emphasises the need not just for enforcement of isolation and quarantine but support for individuals who are doing so to promote and enable compliance, rather than simply punishing non-compliance.

Support

Measures ranging from provision of guidance, and financial support, to food, drink and accommodation, may be needed to ensure socioeconomic stability and public confidence in a FTTIS system.[57]

Providing information to those in isolation or quarantine is routine in study countries. In the UK a detailed guide is available, but only online.[58] Advice includes guidance on the need to stay at home, personal hygiene, avoiding contact with friends and relatives, accessing medical treatment and mental health support. However, concerns have been raised that these materials are not available in all required languages or in forms other than online. South Africa provides information in the local languages on Coronavirus websites and through WhatsApp.[59] Ireland has a range of online and print guidance for self-isolating, including recovering from Covid-19, caring for family members, and setting up community support systems for the vulnerable.[60] Leaflets are provided in Ireland, Spain[61] and Germany,[62] while South Korea provides leaflets at commercial facilities (including hotels and tourist facilities)[63] and in-person self-isolation guidance is provided when health workers make the first visit to people who are self-isolating. Guidance requires a multi-lingual, multi-modal approach with consistent messaging and media cooperation to ensure compliance.

Direct financial or material support varies widely between study countries. In the UK, Germany, Ireland, and Spain, support is mainly financial. Employees who are isolating are entitled to statutory sick pay, provided by national governments.[64][65][66] However, benefits differ, with the daily maximum levels of sick pay in Germany being equivalent to the UK's weekly rate. Moreover, many people do not qualify for even these benefits.[67] Thus, sick pay may not be enough to prevent the financially insecure from continuing to work, even when unwell. In these countries, it is also expected that those self-isolating will be supported by friends, family, or community groups.

In South Korea and South Africa, however, support is more material. Alongside various income support measures for those who are directly affected by Covid-19 (universal 'special disaster allowance' in South Korea, and national disaster benefit including augmented social welfare benefits or unemployment insurance funds in South Africa), the two nations provide food, drink, and accommodation to support those who are isolating. In South Korea, pre-prepared food and drink, along with other necessities, are delivered free to isolating homes by local councils.[68] In South Africa, those making use of isolation or quarantine facilities set up by the government are provided with free meals three times a day for the duration of their stay.[69]

Infection is most likely to be transmitted between individuals that live within the same household. In South Africa, those without sufficient capacity to isolate at home are provided with isolation facilities (for positive cases) or quarantine facilities (for contacts), and families may be housed together, though there is a stigma associated with infection which is inhibiting uptake of these provisions.[70] In Germany and Spain, dormitory facilities are provided on a case-by-case basis by local authorities. In Ireland, a self-isolation facility is provided by the central government, which is staffed by healthcare workers and has access to GP services.[71] In the UK, hotels have been made available as isolation facilities for the homeless when vulnerable individuals have been unable to stay with friends or relatives.[72] However this practice is not used to separate the infectious from co-habiting individuals as part of the UK's FTTIS system.

Discussion

The findings allow a series of lessons to be drawn for each of the study countries. First, no single country has implemented a comprehensive and fully functioning FTTIS system that could not be improved, possibly using measures demonstrated in other study countries. Each country has lessons it can learn from the others (see Table 3).

The South Korean system, reliant on digital technology, is felt by many citizens to be overly intrusive. Continued commitment to limiting the distribution and use of personal data may be necessary to maintain citizen goodwill. Ireland's early issues with case definitions demonstrates a need to engage with GPs and Primary Care physicians to gain an accurate picture of the early presentation of physical symptoms.

The UK, Germany, and Spain have scaled up their testing and tracing services, while the isolation and support measures have gaps that are mainly left to individuals and their communities to address. Some financial support is available in these countries, although

perhaps not at a sufficient level to allow the low paid to maintain isolation by remaining away from their work, for example in the UK. Direct material support is more rarely provided, and only on a case-by-case or special circumstances basis. This is likely due to political economy and cultural differences across study countries, but lessons from South Korea and South Africa show that more direct support measures could be used.

Table 3: Lessons for each of the six study countries, drawn from country comparisons

Country	Lessons
UK	● Consider more direct, material support to those isolating to promote compliance. Statutory sick pay may not be sufficient for many. ● Monitor compliance with isolation guidelines through phone calls and home checks ● Ensure better use and support of local testing and tracing resources
Ireland	● Ensure better early consultation with GPs/Primary Care physicians on case definition ● Devise a specific plan for testing high risk populations such as (i) meat plants and (ii) nursing homes

Germany	● Continue to ensure that test allocation is prioritised as outlined in the RKI testing strategy [74] ● Ensure that the local trace teams have access to sufficient skilled personnel
Spain	● Ensure sufficient testing capacity to detect rapid expansion of community transmission ● Ensure the hiring and training of a sufficient number of tracers to identify contacts in new virus outbreaks
South Africa	● Ensure testing capacity is targeted to areas of high transmission ● Leverage experience of contact tracing for TB by complementing skills of community health workers with digital technology

South Korea	● Ensure proximity alerts do not contain any identifiable, non-essential, personal information ● Provide an option of proximity alerts to be based on residence as well as current location

Finally, and perhaps most importantly, an additional 'evaluation' component in FTTIS systems seems warranted. A willingness to report data on each FTTIS system's performance at national and regional level would promote learning and improvement. Were each country to publish performance based on a standardised set of indicators (examples of which are suggested by the UK's Independent Scientific Advisory Group for Emergencies[1]), best practice would be more easily identified, nationally and internationally. This capacity to evaluate system performances is required not just for post-pandemic lessons but to identify best practices *during* the pandemic.

Conclusions

The development of a FTTIS system is key to limiting the spread of SARS-CoV-2. Over the course of the past few months, study countries have developed varying systems to test for cases and to trace contacts. The FTTIS framework provides a useful structure for comparison of these systems and for exchange of lessons across nations. A number of themes are apparent from the results presented here, from which conclusions are drawn.

As has already been stated, no single country has all components optimally aligned and effectively operating. However, this research has found some general lessons that can be shared across contexts (Fig.2). These general lessons provide clear guidance for the establishment of FTTIS systems in order to limit the transmission of SARS-CoV-2. It is important to also emphasise that these components are interrelated and rely upon one another – optimising one component may not be sufficient for overall improvements in the system.

Fig. 2: Summary of general lessons drawn from comparison of the six country contexts across the five components of FTTIS framework

Lessons from comparisons across the six study countries

Find: Combining active and passive case-finding approaches, identifying high-risk groups and using effective, tailored communication strategies are all imperative.

Test: The accuracy, utility, and reliability of tests depends on the procedures used for sample collection and handling, and processing. Leveraging existing laboratory networks enables rapid scale up of quality-assured tests.

Trace: Centralised, decentralised and digital contact tracing may be complementary, with careful consideration of how data can be shared across the FTTIS systems while protecting privacy.

Isolate: FTTIS systems should include some form of monitoring of individuals in isolation and quarantine to promote adherence and wellbeing.

Support: Offering practical, financial, and material support to individuals in isolation and quarantine promotes adherence and wellbeing.

With an emphasis on optimising all components of FTTIS systems, our final conclusion is the need for open, transparent evaluation and sharing of best practice. These FTTIS systems can evolve and improve continuously as the needs of pandemic response shift, and scientific understanding of Covid-19 develops. Given these lessons, both general and country-specific, demonstrated here, there are opportunities immediately available to develop and improve testing systems to limit the spread of SARS-CoV-2.

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