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COVID-19 surveillance and contact tracing in the WHO South-East Asia Region

Regional Review

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The review was contributed by various stakeholders, involved in COVID-19 surveillance and contact tracing, in all the Member States in WHO South-East Asia Region. In particular, officials of the Ministries of Health and other stakeholders in Indonesia, Nepal and Thailand participated in key informant interviews and focus group discussions. The officials of Ministries of Health in other countries have participated in the validation workshop, reviewed earlier version of this report and provided feedbacks.

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Executive summary

Introduction

The COVID-19 pandemic profoundly challenged and disrupted communities, health systems, and health workers throughout the world. There were more than 61 million COVID 19 cases and 808 750 COVID 19 deaths reported from 2020 until the end of 2022 in the World Health Organization (WHO) South-East Asia Region (SEAR). Surveillance and contact tracing are critical tools for infectious disease outbreak and epidemic response. WHO Regional Office for South-East Asia contracted the Nossal Institute for Global Health of the University of Melbourne to carry out the review of COVID 19 surveillance and contact tracing in the WHO South-East Asia Region, aiming to document lessons and to inform future efforts to further strengthen surveillance and contact tracing for epidemic- and pandemic-prone diseases in the Region.

This project aimed to describe varied country systems and experiences for COVID-19 surveillance and contact tracing across SEAR, how surveillance and contact tracing systems performed to respond to meet the evolving information needs of the pandemic response, and identify lessons learned to inform future strengthening of surveillance and contact tracing for epidemic and pandemic-prone diseases. This project also reviewed the performance and utility of digital technologies deployed to support surveillance and contact tracing for COVID-19, including an assessment of the benefits, challenges, and lessons learned to inform optimization of digital technology applications for surveillance and contact tracing in the future. Finally, this project reflected on the role of WHO in supporting surveillance and contact tracing capacities in SEAR Member States during the pandemic.

Methods

This project aimed to provide reflections and lessons learned that are relevant throughout SEAR, comprising the Member States Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Indonesia, Maldives, Myanmar, Nepal, Sri Lanka, Thailand, and Timor-Leste. A realist, retrospective process-orientated approach was used to explore the perceived utility and effectiveness of COVID-19 surveillance, contact tracing, and digital technologies initiatives and efforts. The pandemic was divided into three key phases to guide data collection and analysis, as follows:

The Alert Phase focused on the first few weeks of the pandemic, from the first international alerts and reporting about the emergence of a novel pneumonia (on or around 30 December 2019) until the WHO declaration that the novel coronavirus 2019 was a pandemic on 11 March 2020.

The Event Phase included the periods defined by the spread of the original variant of SARS-CoV-2, the emergence and spread of the Delta variant of concern, and the first few months following the emergence of the Omicron variant of concern and its descendant lineages (mid-March 2020 until early to mid-2022).

The Transition Phase was dominated by the continued spread of the Omicron variant of concern and its descendant lineages from early to mid-2022 onwards, until the WHO Public Health Emergency of International Concern declaration was rescinded on 5 May 2023.

To address the breadth of experiences and geographic settings in the region, a combination of region-wide and country-specific data collection methods were used. A narrative review of the peer-reviewed and grey literature on COVID-19 surveillance systems and contact tracing, including digital technologies, was conducted covering all SEAR Member States, as well as relevant regional and global analyses. Additionally, in-depth online and in-person qualitative interviews were conducted at national and subnational levels in Indonesia, Nepal, and Thailand. In-depth online interviews were also conducted with key regional stakeholders. Preliminary project findings were presented at an online regional validation meeting to seek further inputs and feedback.

Data analysis was thematic and structured according to pandemic phase, content area, and by country. Findings across countries and data collection methods were synthesized and harmonized to align with commonly used metrics and domains for appraising COVID-19 surveillance and contact tracing, including the contributions of digital technologies and role of WHO.

The project protocol was approved by the SEARO Research Ethics Review Committee (ID 2023.29.MC). All participants gave verbal informed consent to participate in interviews.

Key findings and recommendations

Public health responders throughout SEAR made extraordinary efforts amidst an unprecedented pandemic to implement surveillance and contact tracing to avert cases, deaths, and societal impacts of the pandemic. SEAR Member States achieved system-wide transformations and innovations that improved the performance and utility of COVID 19 surveillance, including the development of new, integrated information systems by in-country agencies during the height of the pandemic response. Similarly, countries made effective use of contact tracing along with other measures to contain and interrupt transmission, especially early in the pandemic period. Countries developed new approaches to scale contact tracing capacity through multisectoral collaboration, even if capacity was ultimately overwhelmed by surging case incidence. However, there were significant challenges affecting the performance and utility of surveillance and contact tracing for COVID-19.

Surveillance for early detection of emerging pathogens

Key findings: Pre-existing surveillance systems generally lacked flexibility to support early detection of COVID-19 cases at points of entry or in the community. Challenges included reliance on specific case definitions in pre-existing early warning alert and response systems (EWARS) that were oriented towards diseases with a different syndromic profile to COVID-19, inclusion of selected sentinel hospitals and laboratories in surveillance networks, lack of integration with point of entry surveillance and event-based surveillance, and lack of timely (daily or urgent) reporting. Instead, COVID-19 surveillance was operationalized through the launch of new, stand-alone COVID-19 surveillance systems, including point of entry surveillance, rapidly scaled laboratory-based testing, syndromic screening of higher-risk groups, active case surveillance in the community, and in some settings – wastewater surveillance. In some countries, strengthened early detection capacity was associated with stringent national responses that led to weeks or months of low or zero COVID-19 incidence, especially in 2020.

Recommendations for WHO: Critically review the approach to early warning surveillance, recognizing the need for multiple types of surveillance to enable early warning and detection of emerging pathogens, including strengthened subnational and national EWARS designed for detection of emerging pathogens in addition to known epidemic diseases, event-based surveillance, point of entry surveillance, and others as appropriate (potentially including wastewater surveillance). Strengthen WHO mechanisms and reduce barriers to support countries quickly and effectively within the first days and weeks of detection of an emerging or known priority infectious disease with epidemic or pandemic potential, including when uncertainty prevails about the magnitude of the threat.

Utility of different types of surveillance for decision making

Key findings: Case reporting was by far the most widely used surveillance type to inform decision making. However, the sensitivity, timeliness and completeness of case surveillance data were often constrained, especially by introduction of testing fees, exclusion of migrants, and limited access to testing. Health ministries and public health responders generally made best use of available data despite these limitations. However, major COVID-19 outbreaks were attributed to delayed case and cluster detection due to these factors.

Serosurveillance was implemented in several countries, mainly in the form of cross-sectional surveys and research studies rather than routine surveillance. Results from surveys and other studies were often reported with considerable time lags and several data quality issues were noted, which compromised utility for decision making in many settings. Serosurveillance was most useful for comparing estimated proportions of the population exposed to SARS-CoV-2 infection compared to estimates derived from case surveillance, and for comparing exposure to infection amongst different population subgroups. However, there were inherent uncertainties affecting the interpretation of serosurveillance data for an emerging pathogen, which constrained the utility of serosurveillance for forward planning.

Genomic surveillance capacities were substantially increased throughout the region during the COVID-19 pandemic. Genomic surveillance was useful for variant surveillance and cluster investigations if results were available within days, rather than weeks as was commonly reported to have occurred. In many countries, genomic surveillance made a limited contribution to variant surveillance in practice due to the substantial time lags in obtaining sequencing results and limited sampling.

Wastewater surveillance was implemented through research studies in several countries, and implemented in collaboration with public health authorities in several major cities in India. These studies and projects demonstrated considerable potential for wastewater surveillance to support early detection of impending infection waves and variant surveillance, as long as resources are available for timely analysis and reporting, and wastewater surveillance is aligned with overall surveillance objectives.

Recommendations for WHO: Support Member States to strengthen case surveillance for infectious diseases, especially sensitivity, coverage, and timeliness of surveillance. Critically review the utility of different surveillance types against surveillance objectives for different national contexts, and strengthen capacity for key surveillance types with demonstrated potential to substantially improve sensitivity, timeliness, and coverage of surveillance for emerging pathogens.

Integration of multiple data sources to improve utility of surveillance

Key findings: Progress towards integration of multiple types of surveillance was achieved in many countries, operationalized through integrated information systems developed in-country specifically for COVID-19 surveillance and with the goal of supporting decision making during the response. However, many key types of data remained outside of public health surveillance systems or were poorly integrated, especially data from private sector hospitals, healthcare clinics, and laboratories, and data from COVID-19 apps developed outside of the health sector.

Recommendations for WHO: Introduce and promote collaborative and integrated surveillance approaches in selected Member States where foundational aspects of surveillance, including case surveillance capacities, are well established. In Member States where foundational aspects of surveillance require strengthening, prioritize supporting investments in core surveillance functions while gradually introducing collaborative and integrated surveillance approaches, commencing with high priority infectious diseases or use cases.

Contribution of digital technologies to surveillance

Key findings: Most countries' pre-existing disease surveillance information systems could not be rapidly adapted to incorporate COVID-19 surveillance. Instead, most countries initially reverted to familiar, generalist tools for managing data and communications, like Microsoft Excel or WhatsApp, in the alert phase of the pandemic. In some cases, generalist tools were used throughout most of the pandemic, at least at some levels of the health system. Many countries achieved rapid and remarkable transformations of their surveillance information systems by developing new, custom solutions in-country. Some countries are now expanding pandemic-era COVID-19 surveillance information systems to support surveillance and data integration for a wider range of health conditions and events. Despite their widespread use, uncertainty persists about the effectiveness of different types of digital technologies to support decision making during the pandemic response. This includes the appropriate balance between encouraging subnational-level innovation in digital health capacity, whilst retaining interoperability and capacity for rapid integration at national level when required.

Recommendations for WHO: Recognizing that nationally developed information systems were better suited to country needs, support Member States to enhance national capacities to develop fit-for-purpose surveillance and information systems and other digital technologies that are interoperable with other national systems and retain capacity to flexibly integrate familiar, generalist tools when needed.

Contact tracing before onset of widespread community transmission

Key findings: Contact tracing was initiated rapidly in some settings, and with some delay in others. Findings from a range of settings confirm that contact tracing is an effective intervention that can interrupt transmission chains when contact tracing and associated measures (e.g. quarantine) can be implemented comprehensively. Community support for contact tracing was higher when implemented in conjunction with other stringent measures that led to elimination of transmission for extended periods.

Recommendations for WHO: Continue to strongly promote and support early and comprehensive implementation of contact tracing to interrupt transmission chains during outbreaks of epidemic and pandemic-prone directly transmissible infectious diseases. Contact tracing is particularly effective and important when countermeasures such as vaccines are not (yet) available, and as part of comprehensive and rapidly initiated strategies to suppress and eliminate local transmission.

Contact tracing during widespread community transmission

Key findings: Contact tracing objectives were often not clearly defined for different pandemic phases. Consistently across settings, contact tracing was ineffective at moderate to high COVID-19 case incidence, while absorbing substantial resources. Surge workforces were frequently mobilized through a range of mechanisms, but did not allow contact tracing capacity to be fully maintained. Guidance from WHO was often interpreted as emphasizing the importance of continuing contact tracing despite the reality of overwhelmed capacity. This unduly increased the workload of public health responders without supporting the effectiveness of the response overall.

Recommendations for WHO: Develop clear guidance for Member States for a staged pathway from contact tracing through to transitioning to alternatives to contact tracing during periods when capacity to adequately perform contact tracing is exceeded. This includes guidance for appraising the likely effectiveness of alternative strategies, such as active case surveillance or prioritization of immunization programs and other countermeasures, compared to contact tracing in specific contexts. As part of this, develop indicators for contact tracing performance that can be used to appraise in real time whether contact tracing efforts contribute to the goal of interrupting transmission chains over different pandemic phases, and when to switch to alternative strategies.

Resources and collaboration required to effectively implement contact tracing

Key findings: Contact tracing is only effective if surveillance capacities are adequate and when contact tracing is implemented with a suite of complementary measures. This includes testing capacity, data systems to enable rapid identification, notification, and tracking of contacts and linking their test results, and capacity to provide social, logistical, and financial support for facility-based or home-based quarantine. Multisectoral collaboration went some way to addressing these requirements, and is essential as part of a comprehensive contact tracing strategy. However, multisectoral collaboration also introduced other challenges. Despite efforts to mobilise surge workforces, there was no apparent model to sustain contact tracing capacity at high case incidence in any setting.

Recommendations for WHO: Tailor guidance on contact tracing implementation to the range of contexts in SEAR, including settings where facility-based or home-based quarantine is challenging or infeasible to implement at scale, and where social and financial support for contacts are limited. Review and appraise global research on community-based contact tracing initiatives used during the COVID-19 pandemic that reduced the burden of contact tracing for the public health workforce.

Contribution of digital contact tracing technologies designed for use by the public

Key findings: Despite their ubiquity, this project found no evidence for the public health effectiveness of exposure-tracking smartphone apps designed for use by the public to support contact tracing for COVID-19. This includes smartphone apps with proximity- and location-based tracing functions, as well smartphones with QR code venue check-in functions. Published literature originating from SEAR and other regions indicates significant concerns related to privacy, security, technical functions, and community trust when using contact tracing apps. Available data indicates that uptake and use of these apps was typically too low to meaningfully contribute to disruption of transmission chains at population level. Furthermore, contact tracing data from these apps was mostly unavailable to professional contact tracers. Apps with contact tracing features were more commonly used if they incorporated other features, such as displaying vaccination status. However, in these instances, contact tracing features were not widely known or used, thus they did not contribute to contact tracing performance.

Recommendations for WHO: Contact tracing guidance should reflect that there is no clear evidence to support the use of the current generation of digital contact tracing apps designed for use by the public as part of contact tracing strategies. Barring major innovation, pronounced changes in community trust, and more scalable models for contact tracing in general, these tools are unlikely to support the effectiveness of contact tracing in future epidemics, and should not be prioritized for further investment.

Contribution of digital technologies designed for use by public health responders

Key findings: Externally provided specialist digital contact tracing software, including Go.Data, were not fit for purpose and were not widely implemented at national level in SEAR. In some cases, early efforts to pilot such systems absorbed significant resources, but these systems were withdrawn from use within the first months of the pandemic due to lack of suitability and technical support. Many countries made considerable progress developing new data and information systems to support contact tracers and public health professionals to manage contact tracing data. These systems were most useful when fully interoperable with surveillance, vaccination, and other key datasets.

Recommendations for WHO: Support Member States to enhance in-country capacity to develop and deploy contact tracing data management systems, which can be flexibly scaled and are interoperable with surveillance and other key systems, as a core element of public health response capacities. Develop evaluation protocols that can be embedded into future deployments of digital contact tracing technologies for use by public health responders, to strengthen the evidence base for the contribution of digital technologies to contact tracing workflows and contact management and follow-up.

Leadership and system capacities to support surveillance and contact tracing

Key findings: Prior investments in human resources, health system infrastructure, and pandemic preparedness were critical for enabling timely and effective COVID-19 surveillance and contact tracing. The COVID-19 pandemic underscored the need for enhanced health financing, streamlined data linkage and administrative processes within health systems, and regular workforce training to maintain effective response capabilities. Investments in digital technologies including interoperable information systems were important for strengthening surveillance and contact tracing for COVID-19, but digital technologies did not overcome human resources bottlenecks. Political considerations led to under-reporting or delayed reporting of COVID-19 cases in some contexts and time periods – demonstrating that timely outbreak and pandemic response goes beyond the performance of surveillance systems. Decisions made by government leaders enhanced or challenged the generation and utilisation of high-quality surveillance and information systems throughout the pandemic period. Epidemic literacy and public health awareness more generally amongst non-health sector decision-makers was considered a key determinant of the effectiveness of local and national responses.

Recommendations for WHO: Advocate for increased investment in human resources and stable health financing mechanisms post-pandemic, ensuring readiness for future health emergencies at both national and sub-national levels. As part of this, establish mechanisms and platforms to routinely engage non-health sector leaders and decision-makers in existing pandemic preparedness activities, to strengthen institutional-level epidemic and pandemic literacy beyond the health-sector.

Acronyms and abbreviations

AIHSP	Australia Indonesia Health Security Partnership
API	Application programming interface
CDC	United States Centers for Disease Control
COVID-19	Novel coronavirus disease 2019
DDC	Department of Disease Control (in Thailand)
DHIS2	District Health Information System 2
DPRK	Democratic People's Republic of Korea
EMR	Electronic Medical Record
ERC	Ethics Review Committee
EWARS	Early Warning, Alert and Response System
GISAID	Global Initiative on Sharing All Influenza Data
GPS	Global Positioning System
ICTA	Information and Communications Technology Agency (in Sri Lanka)
IHME	Institute for Health Metrics and Evaluation
IHR	International Health Regulations 2005
ILI	Influenza-like Illness
IMU	Information Management Unit (in Nepal)
INSACOG	A consortium of government ministries and agencies established the Indian SARS-CoV-2 Genomics Consortium
IT	Information Technology
NAR	New All Record system (in Indonesia)
NGO	Non-government organization
NNDSS	National Notifiable Disease Surveillance Systems
PCR	Polymerase Chain Reaction
PHEIC	Public Health Emergency of International Concern
PHSM	Public health and social measures
PPKM	*Pemberlakuan pembatasan kegiatan masyarakat*, Enforcement of Restrictions on Public Activities (in Indonesia)
RDT	SARS-CoV-2 antigen-detection rapid diagnostic test
RT-PCR	Real-time polymerase chain reaction
SARI	Severe Acute Respiratory Infection
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
SEAR	World Health Organization South-East Asia Region
SEARO	World Health Organization South-East Asia Regional Office
WHO	World Health Organization
VHV	Village Health Volunteer

1. Introduction

1.1. Background and rationale

The COVID-19 pandemic profoundly challenged and disrupted communities, health systems, and health workers throughout the world. There were more than 61 million COVID-19 cases and 808 750 COVID-19 deaths reported from 2020 until the end of 2022 in the World Health Organization (WHO) South-East Asia Region (SEAR) (1). The COVID-19 pandemic also led to widespread disruption of efforts to prevent, detect, and respond to other high priority endemic infectious diseases in the region (2). To respond more effectively to the ongoing COVID-19 pandemic and prepare for future health emergencies, national and regional health stakeholders must work together to identify the key lessons learned from the COVID-19 pandemic and prioritize actions to further strengthen health security and health system resilience.

Surveillance and contact tracing are critical tools for detecting and responding to infectious disease outbreaks, epidemics, and pandemics. Surveillance is the systematic, ongoing collection, analysis, dissemination, and use of data to inform public health responses (3). Contact tracing involves the identification, assessment, and management of those who have been exposed to an infectious pathogen and is a key first-line response to interrupt chains of transmission. The target events and populations of surveillance, as well as the intensity and targets for contact tracing approaches, can vary over different phases of an outbreak and pandemic response. The scale of contact tracing and the associated resource demands during the COVID-19 pandemic far exceeded any previous experience in the region, or globally. Despite efforts to mobilize large scale surge capacities and the engagement of other sectors and communities for contact tracing, capacities were eventually overwhelmed in most countries. Digital technologies became increasingly prominent as potential avenues for scaling up and increasing timeliness of contact tracing as well as increasing access to and utility of surveillance data for decision making.

Prior evaluations and reviews related to COVID-19 in WHO SEAR Member States have covered the entire range of pandemic response pillars, with surveillance and contact tracing being one of many aspects only covered briefly (4,5) or in other cases, have focused more on public policy (6). Some regional consultations were conducted early in the pandemic but were focused on reviewing 'lessons learned' regarding health systems strengthening and health security more broadly (7), rather than in-depth evaluations on surveillance and contact tracing for COVID-19. Where evaluations of surveillance and contact tracing for COVID-19 in WHO SEAR have been conducted, focus has been on specific aspects, e.g. point of entry screening (8), or selected quantitative indicators used at provincial/sub-national levels (9). There has been no comprehensive review at national or regional level of surveillance and contact tracing for COVID-19 in SEAR, which would be useful for collating and applying lessons towards strengthening policy, planning, and future evaluative efforts and informing WHO activities in these technical areas across the region (and potentially beyond).

1.2. Aims and objectives

This project aimed to explore how information needs for public health decision making evolved during the COVID-19 pandemic, how surveillance and contact tracing systems performed and were adjusted to meet the evolving needs of the pandemic response, including through use of associated digital technologies, and how these systems could be further strengthened for future pandemics and epidemics. The objectives were:

- **Objective 1**: To describe country systems and experiences for COVID-19 surveillance and contact tracing across SEAR. This includes reviewing performance against programmatic objectives, the relevance of WHO's technical contribution, and identifying lessons learned to inform future strengthening of surveillance and contact tracing for epidemic and pandemic-prone diseases.
- **Objective 2**: To review application and utility of digital technologies for COVID-19 surveillance and contact tracing across SEAR. This includes the assessment of benefits, challenges, and implications, and to identify lessons learned to inform optimization of digital technology application for surveillance and contact tracing, including potential roles of WHO.

2. Methods

2.1. Key definitions

Surveillance: Public health surveillance is "the ongoing, systematic collection, analysis, and interpretation of health-related data essential to planning, implementation, and evaluation of public health practice" (10). An initial list of COVID-19 surveillance types was compiled, drawing on WHO interim guidance for public health surveillance of COVID-19 (last updated February 2022) (11) and COVID-19 surveillance sources defined in a National Academy of Sciences consultation on evaluating COVID-19 surveillance for decision making, namely: reported COVID-19 cases; reported COVID-19 deaths; reported COVID-19 hospitalizations; hospital capacity (including, for example, admissions to intensive care, staff absences, total bed occupancy); serosurveillance; genomic surveillance (including variant surveillance); and event-based surveillance (16). Other types of surveillance, including community-based syndromic and risk-based surveillance, wastewater surveillance, and point of entry surveillance, emerged through the literature review and key informant interviews as key types or subtypes of COVID-19 surveillance with relevance to decision making.

Digital technologies for surveillance: Digital technologies support various aspects of public health surveillance, from data collection at the community or user-level, through to enabling automated analyses and alerts. Digital technologies used for COVID-19 surveillance have included tools requiring user interaction amongst the general public (such as smartphone applications for self-assessment of symptoms or contact tracing), and technologies that did not rely on user participation amongst the general public (e.g. closed-circuit television (CCTV), social media or artificial intelligence/automated data analysis tools) (12). Many digital technologies for surveillance, including a wide range of data management and analysis software, were designed primarily for use by public health officials. Many of these technologies were developed or adapted specifically for COVID-19 surveillance. Some digital technologies for surveillance also included contact tracing functions.

Contact tracing: Contact tracing is a set of related activities implemented as part of outbreak and pandemic response, which aims to interrupt chains of transmission. Contact tracing can be described as comprising four main processes:

- Case identification and notification (note that this process is the same as case surveillance);
- Case investigation (i.e., identification of contacts of cases);
- Tracking and notification of contacts;
- Contact follow-up, including testing, quarantine, and health monitoring, as appropriate.

Digital technology for contact tracing: Digital contact tracing technologies for COVID-19 included smartphone applications, physical tokens, or wearable devices. The types of technologies that support contact tracing include Bluetooth proximity tracing, Quick Response (QR) code location check-in, GPS tracking and radio frequency signals (13).

2.2. Scope and approach

A realist, retrospective process-orientated approach was used. The 'realist' emphasis enabled an applied, context-relevant focus, with exploration of perceived utility and effectiveness of COVID-19 surveillance, contact tracing and digital technologies initiatives and efforts, in relation to evolving COVID-19 response phases and policy contexts. Perspectives were acquired primarily from senior and mid-level technical public health responders in three case study countries. The process orientation aimed to determine whether COVID-19 surveillance and contact tracing activities, including digital technologies, had been implemented as intended and led to anticipated outcomes. The process-oriented approach aligns with the goals of WHO Intra Action and After-Action Reviews, and enabled a practical, learning orientation.

In this project, the COVID-19 pandemic period was divided into three key phases to guide data collection and analysis. These phases align with the Alert, Event, and Transition phases and draw on the concept of multi-source surveillance first articulated in the Asia Pacific Strategy for Emerging Diseases and Public Health Emergencies - Third Revision (APSED III) (14), and further adapted by SEARO (Figure 1). This concept was extended to include analysis of the objectives, performance, and utility of contact tracing at the different phases of the pandemic.

Figure 1: Multisource surveillance over different phases of the health emergency cycle

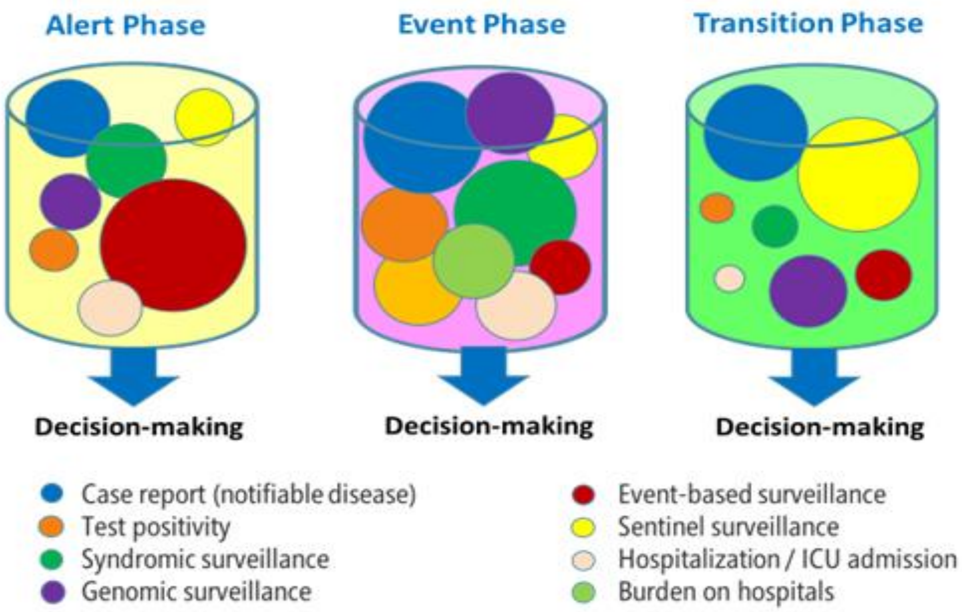


Figure 1 note: This image was derived from a publication by WHO SEARO (15).

Alert phase: The *alert phase* spanned the first few weeks of the pandemic, from the first international alerts and reporting about the emergence of a novel pneumonia (on or around 30 December 2019) until the WHO pandemic declaration on 11 March 2020. This phase included the declaration of a public health emergency of international concern (PHEIC) on 30 January 2020.

Event Phase: The *event phase* spanned most of the pandemic period, from the spread of the original strain of SARS-CoV-2, through to the emergence and spread of variants of concern, most notably the Delta and Omicron variants of concern. Though timelines vary between countries, in general this phase was considered to have lasted from mid-March 2020 until early to mid-2022.

Transition Phase: The *transition phase* was defined as the period dominated by the continued spread of the Omicron variant of concern and its descendant lineages, and the scaling down or withdrawing of emergency response measures, from early to mid-2022 onwards, until the WHO PHEIC declaration was rescinded on 5 May 2023. The timing of the transition phase varied between countries, as some countries shifted their response measures earlier than others in the region. In general, beyond mid-2022, the increasing availability and uptake of COVID-19 vaccines and national policy changes led to reduced testing and contact tracing for COVID-19. As with many countries across the world, the reporting of COVID-19 cases to WHO declined substantially in SEAR Member States from early 2022 onwards, reflecting reduced surveillance and the transition to non-emergency settings.

Given the complexity and magnitude of the pandemic response, it was not possible to comprehensively evaluate all aspects of surveillance and contact tracing over all pandemic phases, including the digital technologies that supported these functions. Instead, this project focused on clear examples of best practice and common challenges from countries in the region, to inform recommendations for strengthening efforts within and across SEAR Member States.

2.3. Data collection and analysis

2.3.1. Settings

The project aimed to provide reflections and lessons learned that are relevant throughout SEAR, comprising Bangladesh, Bhutan, Democratic People's Republic of Korea (DPRK), India, Indonesia, Maldives, Myanmar, Nepal, Sri Lanka, Thailand, and Timor-Leste.

As described in section 2.3.2. below, a literature review of peer-reviewed studies and technical reports was conducted covering all SEAR Member States. A regional validation meeting and interviews with regional key informants were also conducted. Additionally, in-depth qualitative interviews were conducted at national and subnational levels in Indonesia, Nepal, and Thailand. These countries were selected through discussions with WHO stakeholders, based on the following considerations:

- Representation of the range of COVID-19 epidemic contexts in SEAR, especially during 2020 when surveillance and contact tracing systems were being initiated. For example, Thailand was the second country in the world to report a COVID-19 case to the WHO in January 2020, though had relatively few locally acquired cases of COVID-19 throughout 2020 (1). Several other SEAR Member States also reported zero or low incidence of COVID-19 in 2020. In contrast, Indonesia and Nepal, like other SEAR Member States, experienced substantial waves of community transmission of COVID-19 during 2020 (1).
- The introduction and scale up of digital technologies for COVID-19 surveillance and contact tracing during the pandemic, and their collective experiences being reflective of the range of tools used in the region.
- Inclusion of countries with decentralised models of government to enhance exploration of differences in national and subnational responses.
- The availability of published literature and technical reports comprehensively describing the national COVID-19 response, enabling the project team to focus on specific topics of interest in detail.

- Previous in-country operational experience which enabled project team to leverage existing partnerships and experience with Ministries of Health and other stakeholders to facilitate rapid mobilisation of senior personnel as key informants, in collaboration with WHO Country Offices.

2.3.2. Data collection

Literature review

A narrative review of the peer-reviewed and grey literature on COVID-19 surveillance systems and contact tracing, including digital technologies, was conducted. The non-systematic iterative literature search was conducted using PubMed and Google Scholar for peer-reviewed literature, as well as open web searches for non-scholarly documents. Key search terms related to COVID-19 surveillance included “COVID-19” and “surveillance”, “testing”, “case”, “mortality”, “deaths”, “reporting”, “notification”, “cluster investigation”, “point of entry”, “hospital*”, “seroprevalence”, “serosurveillance”, “early warning”, “early detection”, “hospital capacity”, “nowcasting”, “genomic”, “wastewater”, “sewage”, and others. Key search terms related to contact tracing included “contact tracing”, “tracing”, “tracking”, “proximity tracing”, “location check*in”, “QR check*in” and others. Key terms related to digital technologies included “digital tech*”, “electronic information system”, “smartphone app*”, “EWARS”, “GPS tracking”, and others. Searches were conducted separately for each SEAR Member State, as well as for the region. Titles and abstracts of retrieved literature sources were screened, and an informed selection of high-quality and informative articles was conducted. Reference lists of key articles were reviewed to identify additional relevant literature. Technical reports, presentations, and other types of grey literature provided by Ministries of Health, SEARO, and WHO Country Offices in Indonesia, Nepal, and Thailand were also reviewed.

Noting that the literature review sought to retrieve data for all SEAR Member States, no peer- -reviewed articles or technical reports could be retrieved that described COVID-19 surveillance or contact tracing in the DPRK. According to the WHO COVID-19 dashboard, DPRK had not reported any laboratory-confirmed COVID-19 cases or deaths to WHO as of 30 June 2024 (1).

Qualitative data collection

Primary data for each case study country were collected through semi-structured key informant interviews conducted online and in-country in Indonesia, Nepal and Thailand from September to November 2023. In each country, members of the project team conducted interviews with government stakeholders at national and subnational level, WHO Country Office representatives, and with non-government organizations (NGOs) that contributed to COVID-19 surveillance and contact tracing efforts. Government stakeholder participation was facilitated by the national or provincial-level health department or unit, in coordination with WHO Country Offices. Interviews with NGOs were based on direct invitation by the project team, and often included other colleagues in addition to the lead interviewee. Project team members comprised epidemiologists, public health specialists and qualitative health researchers with considerable experience working in the South-East Asia region. For each interview, one project team member with training in epidemiology or public health and one team member with training in qualitative research methods participated. For most interviews, two project members with these complementary skills participated. A small number of interviews in Nepal were conducted by only one project team member due to a travel disruption affecting the second team member.

Selected key stakeholders in each country were invited to participate in an online interview prior to the project team’s arrival in country. Participants for the online interviews were selected and invited based on their seniority and technical expertise as recommended by WHO Country Office personnel, their previous collaboration with members of the project team, or both. These interviews aimed to support the formative review of key events and aspects of the pandemic response in each country, identify types of COVID-19 surveillance and contact tracing that were in place, and describe the types of digital technologies used to support surveillance and contact tracing functions. To guide country-specific enquiries, salient events were discussed that represented key moments or periods during each phase of the pandemic response. These events were used to structure discussion and stimulate recall during key informant interviews.

Interviews held in-country were conducted face-to-face, mostly in meeting rooms located at the workplace of interviewees. Almost all in-country interviews were conducted as group discussions despite being initially planned as one-to-one encounters. This approach was opportunistically pursued and considered to have usefully added to the nuance and complexity of the data generated. For instance, in Thailand, each subnational interview included at least five respondents. This supported the rapid validation of key insights generated by the participants as the facilitator was able to gain real-time clarification and elaboration from multiple perspectives. Where group interviews occurred, the interviewers sought the views of all group participants. Notably, in most group interviews, multiple participants with different position levels and responsibilities contributed to the discussions. However, as group members often had different levels of seniority, this may have influenced participation. Some in-country interviews were completed within approximately 1.5 hours, and several in-country interviews were conducted over the course of a half-day or full-day, with multiple breaks, particularly when many interviewees participated in a group interview. Online and some in-country interviews were conducted in English. Live simultaneous interpretation was provided by professional interpreters for interviews where participants preferred to converse in national languages. Some interviews in Indonesia were conducted directly in Indonesian by a native speaker who was a member of the project team, however an interpreter provided live simultaneous interpretation for the second project team member who was conducting the interview.

Primary data were also collected through four online interviews with four key informants at regional level, comprising current and former SEARO staff and consultants with key roles in the pandemic response. These interviews were conducted as one-on-one interviews in English.

For all online and in-person interviews, a comprehensive, semi-structured topic guide was used and refined iteratively based on the emerging data. All participants gave verbal informed consent to participate in the interview after being provided with a written copy of the project information sheet, which was translated into national languages. A verbal summary of the project information sheet and consent process was also provided. For group interviews, informed consent was sought and obtained for all group members who participated. In some group interviews, the primary interviewee invited many of their colleagues to join in the meeting room where the interview took place, but these colleagues acted as observers and did not participate in the interview. Individual informed consent was not obtained from all observers in this case; instead, the project information sheet was shared widely and verbally summarized, and the assent of the observing group was obtained. As the observers were invited to join by the primary interviewees, no adverse impacts on participant confidentiality arose through the group interview process. Additional consent was sought to audio record interviews online and in-person. For interviews conducted in English, the conversations between the interviewer and interviewees were recorded directly. For interviews conducted in other languages, the live simultaneous interpreter was recorded to capture the audio in English for the transcribing purposes.

A summary of the number of in-country interviews at different jurisdictional levels is presented in Table 1.

Table 1: Summary of key informant interviews completed

Country	National government	Subnational government	Non-government organisation	Total
Indonesia	4	5	4	13
Nepal	7	6	3	16
Thailand	8	2	1	11
Regional	N/A	N/A	4	4

Note: the data in Table 1 represents the number of interviews, not the number of participants in each interview. As noted in the main text, many interviews had several participants.

2.3.3. Data management and analysis

The findings of the literature reviews were used to inform the development of the topic guide, and were used to extend, triangulate, and contextualize the findings of the qualitative data collection.

Automatic transcription software (Otter.ai Inc) was used where recordings were of sufficient clarity to generate quality transcripts. Automated transcription was only possible for English language audio material, spoken by the interviewee directly, or by the interpreter. Automated transcripts were reviewed and edited for accuracy and clarity by interviewers. Where the quality of the audio recording was insufficient for automated transcription, or the participant/s did not consent to being audio recorded, comprehensive debrief notes were produced by the interviewers as soon as practical after the interview. Debrief notes were also prepared for all interviews with good-quality audio recordings to supplement and back-up the transcript and aid analysis and interpretation.

Formal qualitative analysis of the transcripts and debrief notes was undertaken. Analysis was thematic and structured according to phase, content area (i.e., surveillance and contact tracing) and specific events. An *a priori* thematic structure for coding the dataset within each content area of focus was developed based on the literature review and debrief notes. All project team members were involved in the process of generating the coding frame, which was then piloted by coding two transcripts per country which led to subsequent updates and adjustments to the coding frame. The coding frame stayed open through the coding process such that new codes were created where new content could not effectively be coded by the initial codes, with each addition to the coding frame agreed by all coders and previous coding efforts revisited as considered necessary. Each country dataset was independently coded by a different team member with their coding reviewed throughout the process through regular 'coding meetings' where examples of coding processes were discussed and compared across coders (and thereby countries). The final coded dataset and topline findings for each country were presented to the whole project team for feedback and cross checking before finalization. Analysis was conducted using Dedoose (Version 9.0) qualitative analysis software, which is cloud-based and facilitates team-orientated working. Key findings from the three countries were then synthesized in accordance with the project objectives, whilst also highlighting other notable findings.

The findings from the literature review and qualitative data analysis were then combined and synthesized in line with the coding frame. Preliminary findings from the literature review and qualitative data collection were presented by the project team to a SEARO-convened, online meeting attended by key stakeholders from WHO Country Offices and Ministries of Health from SEAR Member States. In breakout discussions, responses of stakeholders to the key findings were captured, with confirmatory and contradictory examples noted. This validation measure informed the final data synthesis and interpretation.

Thematic results are presented in sections 3 and 4 below, including illustrative quotes to support the interpretation provided. Direct quotes are attributed to the participant who provided them according to their country or regional role (i.e. Indonesia [I], Nepal [N], Thailand [T], regional [R]), and the numerical order assigned to their interview during data collection (e.g. N.1). This approach aims to anonymize the identity of quoted participants in this report while broadly reflecting the data breadth and source(s). Data retrieved from the literature review is acknowledged through a citation to the source, listed in the references. Findings reported without citations are attributable to the qualitative component, including in-country and regional interviews, and the regional validation meeting. Where possible and to support data interpretation, the qualitative data source is broadly described (e.g. the country/ies to which the finding applies), while protecting anonymity of participants.

2.4. Ethics

The project protocol, including the qualitative data collection component, was approved by the SEARO Research Ethics Review Committee (SEARO-ERC) on 20 September 2023 (project ID 2023.29.MC). Verbal informed consent was sought from all participants to participate in online and/or in-person interviews. The consent process was documented by the interviewers. Additional verbal consent was sought to audio-record interviews. Plain language summaries of the project were made available to participants in local languages. Participants were free to withdraw their consent to participate, including withdrawing consent for audio-recording of the interview, at any time.

3. COVID-19 surveillance

This section presents the findings regarding the types, performance, and utility of COVID-19 surveillance.

3.1. Description of COVID-19 surveillance

This section reviews the types of COVID-19 surveillance that were implemented in WHO SEAR, with reference to the pandemic phase(s) in which different types of surveillance were used, where available or relevant. It also describes the coordination structures, information systems, and workforce through which surveillance was implemented.

3.1.1. Surveillance objectives

Surveillance was considered an important part of the pandemic response in all countries, according to in-country and regional interviews.

"Surveillance was always important. We knew that in each phase of pandemic, it was very crucial to have surveillance and get evidence. So in the very beginning, when there were a few cases, we could contain those cases as needed. And later on, when there were more cases, we again demand that we need more surveillance activities to contain more cases" (N.1).

Surveillance objectives varied throughout the different phases of the pandemic. Common objectives included:

- Initially, the primary objective was early detection and containment of outbreaks, and close monitoring of travellers and those exposed to imported cases, to prevent community transmission.
- As community transmission became established (the timing of which varied considerably between countries), surveillance objectives typically shifted to monitoring and tracking of spread within the community, identifying and responding to high transmission zones, understanding transmission dynamics, and adjusting public health measures accordingly.
- As surveillance data coverage and availability improved, surveillance objectives included guiding implementation of public health and social measures including 'lockdowns' and other social distancing initiatives, and adjusting strategies based on timely data. Earlier in the pandemic, these measures had been implemented rapidly without necessarily being closely guided by surveillance data.
- During the event phase, surveillance objectives included supporting planning, predicting, and managing hospitalizations and intensive care admissions, and planning healthcare resourcing and isolation centre availability (when used).
- With the development and rollout of vaccines, surveillance objectives included monitoring vaccination rates and effectiveness, understanding vaccine impact on transmission and disease severity, guiding booster shot policies, and managing public expectations.
- Later in the pandemic and towards the transition phase, surveillance aimed to inform decision-making about safe reopening.
- Through the transition phase, surveillance objectives increasingly focused on long-term monitoring for COVID-19 and preparedness for future health crises. This included establishing sustainable surveillance systems for ongoing monitoring and rapid response capabilities.

The extent to which surveillance objectives were specifically articulated varied between countries. In some countries, surveillance was clearly linked to the goal of averting or eliminating community transmission, particularly during the first year of the pandemic. Most countries also aimed for early detection and containment of outbreaks, to monitor incidence of cases, hospitalizations, and deaths, and to detect, contain, and monitor emerging variants. There were variations between countries in terms of whether surveillance objectives were modified prospectively, in line with a recognized shift in the pandemic response phase, or somewhat retrospectively, in response to severe resource constraints amidst surging cases.

For example, in **India**, revised operational guidelines for COVID-19 surveillance were published in June 2022, during a period of sustained low incidence of cases, hospitalizations, and deaths. The revised strategy notes that this context allows for a renewed focus on early case detection and isolation, and detection and containment of outbreaks of emerging SARS-CoV-2 variants, as well as monitoring epidemiological trends (16).

National COVID-19 surveillance guidelines articulated COVID-19 surveillance goals, however key informants in case study countries reported that changes to surveillance goals were not always effectively communicated and implemented at all levels of the public health response.

Thailand offers a case study of clear articulation of prospective and responsive changes in surveillance goals over different phases of the pandemic, with surveillance objectives clearly linked to data and information needs for decision making as part of the overall response strategy (Box 1).

Box 1: Surveillance goals during the COVID-19 pandemic in Thailand

National-level stakeholders identified three key phases of Thailand's COVID-19 response, with corresponding surveillance goals.

Phase 1 (2020): 'Zero COVID-19'. For most of the first year of the pandemic, when cases were mainly imported, containment of clusters and interruption of transmission chains was emphasized. This phase was resource intensive, with a national lockdown followed by targeted lockdowns implemented periodically. Surveillance goals included early and complete case finding, implemented through comprehensive point of entry surveillance and quarantine measures, active case finding and investigations in the community, and timely access to and turnaround times for testing (facilitated through the "one lab, one province" policy). During this phase, there were 100 days without recorded community-acquired cases after interruption of transmission chains associated with the first detected community-acquired cluster of cases in March 2020. COVID-19 cases continued to be detected amongst quarantined international arrivals during this time.

Phase 2 (2021): 'Living with COVID-19'. From late 2020/early 2021, there was sustained community COVID-19 transmission. Surveillance goals shifted to identifying cases and deaths, and to enable a 'matrix' system of local and provincial level restrictions to suppress transmission. This allowed for stratification of surveillance activities according to risk level, for example active surveillance in the community was used in Bangkok, whereas lower risk rural areas primarily relied on passive hospital surveillance. Provinces were empowered to maintain surveillance and other activities targeting a higher level of stringency than the national policy, for example some provinces maintained 'zero COVID-19' goals for longer than nationally. The national government recognised the need to support economic stability and growth, especially imports and exports, which required stabilizing outputs in factories and the manufacturing sector. Correspondingly, the "bubble and seal" surveillance approach was launched, which used symptom screening and active case finding via frequent testing within key workplaces, with testing to exit the 'bubble'. Once the vaccination campaign began in February 2021, surveillance data was also integrated with vaccination data to appraise transmission risks. Once SARS-CoV-2 rapid antigen-detection diagnostic kits became widely available, a call centre was established for cases in the community to self-report their case status.

Phase 3 (2022): 'Living with COVID-19' and transitioning to post-pandemic. During this phase, there was greater emphasis on rapid antigen testing, continued vaccination, and risk mitigation for opening borders. During this phase, surveillance goals shifted to focus on case detection in high-risk individuals and communities (e.g. aged care homes), monitoring vaccination coverage, supporting decision making relating to reducing and removing restrictions, and risk mitigation for returning travellers.

3.1.2. Types of surveillance

Case surveillance

Case surveillance was the mainstay of COVID-19 surveillance programs throughout WHO SEAR, and the primary surveillance indicator across countries.

Case surveillance was mainly based on molecular diagnostic testing of patient samples (predominantly nasopharyngeal samples) in public and private laboratories by polymerase chain reaction (PCR). In some cases, serology testing was used to diagnose recent SARS-CoV-2 infections. During the pandemic, SARS-CoV-2 antigen-detection rapid diagnostic tests (RDTs) became increasingly available for point-of-care or self-testing. Some countries incorporated self-reported or point-of-care-reported positive RDT results as part of COVID-19 surveillance, but this was much less consistent than reporting of laboratory-confirmed cases.

In several countries in the region, COVID-19 surveillance systems were rapidly initiated in the alert phase of the pandemic. For example:

- **Thailand** was the first country in the world outside of China to detect a COVID-19 case, in a recent arrival from Wuhan, China, in January 2020. All international arrivals from Wuhan, China, were screened for COVID-19 commencing 3 January 2020, and genomic sequencing confirmed a SARS-CoV-2 infection for a recent arrival, which was declared on 13 January 2020. Thailand's national COVID-19 surveillance system (which aimed to detect community-acquired cases as well as cases amongst international arrivals) was operationalised in February 2020 (17), and comprised a standardised screening form with key demographic, medical and surveillance-related information (17). COVID-19 surveillance was nationally coordinated and implemented in close alignment with the national strategy by provincial governments (18).
- In **Sri Lanka**, definitions for cases and protocols for testing were developed before the first case was reported in-country (19). Following the first locally acquired infection case (11 March 2020), Sri Lanka responded with strict public health measures including compulsory quarantine for returning citizens, compulsory isolation of cases in dedicated hospitals, scale up of testing capacity, comprehensive case investigation, compulsory quarantine for contacts/suspect cases, and island-wide lockdowns. Within a month, a passive case detection system was established across Sri Lanka with approximately 1000 tests conducted per day (20). Establishing comprehensive surveillance of cases and their contacts early on was considered key to the early successes of Sri Lanka's COVID-19 response (21).

Point of entry surveillance was an important type of case surveillance that was initiated from early in the pandemic in most countries, and was typically coupled with complete or partial international border closures and stringent facility-based quarantine for international arrivals.

Box 2: Point of entry surveillance and quarantine to delay onset of community transmission

Point of entry surveillance initially consisted of syndromic or risk-based screening of incoming international arrivals. As testing capacity improved, many countries tested all international arrivals, though point of entry testing and surveillance was scaled back as countries reduced or removed international border restrictions. Several countries mandated facility-based quarantine of all international arrivals regardless of test status – these policies were maintained for variable durations in the region. Examples include:

- In **Bhutan**, it is notable that the first case of COVID-19 occurred in an international tourist who initially presented with symptoms that did not conform to Bhutan's case definition. Nonetheless, the case was detected on 5 March 2020 (22), and the case definition was updated 7 times by 1st April 2020 (23). By 27th May 2020, over 24 000 people had been screened at points of entry and nearly 16 000 tests had been conducted (of which 4 318 were PCR tests and 11 544 were rapid antibody tests) (24). Antibody tests were mainly used at the end of the 21 day quarantine period prior to releasing individuals from quarantine (24).
- Of the first four cases in **Thailand**, the first two cases were detected at Suvarnabhumi International Airport, and the fourth at Phuket International Airport (the third case was detected in hospital). Key informants advised that this reflected an early, unique, and close collaboration between the Ministry of Health and the border authorities, which continued throughout the pandemic. For example, both agencies shared a risk matrix to establish and monitor pandemic restrictions. The Ministry of Health assigned national, provincial, and district-level risk levels to enable or restrict movements, and operation of businesses and other entities, while the border agencies worked in tandem to restrict passenger numbers or adjust arrival strategies according to the national risk level. Key informants advised that the effectiveness of this collaboration was internationally recognized when the international Airline Operation Committee made an agreement with the government in Thailand to preferentially direct regional air traffic through Suvarnabhumi International Airport in part due to its performance on surveillance and control of COVID-19.

Compared to screening at international airports, most countries with land borders struggled to implement comprehensive screening at international land crossings, especially at informal crossing points and for irregular border crossings.

In contrast to screening at international points of entry, there was far less consistency in how travellers were screened at domestic points of entry. In some cases, subnational jurisdictions implemented screening and/or testing for domestic arrivals at land crossings, seaports, and domestic airports. For example, the province of Bali in **Indonesia** implemented surveillance at domestic air- and seaports. With support from the Australia Indonesia Health Security Partnership (AIHSP) program, the Bali domestic point of entry screening program recruited and trained community volunteers to conduct COVID-19 health screening for domestic arrivals at the main port of arrival for ferry passengers from Java Island. This comprised symptom screening, review of case status (displayed in the PeduliLindungi app once operational), vaccine status, and travel history. Unvaccinated travellers were offered COVID-19 vaccination at a vaccine clinic established at the port. Screening procedures were adapted from the screening protocols deployed at international points of entry.

During the event phase of the pandemic, some countries in the region were able to scale testing capacity rapidly and effectively despite significant resource constraints. Bhutan and Timor-Leste offer compelling case studies in this regard (Box 3 and 4).

Box 3: Comprehensive point of entry and community surveillance for COVID-19 in Bhutan

In **Bhutan**, the COVID-19 testing program was enabled through effective governance and leadership (25). Key policies and activities that contributed to effective surveillance included:

- An integrated COVID-19 and influenza surveillance system was rapidly established, building on the pre-existing National Early Warning Alert and Response surveillance system (25). Testing sites were established in all 20 districts, including five RT-PCR testing facilities (25).
- Effective testing and quarantine of international arrivals, in conjunction with entry restrictions, delayed onset of community transmission by several months. The first locally acquired case was detected in August 2020 (26).
- A zoning strategy was used as part of the surveillance plan during the first lockdown period: high risk areas of the country were designated as active surveillance zones, whereas lower risk areas (e.g. rural, highland areas) were subject to passive surveillance and fewer movement restrictions (25). Active surveillance strategies included random sampling of adolescents and adults in Thimphu and Phuentsholing (26). After the first confirmation of a local cluster of cases outside of a quarantine facility, individuals aged 10 years and over in Phuentsholing were systematically tested (over 30 000 RT-PCR tests) during a 21 day lockdown (26). Door to door testing strategy reduced testing site bottlenecks (25). Additionally, more than 7 000 migrant workers and travellers who had left Phuentsholing in the two weeks prior to the lockdown were traced and tested, and random testing of travellers along a major highway leading out of Phuentsholing was also conducted. Over 4 000 individuals working in embassies, non-government organisations and other foreign institutions were also tested (26). This active surveillance strategy detected 111 cases representing multiple clusters, which were subsequently contained.

Other countries also rapidly scaled testing capacity. For example, in the **Maldives**, there were more than 100 days from the first international notification of COVID-19 in Wuhan, China, to the first confirmed community case on 15 April 2020, achieved through stringent point of entry surveillance and quarantine (including detection and isolation of the first imported case on 7 March 2020) along with international border closures, which gave health authorities time to prepare their surveillance and response systems (27). COVID-19 case surveillance was initially constrained by testing capacity, however emergency contingency funds were released to rapidly scale up PCR testing and integrate private sector and forensic laboratories into the laboratory network for COVID-19 testing (27). By June 2020, testing capacity had increased from 200 tests per day to 750 tests per day, and increased to over 3000 tests per day by September 2020 (28). GeneXpert units were also used to expand testing capacity (29).

Box 4: Scaling testing capacity through international collaborations in Timor-Leste

Timor-Leste demonstrated the capacity to scale testing capacity rapidly and substantially in a resource-limited context. Scaling testing capacity was an acute challenge in Timor-Leste. Prior to the COVID-19 pandemic, molecular diagnostic capacity for influenza-like illnesses (ILI) comprised a single PCR machine with capacity for 500 tests for influenza A/B virus per month, located at the Molecular Diagnostic Laboratory at the National Health Laboratory and staffed by five scientists/technicians (30). There were several key steps in the rapid scaling of testing capacity:

- Initially, all samples for suspected COVID-19 cases were shipped to Darwin, Australia for testing, with a turnaround of seven days.
- Testing for SARS-CoV-2 was established in Timor-Leste at the Molecular Diagnostic Laboratory using existing capacity in March 2020, and testing capacity significantly expanded over the following six months with the support of WHO and the Menzies School of Health Research in Darwin, which had a longstanding collaboration with the National Health laboratory (30). This support included the recruitment and training of an additional 28 scientists and technicians to increase testing capacity.
- Drawing partly on funding for laboratory refurbishments from an existing project and with additional support from the Australian Government, construction of a new Biosafety Level 2 (BSL2) laboratory commenced in May 2020 and was completed by December 2020. Testing for SARS-CoV-2 continued onsite through the construction period (30). Test results for samples collected in Dili were returned within 24-48 hours.
- Initially, samples collected in areas outside the capital were sent to Dili (the capital of East Timor) for testing, with a turnaround of 2-4 days. Testing capacity was expanded throughout the country by utilising GeneXpert machines, including eight units that were previously in place for tuberculosis testing and 14 newly acquired units as of November 2022 (30). Each municipal-level facility operating GeneXpert machines was ultimately able to process samples and report test results independently. This reduced test turnaround in areas outside the capital to approximately 24 hours.
- Testing capacity increased from approximately 100 tests per day in the first few months of the pandemic, to 2 500 tests per day by June 2021. By June 2022, more than 200 000 tests for SARS-CoV-2 had been conducted, including diagnosis of approximately 23 300 COVID-19 cases (30,31). Quality assurance procedures for SARS-CoV-2 testing included ongoing submission of selected samples to Australia for confirmatory testing.

Mortality surveillance

A global modeling study estimated the ratio of total excess deaths during the pandemic to confirmed COVID-19 deaths to be as high as 9.46 (95% CI 8.45 to 10.22) in South Asian countries (including Bangladesh, Bhutan, India and Nepal) compared to 3.78 (95% CI 3.20 to 4.54) in Southeast Asian countries (including Indonesia, Maldives, Myanmar, Sri Lanka, Thailand and Timor-Leste) (32).

There were numerous severe challenges to reliable ascertainment of COVID-19 deaths in many countries in the region and worldwide. For example:

- Some challenges estimating COVID-19 deaths were partly related to competing priority groups for COVID-19 testing amidst testing shortages. For example, in **Indonesia**, domestic travellers accounted for a substantial proportion of all COVID-19 tests, whereas lack of access to or prioritization of testing for suspected cases led to under-ascertainment of COVID-19 deaths in official datasets (5). This was reported by key informants in addition to being described in Indonesia's Intra-Action Review of the COVID-19 response (5).

- Quality of COVID-19 death registration data reflected the quality of vital statistics systems more broadly. For instance, in **India**, all-cause mortality estimates were only available for 2010 to 2013, which hindered efforts to estimate excess mortality during the pandemic (33). Only 21-22% of deaths in India are medically certified, with most deaths in rural areas in particular occurring outside of health facilities (34).

Event-based surveillance of excess mortality events and clusters presented an alternative data source for estimating COVID-19 mortality, but the extent to which these data sources were integrated with surveillance data originating from the health sector is unclear. For example, a WHO Situation Report in **Indonesia** noted that there were 1 300 more burials in Jakarta in March 2020 than in March 2019 (36). As of 9 April 2020, the Ministry of Health had officially reported 280 COVID-19 deaths nationwide and 95 COVID-19 deaths in Jakarta. Over the same period, a separate government agency, the Jakarta Parks and Forestry Agency, reported that there were 639 burials in Jakarta that followed the protocols for burial of suspected or confirmed COVID-19 cases, however the agency could not triangulate this against confirmed COVID-19 deaths from surveillance data. Many suspected cases were reported by the Ministry of Health to be under surveillance or general monitoring and had died before their test results were available (36).

Surveillance for COVID-19 deaths was much more complete in countries and time periods where case incidence was low. For example, in **Sri Lanka,** there were only a few clusters and no evidence of sustained community transmission until November 2020, which has been attributed to the implementation of an active surveillance strategy (as described in 'Case surveillance') (20). Over the same period, there were fewer than five COVID-19 deaths per day recorded (20) . The very low mortality rate was partly attributable to the low case incidence, but also timely hospitalization of cases (within 3 days of symptom onset in at-risk cases) (20). This likely further enhanced the completeness of reporting of COVID-19 deaths, as COVID-19 deaths after discharge were uncommon.

Hospitalizations and hospital capacity

Monitoring of hospitalizations and hospital capacity was introduced at different time points in the pandemic. Some countries introduced surveillance of hospitalizations in the alert or early event phase and incorporated indicators of hospital capacity (such as hospital bed occupancy, intensive care unit bed availability) into planning and setting of public health and social measures and other response components. For example, in the **Maldives**, hospital bed occupancy and hospitalization rate were monitored by the Health Protection Agency from late May 2020 onwards (28). The **Sri Lanka** Ministry of Health established an integrated information system ("The National COVID-19 Surveillance System") as part of the national Preparedness & Response Plan for COVID-19 in April 2020, which provided a platform for hospitals to report daily resource usage, case information, equipment requirements, and laboratory information (37).

In other countries, surveillance of hospitalizations and hospital capacity was only introduced during or after peak waves of infections, in 2021 or later, by which point hospitals had already been overwhelmed at times. For example:

- In **India**, hospital capacity during the first wave was considered excellent but had been (in hindsight prematurely) scaled down at the end of 2020/early 2021. Hospitals quickly became overwhelmed during the emergence and spread of the Delta variant of concern (38). Close monitoring of hospital capacity was lacking during the Delta wave but strengthened subsequently.
- In Jakarta, **Indonesia**, the provincial Department of Health introduced an integrated information system that tracked not only the number of confirmed cases, but also the capacity of hospital beds, distribution maps and area control maps (39). However, this was only

developed in 2021 amidst the Delta wave, during which hospital capacity was substantially exceeded.

Serosurveillance

There were numerous studies conducted in several countries in the region to estimate the proportion of the population exposed to SARS-CoV-2 infection using serology. In some cases, this information was intended to support decision making for measures such as easing of lockdown/movement restrictions and re-opening international borders, and was recommended for inclusion in COVID-19 surveillance systems in several countries as part of the WHO Unity Studies (40) and/or during national reviews. For example, in **Indonesia**, an Intra-Action Review of the pandemic response recommended incorporating serosurveillance into the national COVID-19 surveillance system (41).

Examples of the implementation and outcomes of serosurveillance in the region include:

- In **Timor-Leste**, serosurveillance was conducted in the form of two seroprevalence studies over multiple time points and sites. The studies were conducted through collaboration with Australian research institutions (30). Studies were conducted in healthcare workers (42) and with residual stored serum samples collected in the general population (43). The findings of the latter study confirmed the feasibility of using stored serum samples for seroprevalence studies in Timor-Leste (43). The serology data supplemented other surveillance sources and confirmed key epidemiological trends, including higher case incidence in western provinces bordering Indonesia, as well the relatively low uptake of vaccination amongst elderly people (43). The seroprevalence study in healthcare workers was conducted at two time points to track the change in seroprevalence over the course of the first wave of COVID-19 in the country (42). This study was described as "an opportunity for strengthening surveillance and serological testing capacity", but the quality of serosurveillance data was limited by a high dropout rate amongst healthcare workers, and potential for false positive and false negative results (42).
- In the **Maldives**, a representative survey of residents in the greater Malé area was conducted after the first two waves of COVID-19 to estimate population exposure to SARS-CoV-2 through serology (44). The study found that 13% of residents had antibodies indicating previous SARS-CoV-2 infection, which suggested that five times more residents had been infected than reported in the official COVID-19 case surveillance data (44). However, there were important limitations to the accuracy of estimated cumulative exposure through serology. For example, amongst individuals who reported a previous COVID-19 diagnosis, 42% were classified as seronegative. This is consistent with waning immunity, with antibody titres declining over time and largely undetected 200 days after infection (44).
- In **Nepal**, two rounds of serosurveys were conducted in October 2020 and July-August 2021 (45). The first serosurvey found that men and women were similarly likely to test positive for SARS-COV-2 antibodies, in contrast to case surveillance data which skewed strongly towards men. This demonstrated gaps in access to testing for women. The first survey also showed the highest seroprevalence for SARS-CoV-2 antibodies in Madhesh Province, whereas the highest case incidence had been reported in Bagmati Province. This study reported that by August 2021, an estimated 70% of Nepal's population had been exposed to SARS-CoV-2, which the authors state vastly exceeded the number of cases detected through COVID-19 case surveillance at the time. The study was supported by WHO Unity Studies (a global serosurveillance standardization initiative), the Ministry of Health and Population of Nepal, and WHO Country and Regional offices (46). This would imply that the findings could have

been readily available to key decision-makers, however the timeliness of the findings and integration with other surveillance data or response measures were not described.

- **Sri Lanka** also conducted serosurveys in accordance with the WHO Unity Studies protocol. A serosurvey was implemented in response to the first cluster of COVID-19 in a densely populated area of Colombo in April/May 2020 (47). Similarly to other serosurveys described above, this study found that serology detected individuals with recent infection who had not been detected through case surveillance. Waning immunity represented a significant limitation to the reliability of the findings, with a substantial drop in seropositivity by 160 days after the first positive serology result. It is also reported that a serosurvey was conducted in Navy personnel following an outbreak at the Sri Lankan naval base, but the results from this survey do not appear to have been made public (19).
- Many seroprevalence studies were conducted in **India** in different pandemic phases. For example, a study was conducted between June and July 2020 in Mumbai to compare the prevalence of antibodies to SARS-CoV-2 amongst slum dwellers compared to non-slum dwellers (48). This study reported that 54.1% of slum dwellers were seropositive, compared to 16.1% of non-slum dwellers. There were significant and substantial differences over small geographic areas, reflecting the importance of differences in population density, housing conditions, adherence to social distancing measures, and hygiene measures in driving transmission patterns (48). Regionally, this study was considered amongst the first high-quality evidence of the extent of SARS-CoV-2 transmission in some communities, with estimated exposure in slum populations substantially exceeding case notifications at this time. A meta-analysis of 53 seroprevalence studies conducted up to August 2021 in India estimated that the national cumulative seroprevalence reached 20.7% in the first wave and 69.2% in the second wave (49).

Syndromic and risk-based surveillance

Early in the pandemic before testing was widely available, community-based surveillance based on symptom screening and/or risk classification was used to identify and support high-risk individuals, and encourage/direct high-risk individuals to quarantine or isolate even in the absence of confirmatory testing in some settings. Available studies and reports have mostly described rather than evaluated community-based surveillance, which limits assessment of the accuracy and efficiency of community-based syndromic and risk-based surveillance compared to case-based surveillance.

- Community-based surveillance in **Thailand** is reported to have played a key role in enabling Thailand's highly effective response in the first wave of the pandemic (50). To bridge the shortfall in health workers in rural areas, village health volunteers (VHVs) were trained to support key components of the response, including encouraging self-quarantine of migrant workers returning to their home provinces following the imposition of a lockdown in Bangkok, monitoring and referral of suspected community cases to designated COVID-19 hospitals. VHVs identified and monitored over 800 000 returnees and referred 3 346 suspected (symptomatic) cases to designated COVID-19 hospitals by 13 July 2020 (50). Community-based surveillance relied on symptom screening and strong encouragement of self-quarantine for returned travellers; there was no widespread testing in place in the first few months of the pandemic response. It is significant that all clusters of cases were fully controlled and further transmission averted nationwide in this period; it has been argued that the contributions of the VHVs were pivotal to this success (50). However, this study did not report the number of confirmed cases amongst the 3 346 suspected cases referred to hospitals by VHVs. This makes it challenging to verify the contribution of community surveillance specifically to controlling the first wave of COVID-19 in Thailand. A study of the source of exposure for confirmed

COVID-19 cases over the first 17 months of the pandemic demonstrated that 43.9% of 152 979 confirmed cases were close contacts of a previously confirmed case, and a further 25.7% were resident in a community with a cluster of cases (51). Active and community surveillance played a particularly important role in the third wave of COVID-19 in Thailand, in April to May 2021, which accounted for 83% of Thailand's COVID-19 cases at that point in the pandemic (51).

- In **Bangladesh**, a national digitally-enabled community-based COVID-19 surveillance system was launched in April 2020, when testing capacity was severely constrained (52). This system collected data on symptoms (e.g., fever, cough) and comorbidities associated with severe COVID-19 (e.g., hypertension, diabetes, kidney disease), and assigned a risk category based on reported symptoms. Individuals assigned to the lowest risk category were classified as "safe" and not directed to testing; higher risk categories were referred for testing and medical care as appropriate. Surveillance data were disaggregated by age, gender, comorbidities, location, and other factors. Between April 2020 and December 2022, 1 980 323 individuals were screened, of which 14% were classified as mid, high or very high risk (52). This study did not report on the proportion of positive tests for SARS-CoV-2 infection by risk category, or on the number of positive tests in individuals screened into low-risk categories, but it plausibly represented a rational risk-based strategy to allocate scarce testing resources and promote access to testing for higher risk and clinically vulnerable people.

Genomic surveillance

A global landscape review characterised the implementation of genomic surveillance for SARS-CoV-2 in the WHO SEAR as of October 2021 (53), summarized in Table 2. Larger and higher-income countries in the region had pre-existing capacity for genomic sequencing, including **Bangladesh**, **India, Indonesia, Thailand,** and **Sri Lanka** (19). Genomic sequencing was accessible through regional reference laboratory networks in the early weeks of the pandemic in several countries, including the **Maldives** (27), **Nepal** (54) and **Timor-Leste** (30,55). National and regional key informants confirmed that national genomic sequencing capacity was established during the pandemic in several countries, including **Bhutan**, **Nepal**, **Maldives**, and **Timor-Leste**.

Genomic surveillance was conducted for different populations throughout the region. For example, in **Thailand**, key informants reported that genomic surveillance focused on severe and fatal COVID-19 cases, as well as significant clusters of cases. In **Indonesia**, key informants reported that genomic surveillance was used as part of risk mitigation for international events, with genomic sequencing performed on samples collected from international arrivals who were participating in major events, in addition to limited sequencing of confirmed community-acquired cases.

Table 2: Overview of genomic surveillance for SARS-CoV-2 in WHO South East Asia region as of October 2021, based on a global landscape review (53)

Country	Surveillance strategy [1]	Sequencing availability 2	Target population	Sampling method	Sequenced volume	Reporting frequency
Bangladesh	Limited genomic surveillance	High availability	RT-PCR positive cases with Ct value < 30	Randomly selected	748 samples sequenced from Dec 2020 to Jun 2021; 178 samples sequenced in July 2021; represents fewer than 1% of confirmed cases sequenced	Weekly
Bhutan	N/A	Moderate availability	N/A	N/A	N/A	N/A
India [3]	High level of routine genomic surveillance	High availability	1) RT-PCR positive cases with Ct value <30 2) Vaccinated positive samples 3) Post-infected and re-infected positive samples	Randomly selected	0.5% of positive samples sequenced [#]	N/A
Indonesia	Moderate level of routine genomic surveillance	High availability	1) Specimens from imported travellers testing positive 2) Vaccine failures 3) Reinfections 4) Severe illness and death 5) Outbreaks with unusual characteristics	N/A	1000 or more samples sequenced per month	Weekly
Maldives	N/A	Moderate availability	RT-PCR positive SARS-CoV-2 samples with Ct value <30	Random	N/A	N/A
Myanmar [4]	N/A	N/A	N/A	N/A	N/A	N/A

Country	Surveillance strategy [1]	Sequencing availability 2	Target population	Sampling method	Sequenced volume	Reporting frequency
Nepal	Limited genomic surveillance	Moderate availability	SARS-CoV-2 positive samples	N/A	100 samples sequenced as of July 11, 2021	N/A
Sri Lanka	Low level of routine genomic surveillance	High availability	RT-PCR positive cases with Ct value < 30	Several rounds of sequencing had been performed	About 200 samples sequenced per month	N/A
Thailand	Moderate level of routine genomic surveillance	High availability	RT-PCR positive cases	Randomly selected (surveillance network of laboratories across the country)	1000 or more samples sequenced per week	Weekly
Timor-Leste	N/A	Moderate availability	N/A	N/A	70 positive samples sequenced between May 2020 and March 2021; the first week of August sequenced 27 samples	N/A

Data sourced from a global landscape of SARS-CoV-2 genomic surveillance and adapted for use under a Creative Commons Attribution 4.0 International License (53). 1 High, moderate, and low are defined with respect to strategy as “one entity regularly (per month or per week) collects nationwide samples to implement genomic sequencing, coupled with at least 5%, 2.5%, or 1% respectively of all positive specimens sequenced. 2 High availability defined as capacity to collect viral isolates from clinical samples and conduct in-country genomic sequencing. Moderate availability defined as capacity to collect viral isolates from in-country samples, but with external laboratory support required for genomic sequencing. 3 Data for India were replaced by data sourced from a national review of COVID-19 surveillance in India (56) 3 The landscape review did not present data for Myanmar.

Other types of surveillance

Wastewater surveillance

Wastewater surveillance emerged as a key surveillance innovation that was scaled during the COVID-19 pandemic in high-income countries, but was not widely implemented in low-and-middle income countries (57). However, it is notable that wastewater surveillance was implemented in several SEAR Member States, as pilot-scale projects and research studies in urban settings within the first year of the pandemic in **Bangladesh**, **Nepal**, and **India,** and during the transition phase in **Thailand.** Larger scale wastewater surveillance projects were implemented in multiple subnational regions in **India.** Examples of studies of wastewater surveillance in the region are summarized below.

A study was conducted to investigate the utility of wastewater surveillance for SARS-CoV-2 compared to COVID-19 case surveillance in Dhaka, **Bangladesh** (58). The study involved collecting sewage samples weekly from 37 sites that formed part of an informal sewerage network in Dhaka spanning eight local areas (wards) of varying income levels and population density, from December 2019 to December 2021. The sewage samples were analyzed retrospectively from December 2019 to February 2020 using samples collected for another project, and collected prospectively from March 2020 to December 2021. Data on daily positive COVID-19 test results were retrieved from the Aspire to Innovate testing program from March 2020 to December 2021. Key findings include:

- *Early detection*: Wastewater surveillance detected SARS-CoV-2 on 23 March 2020, preceding clinical case detection in the catchment area. Continuous viral detection in sewage subsequently indicated ongoing community transmission, even during periods with no reported cases in some areas.
- *Correlation with clinical cases*: Overall, mean sewage viral load closely correlated with reported cases in the same week and with a 5-day lag. This suggests the potential for wastewater surveillance to serve as an early warning system for impending infection waves.
- *Correction for disparities in access to and uptake of testing*: Wastewater surveillance demonstrated utility in estimating patterns of community transmission, particularly in areas with variable access to and uptake of clinical testing. Despite differences in income levels and population density across the catchment area in Dhaka, there were only small variations in viral load between higher and lower-income areas, as well as areas with different population sizes. This contrasts with clinical case data, which showed bias toward higher-income areas with greater testing rates.
- *Feasibility in urban areas*: The study demonstrated the feasibility of mapping sewerage networks and estimating catchment populations in urban areas with largely informal sewerage infrastructure.

One important limitation is that the study did not sequence sewage samples, limiting its contribution to genomic surveillance for variants of interest or concern (58). However, a study in **Nepal** utilised sewage samples as part of a project to develop a rapid genomic surveillance methodology (59) .Similarly to the study in Bangladesh, the project involved mapping sewerage lines and population size to define catchment areas. Sewage samples were collected from 22 catchment areas in Kathmandu from July to December 2020. Sewerage lines and catchments had previously been defined for a wastewater-based typhoid surveillance project conducted by the same research team. Samples were processed in a laboratory in Kathmandu using highly sensitive nested PCR in combination with portable next-generation sequencing technology (Oxford Nanopore Technologies MinION long-read sequencer; a unit that is considerably cheaper than sequencing platforms commonly used in high-income countries). The study identified 3 major circulating SARS-CoV-2 lineages and detected mutations that had not previously been reported in the Global Initiative on Sharing All Influenza Data (GISAID) database (59).

A longer-term research study on wastewater surveillance was conducted in from the event phase through to the transition phase in **Thailand**. Commencing in July 2020, this study collected wastewater samples bimonthly from wastewater treatment plants and a range of closed non-sewered sites, including residential housing complexes, food markets, office complexes, entertainment facilities, and other sites, with sampling conducted in 186 urban and rural districts across nine provinces (60). An analysis of wastewater samples from November 2020 to August 2021 reported several key findings, including that reported cases lagged SARS-CoV-2 concentration in wastewater by 14 days in urban areas, and 20 days in rural areas (60). The presence of the Alpha and Delta variants of concern in wastewater samples was detected in wastewater samples collected approximately two weeks prior to the first notifications of cases infected with these variants (60). This wastewater surveillance study was continued through the pandemic and a second analysis reported the detection of the BA.2.86 variant under surveillance in Bangkok province in July 2023, during the transition phase when clinical testing rates had substantially declined (61). There had been reported cases with this variant in Asia as of 30 August 2023 (61). As these findings were reported as part of research studies, it is unclear whether these detections occurred in real-time, or were based on analysis of samples collected weeks or months prior. However, these findings imply that routine wastewater surveillance with timely analysis could substantially improve the timeliness of detection of pandemic waves, as well as providing a comprehensive overview of community transmission patterns and circulation of variants during the transition phase or any other time periods when clinical testing rates are low.

India provides an interesting case study of implementing wastewater surveillance during the COVID-19 pandemic, from pilot-scale projects in multiple states through to integration in national surveillance strategies. Early in the event phase, in May 2020, a wastewater surveillance study was conducted over a two-week period in Ahmedabad city, Gujarat State, offered a proof-of-principle demonstration of the feasibility of detecting SARS-CoV-2 from wastewater samples in India (62). In the city of Pune, Maharashtra State, a research project conducted from December 2020 to March 2021 demonstrated the feasibility and utility of routine sampling of wastewater from open drains for the detection of SARS-CoV-2, including the occurrence of novel variants prior to the first clinical case detection (63). Following the success of this pilot project, the Pune Wastewater Surveillance project was implemented in August 2021 as part of a national effort to track the emergence of new viral variants (64). Implemented as a collaboration between municipal governments, research institutions, and sanitation services, the wastewater surveillance results were made available via a public dashboard, which presented maps and graphs of viral load detected in wastewater as well as clinical case detections in the same local areas (64). Other states also implemented wastewater surveillance to complement COVID-19 case surveillance and variant surveillance. For example, a wastewater surveillance study reported the findings of analyses of wastewater samples collected weekly from 28 sites from January to June 2022 in Bengaluru city, Karnataka State (65). This study formed part of a larger initiative to establish wastewater surveillance to complement COVID-19 case surveillance in Bengaluru from May 2021 onwards, following acute challenges with clinical testing during the Delta wave (66). Similarly to other studies, SARS-CoV-2 concentrations in sewage correlated with reported case incidence one to two weeks in advance, and detected variants and mutations up to two months prior to detection in clinical samples (65). The data were analyzed in near-real time and shared with municipal authorities to support local-level decision-making about the COVID-19 response(65,66). Examples of data and information sharing arising from wastewater surveillance included early warning of impending infection waves, forecasting epidemic peaks, and early detection of high-frequency and low-frequency viral variants. It was noted that wastewater surveillance is less useful for decision-making after an epidemic peak, as persistent viral shedding in clinically recovered individuals perturbs the correlation with incident cases at this stage of an outbreak (66). Wastewater surveillance studies for COVID-19 surveillance were conducted in cities in several other Indian states, including cities in Uttarakhand, Gujarat and Rajasthan states, in the cities of Hyderabad, Chennai, and Mumbai, and other locations (67). **India** incorporated planning for wastewater surveillance into its operational guidelines for COVID19 surveillance in 2022 (16).

Monitoring of mobility data

Another emerging source of surveillance data was digital mobility data, derived from smartphone-based use of major global technology service providers whose applications have inbuilt location tracking features, including Google. These service providers made population-level mobility data publicly available in anonymized and aggregated formats during the pandemic. National and international public health agencies and research institutions used mobility data to monitor compliance with public health and social measures (PHSMs) including movement restrictions and lockdowns. For example, in **Indonesia**, researchers investigated correlations between Google Community Mobility Reports data and COVID-19 incidence in Jakarta (68). This study found that local scale mobility (for example, to grocery stores and pharmacies, retail and recreation sites, parks, and others) correlated with COVID-19 cases with a seven-day lag. Long weekends associated with religious holidays and festivals were associated with increased mobility and an increase in COVID-19 cases in the following week (68). Key informants reported that this data informed national government decision-making about movement restrictions during major religious holidays and other major events. At regional level, the World Health Organization Regional Office for South-East Asia (SEARO) also used mobility data to monitor compliance with movement restrictions and forecast COVID-19 incidence. Regional key informants provided case studies demonstrating the correspondence between introduction of stringent movement restrictions, level of compliance by the population as estimated by mobility data, and subsequent declining case incidence (Figure 2). Studies investigated the association between Google Community Mobility Reports data and COVID-19 cases in other SEAR Member States, for example **Bangladesh** (69) **India** (70,71) and **Nepal** (72), but as these were research studies, it is unclear whether the findings were communicated to public health officials to support decision-making during the COVID-19 pandemic response.

Figure 2: Correlation between movement restrictions, population mobility, and COVID-19 case incidence in Delhi, India, 2021

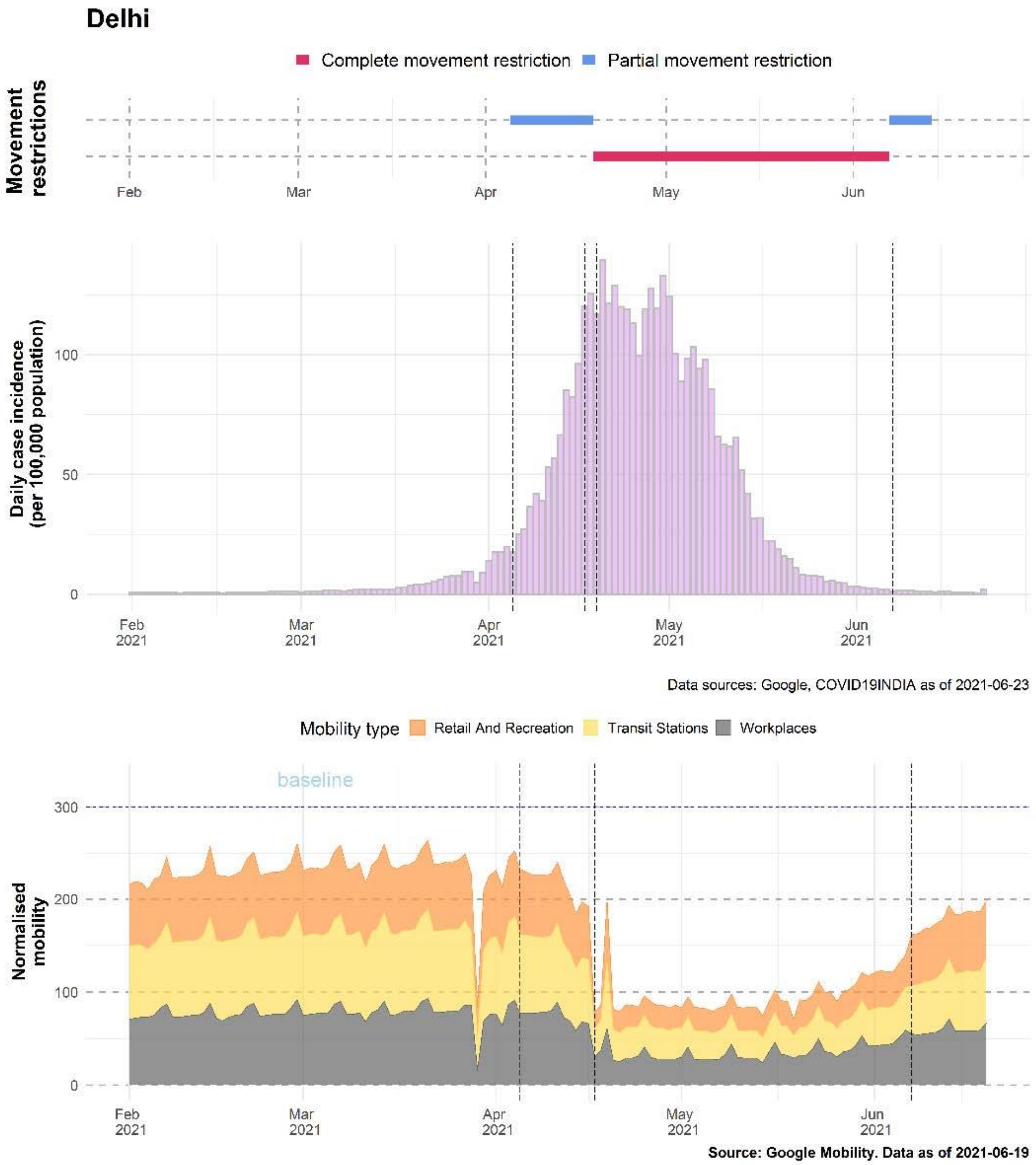


Figure 2 provided by WHO Regional Office for South-East Asia and reproduced with permission.

Integrated surveillance

Surveillance strategies and accompanying information systems to bring multiple types of surveillance data together were developed over the course of the pandemic. This is described here as ‘integrated surveillance’, though in reality the extent of integration and the relative prominence of different types of surveillance data varied across countries. Most countries initially commenced with looking to integrate active and passive case and deaths surveillance, then progressively added other types of surveillance in response to the evolving pandemic context. As described further in section 3.2., digital technologies played an essential role in facilitating integration of different types of surveillance into accessible platforms for data analysis and visualization.

Sri Lanka was one of the first countries in the region to establish an integrated surveillance system combining case surveillance data with hospitalizations and hospital capacity indicators. The Sri Lanka Ministry of Health established an integrated information system (the 'National COVID-19 Surveillance System') as part of the national Preparedness & Response Plan for COVID-19 in April 2020 (37,73). This was used as a platform for hospitals to report daily resource review, individual case information, data on equipment requirements and laboratory information. Data gathered through this system was used for decision making and media briefings by the Ministry of Health (37).

Epidemiological and health system capacity indicators were monitored weekly in the **Maldives**, which informed adjustment of PHSMs (28). It has been reported that the real-time information management system played a crucial role in epidemic monitoring and calibration of public health and social measures to health system capacity (28). In particular, a lockdown was averted during the second COVID-19 wave based on the analysis of multiple sources of data, which led to an assessment that hospital capacity would likely not be overwhelmed (28).

Indonesia progressively developed a comprehensive approach to integrated COVID-19 surveillance, commencing with the introduction of the New All Record (NAR) system for case notifications, first introduced in April 2020. NAR commenced by recording facility-based cases linked to the cases' citizen identification number. NAR evolved into NAR-PCR, for integrating laboratory testing, and NAR-antigen, for integrating RDTs. NAR was considered fully functional by mid-2021, with further integrations of new hospital bed management systems, contact tracing data management, vaccination records, telemedicine, and linkages to provincial-level laboratory, surveillance, and clinical care-supporting applications. Further information about Indonesia's integrated surveillance approach is included in sections on digital technology for surveillance (3.2.2) and contact tracing (4.2.2).

In **Timor-Leste**, the Ministry of Health developed a comprehensive approach to integrated surveillance, enabled through a digital platform known as the 'TLCOVID-19 Management System'. This web-based mobile and desktop application was designed to enable efficient case management, contact tracing, quarantine management, and vaccine status monitoring, including timely analysis and reporting to health authorities to support decision-making.

Integrated surveillance approaches were also developed at subnational level in addition to the national level, including integration of different surveillance types, as well as vertical integration across multiple levels of government and partners. Examples of effective implementation of integrated surveillance at subnational level included:

- In the Delhi National Capital Region in **India**, an integrated data management framework was developed, consisting of four portals (facility management, sample collection monitoring, patient data management, community outreach), each with several modules (74). This allowed visualization of key surveillance indicators such as daily incident cases, deaths, bed occupancy, oxygen supply, distribution of medical equipment and consumables, and daily vaccination trends by dose. It incorporated an automated report generation function (Delhi State Health Bulletin) and offered a dynamic dashboard for targeted monitoring by the integrated command and control centre in Delhi. Pooled data was used for forecasting case incidence and hospital and health system resource requirements. This integrated framework was described as crucial for the COVID-19 response in the Delhi region (74).
- The provincial health department in Jakarta, **Indonesia**, developed an integrated information system that included not only the number of confirmed cases, but also the capacity of hospital beds, distribution maps and area control maps (39).

By the transition phase**,** declining case incidence and severity attributed to widespread vaccine-acquired and infection-acquired immunity provided an opportunity for a re-orientation of COVID-19 surveillance towards earlier detection and containment of cases once again (Box 5 for example).

Box 5: Integrated COVID-19 surveillance in the transition phase in India

In June 2022, the Government of **India** developed an integrated surveillance strategy to meet its surveillance goals of "early detection, isolation, testing and confirmed cases", detection and containment of outbreaks, and variant surveillance (16). In brief, the revised integrated surveillance strategy included the following surveillance types:

- Point of entry surveillance of incoming international travellers, based on screening a randomly selected 2% of all international arrivals, with samples tested by PCR and genomic sequencing performed if positive;
- Sentinel case surveillance, comprising ILI and Severe Acute Respiratory Infection (SARI) surveillance in selected hospitals, as well as laboratory reporting of COVID-19 test results;
- Community-based surveillance, comprising event-based surveillance and response, and indicator-based surveillance focused on ILI and SARI cases;
- Wastewater surveillance, comprising a proposed pilot project to integrate "multiple systems presently existing for a pan-India sewage/wastewater surveillance" with the aim of providing early warning of surging case incidence, estimating virus load in the community, and contributing to variant surveillance;
- Serosurveillance, comprising a proposed serosurvey that may be undertaken if deemed to be of added value as part of the overall surveillance strategy.

3.2. Contribution of digital technologies to surveillance

There are numerous examples of introduction and enhancement of digital technologies to support the data and information needs inherent to COVID-19 surveillance, including several examples that have been referred to in the previous sections. This section highlights examples of how some countries in the region were able to achieve significant innovations and rapid scaling of digital technologies at national level.

However, it is notable that that there is very limited evidence from formal evaluations or prospective studies to assess the contribution of digital technologies to the performance of COVID-19 surveillance. Available evidence from the published literature is mostly descriptive or qualitative, and may be biased towards positive findings and should therefore be interpreted with caution accordingly. In contrast, information from key informant interviews revealed significant shortcomings of digital technologies used for COVID-19 surveillance.

3.2.1. Digital technologies supporting surveillance in the alert and early event phases

In many countries, specialist epidemiological data management software and tools that pre-dated the pandemic were not widely used from early in the alert phase. Broadly, these systems lacked flexibility to introduce new data collection and reporting formats needed for COVID-19 surveillance, technical support to implement and troubleshoot the required changes could not be rapidly mobilised, these systems were not available to users with key responsibilities for data entry and analysis at all levels of the health system, and there was not enough time to train new users amidst the urgency of the pandemic response. This includes existing National Notifiable Disease Surveillance (NNDS) systems, which reportedly could not easily be adapted to accommodate the requirements of pandemic surveillance.

Instead, in most countries, public health officials at multiple levels of government used familiar, generalist software and communications technologies rather than specialist software for the first weeks and months of the pandemic response. In some cases, use of widely available data management and analysis software such as Microsoft Excel was used throughout the pandemic. Key informants in country case studies recounted substantial limitations of tools such as Microsoft Excel and Google Sheets for COVID-19 data management. For example, in **Thailand**, key informants reported that substantial effort was needed to clean, collate, and validate data submitted by provinces in Microsoft Excel sheets with different formats and risk of data entry errors. In addition to province-specific surveillance reports, each laboratory also had different reporting forms, compounding the challenges. At times, surveillance officers reverted to manual data and collation due to the lack of computability of laboratory reporting formats. In **Nepal**, data was submitted via Microsoft Excel sheets, Google Sheets, email, and fax, and all data had to be manually reviewed, verified and collated by a team of 10-12 people who were coordinating the national surveillance data.

Despite their limitations, the ubiquity of access and familiarity with these tools at all levels of the health system was an important advantage in the early weeks of the pandemic response. For example, familiarity with their use meant that public health responders could quickly improve forms and systems without specialist information and technology (IT) support. Similarly, widely used messaging (e.g. WhatsApp) and videoconferencing (e.g. Zoom) software were frequently used to share unstructured and emerging surveillance data and with aim of coordinating the response.

There were several examples of the early development, introduction and enhancement of new digital technologies designed specifically to improve COVID-19 surveillance in the region (for example, see Box 6). Many of these tools and systems were developed and deployed by in-country teams, via collaborations between Ministries of Health and Ministries for Information and Communications (or equivalent).

Box 6: Deployment of digital technologies for COVID-19 surveillance in Sri Lanka

Sri Lanka offers a salient example of the opportunities to strengthen pandemic response through integrating public and private sector digital technologies and agencies. A study reported on the development of an integrated digital surveillance system in Sri Lanka (75). Key aspects of the design and operationalisation of this system included:

- Changes to the existing District Health Information System 2 (DHIS2) system in Sri Lanka were discussed prior to the first case in the country.
- Changes to DHIS2 to accommodate the need to collect data from incoming international travellers were added within two days. By early February 2020, the system was fully ready/adapted at points of entry to screen arriving passengers at all airports in Sri Lanka. This allowed Sri Lanka to keep its borders temporarily open to tourists whilst monitoring COVID-19 globally and within the country (75–77).
- Within weeks, it became apparent that the need for an integrated surveillance system required new applications and DHIS2 functionalities; however, the government Information and Communications Technology Agency (ICTA) lacked the resources to implement these changes quickly.
- The ICTA announced a hackathon on Twitter and enlisted the support of 25 volunteer developers, most from Sri Lanka. The University of Oslo contributed a DHIS2 core developer to the initiative. Within two weeks, the developer team had developed a customized data capture application for point of entry surveillance and contact tracing data, an analytics tool for examining COVID 19 transmission chains, and an interoperability solution for data exchange with immigration data.

- Sri Lanka also integrated a hospital bed tracking component into the COVID-19 surveillance system. This allowed health facility users to input and update the availability of intensive care unit and non-intensive care beds. This facilitated planning and the allocation of patient flow, including patient transfers.
- The system was further expanded to include a national COVID-19 immunization registry, vaccine stock monitoring at vaccination sites, and pre-registration of vaccine-eligible individuals based on existing immunization registries. Real-time monitoring of vaccine stock supported distribution of the available stock, particularly at a time when national and international supplies were severely constrained.

There is very limited evidence from prospective studies or evaluations to formally assess the contribution of digital technologies to COVID-19 surveillance. However, **Thailand** offers an example of how the contribution of digital technologies to improving surveillance was able to be evaluated during the alert and early event phases of the pandemic response (Box 7).

Box 7: Formal evaluation of contribution of digital technologies to COVID-19 surveillance performance

In **Thailand**, the contribution of digital technologies to improving surveillance was able to be evaluated during the alert and early event phases. Within a few weeks of use, several limitations were evident in the initial COVID-19 surveillance information system in Thailand, including delays and challenges with verifying case reports, delays to integrating laboratory test results, and identification of clusters, amongst other limitations (17). The COVID-19 surveillance information system was improved in April 2020 through the inclusion of five additional features, namely:

i. auto-verification to verify patient according to screening criteria
ii. (ii) laboratory reporting system which was coordinated with a laboratory centre and integrated with the case reporting system
iii. (iii) data exporting
iv. (iv) visualization which was able to fulfill data feedback loops
v. (v) integrated event-based surveillance (17)

- A pre-post design was used to evaluate the contribution of the enhanced information system to COVID-19 surveillance in Chonburi Province, comparing surveillance system performance in February and March (pre-) to performance in April 2020, after the information system enhancements were implemented (17). Surveillance performance was assessed using surveillance attributes defined in the United States Centers for Disease Control (CDC) surveillance evaluation framework. Completeness, timeliness, and data quality were assessed quantitatively using data on 'patients under investigation' and confirmed COVID-19 cases captured through the COVID-19 surveillance information system.
- Across all variables, completeness improved from 55% to 66%, timeliness improved from 75% to 96%, and data quality improved marginally (17).
- Simplicity, flexibility, acceptability, stability, and usefulness were assessed qualitatively through key informant interviews with 16 people in a range of roles (17). Overall, the information system enhancements were considered to have strengthened the performance of surveillance across all domains. There were differences between central data managers and public health officers/laboratory technicians about the acceptability and utility of the information system prior to enhancement. In particular, the usability of the system improved substantially through the inclusion of functions including data export functions and data visualizations. (17).

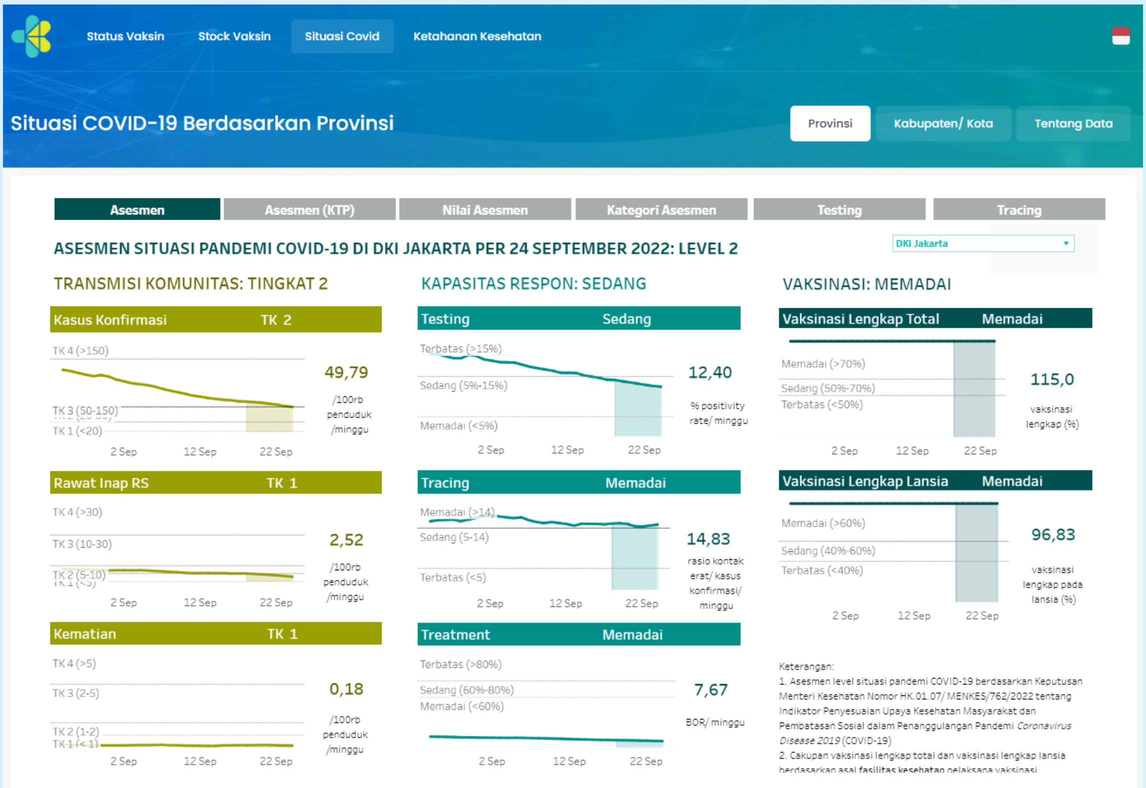
3.2.2. Digital technologies supporting surveillance during the event phase

During the first and second years of the pandemic, many countries made significant progress with developing comprehensive and integrated digital information systems to collect, manage, and report multiple types of COVID-19 surveillance data (see Box 8 for example). In other countries, a comprehensive digital information system for COVID-19 surveillance and response was never fully operationalised. For example, despite the early success of developing a COVID-19 information system in **Thailand** (Box 7), key informants reported that most provinces continued to rely on spreadsheet-based reporting throughout 2020 and 2021. At the beginning of 2022, the COVID-19 Case Report surveillance platform was launched, which integrated data from electronic medical record (EMR) systems in hospitals with national surveillance data via an application programming interface (API). This reportedly replaced spreadsheet-based reporting from hospitals. However, provincial surveillance databases were not integrated at national level, with data shared from province to national level surveillance units via spreadsheets throughout the pandemic. Similarly, a laboratory information management based on Internal Control Number Tracking ('ICN Tracking') enabled management and integration of testing data (primarily from mobile testing clinics) into the national surveillance database for laboratory test results (Co-Lab). ICN Tracking was widely used in Bangkok, supported by additional functionalities such as displaying testing site locations to members of the public and linking to individual-level vaccination status. However, ICN tracking was not linked to hospital data, and was reported to have not been widely used in other provinces.

Box 8: Rapid development of integrated COVID-19 surveillance in Indonesia

Indonesia achieved a remarkably rapid initiation and scaling of digital surveillance and contact tracing tools in response to the pandemic. The development of the New All Record (NAR) system, which later expanded to include NAR antigen and NAR PCR, was perceived as a key turning point from manual to more efficient and integrated digital reporting and data management. Transitioning management of NAR to Pusdatin, the data centre in the Ministry of Health, allowed for a broader integration of multiple sources of data, such as immunization records. This system facilitated the development of 'PPKM' (*Pemberlakuan pembatasan kegiatan masyarakat*, Enforcement of Restrictions on Public Activities) zoning and was involved in quality assurance and validation of data. The integrated surveillance data were made available through a dashboard, with public health responders able to select to view data at provincial (provinsi), district (kabupaten) and municipal (kota) level (Figure 3).

Figure 3: Screenshot of integrated COVID-19 surveillance dashboard, Indonesia



However, late development of NAR, which only became fully functional in 2021, led to duplication of efforts as provinces had developed their own database systems to manage COVID-19 data in 2020-21. For example, Jakarta district used "JAKI" and "ACE"; and in Bali the contact tracing app "SSO" was integrated with point of entry data and later, vaccination certificates, as this was required for travellers from Java Island to enter Bali. Hence, even once NAR was implemented, data sharing, collation, verification, and other data management tasks were initially difficult due to the multitude of provincial data management systems in place.

Even once NAR was available, public health responders continued to struggle at times with the numerous data management systems in place. For example, data on hospital bed occupancy rate was not initially included in NAR, which limited its utility as a single software system for managing COVID-19 surveillance.

In later stages of the event phase and moving towards the transition phase, comprehensive situation analysis required multiple data types. NAR was integrated with contact tracing data (Silacak), as well as data on hospital bed occupancy and patient vaccination status. Data integration allowed for more nuanced strategies such as subnational risk zoning.

Nepal also presents an interesting case study for the challenges and innovations with introducing digital technologies for COVID-19 surveillance in a resource-constrained setting during the Delta wave (Box 9).

Box 9: Development of the Information Management Unit in Nepal

In **Nepal**, there was a clear and well-articulated need from multiple key informants for a single interoperable digital system for COVID-19 surveillance and contact tracing, with capacity for individual level tracking of case status, vaccination status, linked contacts, and other key data items.

Initially, key informants in Nepal reported that they used multiple, non-interoperable reporting systems, sometimes with duplication of data reporting. This added to the burden on healthcare workers already facing severe strains during the pandemic. For example:

- WHO supported training in Go.Data, a case investigation and contact tracing software developed by WHO. However, Go.Data was generally found to be ineffective in the local context. Key informants reported a range of limitations that constrained use of Go.Data, including that it could not be used offline (noting internet connectivity is intermittent in many parts of Nepal); digital literacy amongst the health workforce remains a challenge which limited capacity for uptake; the privacy settings of Go.Data proved unworkable in the field; and there was a lack of training and support to address ongoing technical issues.
- The Ministry of Health and Population reverted to a Microsoft Excel-based, aggregated data reporting system, rolled out via the national Epidemiology and Disease Control Division.

As neither Go.Data or Microsoft Excel-based case management and reporting were adequate for the country's surveillance needs, an in-country team developed the Information Management Unit (IMU) information system, with external assistance. The IMU was launched in mid-April 2021 and was fully functional by mid-May 2021, during the peak of the Delta wave. The IMU comprised a laboratory module (to capture PCR testing), hospital-based case management module, community reporting module, case investigation and contact tracing module, point of entry module, and vaccination module.

The IMU was considered an improvement over previous systems and an important achievement for Nepal in managing the COVID-19 response. However, key informants noted some limitations of IMU, such as a lack of interoperability between modules, and that hospital case management data could not be linked to the contact tracing module. Key informants reported that only the hospital component was consistently considered useful for decision making; otherwise, case numbers reported through IMU were considered to be unreliably low. The IMU was withdrawn during the transition phase.

3.2.3. Digital technologies complementary to surveillance

Digital technologies were also introduced to record and display individual vaccination status, monitor compliance with quarantine and isolation directives (e.g. through Global Positioning System [GPS] tracking), for symptom screening, accessing telehealth and support services, and other purposes. Though exploring these digital tools was beyond the scope of this project, key informants emphasised that several of these tools were widely used and contributed to the effectiveness of the response overall. Of relevance to understanding the performance and utility of surveillance, digital technologies including apps or app features were most widely used when they offered a range of services, and/or facilitated compliance with requirements including vaccination certificates and displaying recent results.

3.3. Performance of surveillance against program objectives

While section 3.1 highlighted how surveillance objectives varied between countries and across different phases of the pandemic, this section reviews the performance of COVID-19 surveillance against program objectives, including analysis of how different types of surveillance described in section 3.2 contributed to the performance of surveillance.

To facilitate cross-country comparison, this section appraises performance of surveillance against core COVID-19 surveillance objectives recommended in global WHO surveillance guidance (78). Additionally, as several countries in the region aimed to contain or locally eliminate transmission in the alert phase and early event phase, the contribution of surveillance to suppressing transmission is included as an additional objective against which the performance of surveillance is discussed.

3.3.1. Early warning and detection

Several countries' surveillance programs aimed for early warning and detection of COVID-19 cases, particularly in the alert phase. Aspirations for early detection of cases persisted throughout the pandemic, through to the transition phase.

There appear to have been no comprehensive strategies or plans specifically addressing the multiple sources of surveillance required to enable early warning and detection capabilities for emerging pathogens prior to COVID-19. Broadly, early warning can be described as a core surveillance objective for indicator-based and event-based surveillance systems, and point of entry surveillance inherently aimed to enable early detection of imported cases. Most countries had pre-existing Early Warning Alert and Response/Reporting systems (various country-specific names for these surveillance programs are summarised as EWARS in this report), which were established to enable timely surveillance and response to high priority, outbreak-prone infectious diseases and syndromes, including in emergency settings. Prior to the COVID-19 pandemic, many EWARS in the region incorporated indicator-based as well as event-based surveillance, and capacity to detect public health events was increasing year-on-year, with 97 events reported in seven SEAR Member States in 2019 (79). In principle, these surveillance systems could have been anticipated to enable early warning and detection of COVID-19 in SEAR Member States, especially in the alert phase. However, across the three case study countries, pre-existing EWARS were reported to lack the sensitivity, coverage, and flexibility to accommodate a novel pathogen such as SARS-CoV-2 and were not equipped to manage a rapid escalation in scale of the pandemic in each country. It should be noted that some EWARS were established to focus on known epidemic or endemic priority pathogens only, rather than emerging pathogens. Nonetheless, EWARS were considered an important part of epidemic preparedness prior to COVID-19.

Factors that contributed undermined the performance of EWARS for early detection and surveillance of COVID-19 included:

- Prior to COVID-19, EWARS often relied on ILI and SARI case definitions, which typically included fever and cough with or without hospitalisation . This meant that most community-acquired COVID-19 cases with asymptomatic or mild symptoms – particularly early in the disease course, when risk of onwards transmission was highest – were missed by EWARS.
- In many countries, EWARS were in place in selected sentinel hospitals only, and not in community health facilities. For example, an EWARS network was established but was not very active prior to the COVID-19 pandemic in **Thailand** and **Nepal**, according to key informants. This limited the sensitivity of EWARS to detect a rapidly spreading emerging respiratory pathogen such as COVID-19. Even in Indonesia, where EWARS has been active in primary health care centres (puskesmas) since 2009 (80), key informants reported that EWARS

detected COVID-19 cases in **Indonesia** only once transmission was widespread. At this point, ILI and SARI surveillance could be used to triangulate against other sources of information about the pandemic situation. In Nepal, key informants reported that EWARS was not perceived as being useful for COVID-19 surveillance during the pandemic.

- EWARS supported timely reporting of priority infectious diseases in pre-pandemic conditions but lacked flexibility for supporting the response to the COVID-19 pandemic. For example, in **Indonesia**, prior to the COVID-19 pandemic EWARS reports were considered 'on time' if submitted within one week of the case detection (81). However, this was not considered 'timely' for the purposes of COVID-19 surveillance, with a requirement for daily reporting.
- EWARS were often not linked to electronic medical records or laboratory data including EMR systems. In **Indonesia**, this constrained timely case detection and sharing of information about severity and outcomes for detected COVID-19 cases (81). In countries where EWARS integrate laboratory-confirmed diagnoses, EWARS are often only linked to specific laboratories rather than the range of laboratories to which clinical samples may be submitted.
- Comprehensive event-based surveillance was not consistently integrated into EWARS in the region prior to the COVID-19 pandemic. For example, event-based surveillance had been incorporated into EWARS in **Indonesia** for outbreak-prone priority diseases including influenza-like illness by 2020 (81), but gaps in coverage and sensitivity of event-based surveillance led to significant efforts to strengthen event-based surveillance during the pandemic in several countries. For example, event-based surveillance was integrated into a new COVID-19 surveillance information system in **Thailand** in April 2020 (17), and WHO supported the introduction of epidemic intelligence from open sources to strengthen event-based surveillance in **Bangladesh**, **Indonesia, Nepal** and **Thailand** from 2022 to 2023 (79).
- EWARS were not linked to point of entry surveillance, which was established as a separate surveillance activity in many countries. In contrast to EWARS, point of entry surveillance comprised risk-based (and later, comprehensive) testing of international arrivals and was therefore able to detect the first confirmed case(s) of COVID-19 in several Member States, including **Thailand**.

In some countries in the region, there are reports of pre-existing EWARS being utilized for COVID-19 surveillance. As previously noted in **Bhutan**, the COVID-19 integrated influenza surveillance system was rapidly established based on the pre-existing National Early Warning Alert and Response surveillance system (25). A regional key informant also noted that some countries in the region detected their first COVID-19 case through EWARS, affirming their role in COVID-19 surveillance. However, in many settings, EWARS remained disease and syndrome-specific, with limited potential to detect unusual events or disease clusters potentially indicative of an emerging infectious disease. For example, a published WHO-led interview with a health sector statistician who attended WHO EWARS training in Bangladesh in 2022 noted,

> *"EWARS is right now operating for nineteen diseases," says Delawar, "That's a great thing. But if EWARS had another system that could detect any unusual event or any unusual disease that is not common to that locality—and if we can know it far, far prior to when the thing will be—then this will help the local population greatly. That would be a great achievement." (82)*

Given the limitations of EWARS, early warning and detection of COVID-19 cases was mainly operationalized through stand-alone indicator-based and event-based COVID-19 case surveillance systems, including point of entry surveillance. As noted in section 3.12, point of entry surveillance appeared to have played a critical role in enabling comprehensive and timely detection of imported COVID-19 cases in most countries in the region, with examples from **Bhutan**, **Maldives, Timor-Leste** and **Thailand** previously noted. However, point of entry surveillance did not consistently perform highly throughout the region. For example, in **Nepal**, key informants reported that point of entry screening was conducted at Tribhuvan International Airport in Kathmandu and along land border crossings. However, the India-Nepal land border is porous, with multiple informal crossing points outside the official border crossings that were equipped with health desks. Point of entry screening was perceived as successful based on screening more than one million people with 15 000 cases detected, but gaps in surveillance and incomplete screening mean that overall, point of entry screening may have had limited to no effect on community transmission in Nepal.

All countries faced significant challenges with timely case detection, particularly in populations with reduced access to testing, or healthcare in general. Failure to detect cases and outbreaks early often led to large outbreaks. For example, the limits of COVID-19 case surveillance in **Thailand** were revealed through a significant outbreak amongst international migrant workers in Samut Sokhon province in December 2021 (83). From the 20 to 27 December 2021, there were 2 629 confirmed COVID-19 cases detected amongst migrant workers, which led to further outbreaks in 44 provinces (83). A study of the outbreak in Samut Sokhon noted that the passive surveillance system did not detect the emerging cluster of cases amongst migrant workers, due in part to challenges for migrant workers to access healthcare, including the impacts of loss of daily wages associated with attending testing facilities, and reluctance of undocumented migrants to interact with government services (83). In contrast to efforts to make information available in English and Chinese for tourists in Chiang Mai (84), there was limited effort to disseminate COVID-19 communications in languages spoken by the migrant worker population. Low health literacy levels amongst migrant workers exacerbated gaps in access to health information, which also contributed to reduced testing (83). These barriers and gaps reflect longstanding issues hindering integration of migrant workers into health services in general, including experiences of discrimination, and mutual distrust (83). There was no active or targeted COVID-19 surveillance amongst migrant workers in place prior to the outbreak. After the outbreak was detected, there were further challenges accessing and providing testing for migrant workers (83).

It appears there is an under-appreciated potential for wastewater surveillance to contribute to early warning and detection. As summarised in section 3.1.2, several pilot-scale and larger-scale wastewater surveillance projects in at least four SEAR Member States demonstrated the potential utility of wastewater surveillance to complement case surveillance in resource-constrained settings with informal sewerage networks and limited testing capacity. In these studies, wastewater surveillance detected SARS-CoV-2 prior to the first clinical case detection, and viral concentration in wastewater samples increased days to weeks earlier than increases in reported case incidence. Variants of concern were consistently detected in wastewater from samples collected days to weeks earlier than the first clinical case detection of these variants from case surveillance. This suggests the potential for wastewater surveillance to serve as an early warning system for impending infection waves, if implemented routinely with prompt analysis and reporting of viral detections in sewage samples.

3.3.2. Suppress and eliminate transmission

Some countries in WHO SEAR, including **Bhutan**, **Maldives**, **Sri Lanka**, **Thailand** and **Timor-Leste** were able to maintain weeks or months of low or zero locally acquired COVID-19 cases, particularly in the first year of the pandemic. This provided these countries with time to better prepare their healthcare and laboratory systems to manage the eventual introduction and spread of community transmission of COVID-19. It is notable that extended periods of zero or very low COVID-19 incidence were achieved in a range of settings: small island nations, as well as nations with land borders with neighbouring countries reporting high case incidence, and lower-middle and upper-middle income economies. Though not clearly an explicit surveillance goal at the outset of the pandemic, these countries maintained low or zero COVID-19 incidence through a very similar set of measures, including stringent international border restrictions including point of entry surveillance and quarantine measures for permitted arrivals, coupled with active case surveillance, case and cluster investigations, case isolation and quarantine for contacts, and movement and business restrictions in the general population. For example, as advised by regional key informants, **Timor-Leste** implemented a mandatory 14-day quarantine for all international arrivals from the start of the pandemic. Every person arriving at international points of entry points was either sent to a government-designated quarantine facility or allowed to quarantine at home, pending authorization from the Ministry of Health following an inspection. Despite sharing a land border with Indonesia, which experienced substantial community transmission of COVID-19 in 2020, Timor-Leste averted community transmission of COVID-19 until 2021. There is no clear evidence available to disentangle the contribution of surveillance compared to other co-implemented measures. However, it is plausible that point of entry surveillance and passive and active case surveillance in the community were key components that supported the achievement of suppression and elimination of COVID-19 transmission chains in multiple countries in 2020.

The transition away from stringent zero COVID-19 settings occurred at different time points, often reflecting locally specific events and contexts. For example, in **Thailand**, repeated containment of outbreaks was achieved until a cluster of cases in December 2021, predominantly amongst migrant workers, which subsequently spread to 44 provinces. In **Timor-Leste**, community transmission of COVID-19 was averted until March 2021, and a national lockdown was implemented (30). Severe flooding associated with a tropical cyclone in April 2021 forced the suspension of lockdown measures and initiation of an emergency response to the floods, including establishing evacuation centres. Displacement and crowding in homes and evacuation centres likely contributed to the case surge. All confirmed cases were isolated in hospitals or dedicated COVID-19 treatment centres until July 2021, after which time home isolation was permitted as part of the strategy to manage rising COVID-19 incidence (31). In **Bhutan**, the first major wave of COVID-19 occurred from February 2022, coinciding with the spread of the Omicron variant of concern. From February to April 2022, there were 54 271 cases with a mean test positivity rate of 6.3%, substantially higher than in 2020 (734 cases, 0.4% test positivity rate) and 2021 (1926 cases, 0.2% test positivity rate) (85). A national lockdown, enhanced testing, and other measures were implemented in January 2022 at the start of the Omicron wave, though restrictions were later lifted following observation of low case severity and mortality rates, attributed to the successful vaccination campaign leading to widespread population immunity (85).

Despite these different circumstances, a commonality was that countries with extended periods of low or zero COVID-19 incidence in the first 12 months of the pandemic eventually experienced substantial community transmission attributable to the Delta variant of concern, coinciding with the increasing availability of vaccines. This generally marked the shift in policies towards tolerance of ongoing transmission and reorientation towards suppressing transmission to prevent severe disease and deaths. By the time of the emergence and international spread of the Omicron variant of concern, which coincided with high coverage of vaccines in most populations and observed reduced clinical severity of COVID-19, these countries pivoted to monitoring case incidence and mortality, and hospital burden.

3.3.3. Monitoring trends in case incidence and mortality

There are numerous examples of case surveillance being rapidly initiated and adapted throughout the region. Through the event phase, some countries in the region were able to scale testing capacity rapidly and effectively despite significant resource constraints. Inevitably, all countries faced significant challenges maintaining testing capacity and timeliness, particularly during infection waves caused by the Delta and Omicron variants of concern.

Common constraints to the performance of surveillance relate to the sensitivity, accuracy, timeliness, and flexibility of case-based and other types of surveillance.

Sensitivity

Across countries, there was poorer coverage of asymptomatic and mild infections compared to moderate and severe infections, and amongst lower income and marginalised groups with reduced access to testing. These discrepancies were most acute in the alert and early event phases, when testing capacity was constrained by reliance on PCR testing, with relatively few laboratories authorised to conduct COVID-19 testing, and limited reagents/test kits. Early in the pandemic, PCR testing typically focused on international arrivals, hospitalised patients, and contacts of cases in most countries, and in some cases was used as part of cluster investigations. Mild cases acquired in the community were often ineligible for testing, especially in the alert phase when testing criteria frequently specified a link to overseas travel. For example, In **Bangladesh**, significant limitations to the performance of surveillance for COVID-19 in the first few weeks of the pandemic have been reported. One commentary noted that that by 1 April 2020, only 1 759 COVID-19 tests had been conducted and 88 cases confirmed, despite 155 898 international arrivals in the same period (86). In the first few weeks, the supply of test kits was severely constrained, which led to narrow eligibility criteria for testing, which was focused on foreign travellers and their contacts rather than suspected cases or vulnerable/high-risk populations (86). Sensitivity was also constrained by health system capacities overall. For example, testing capacity was identified as an early challenge for the pandemic response in **Myanmar**, hampering accurate surveillance (87,88). Limited laboratory capacity has been proposed as the main reason for this bottleneck, both in terms of number of laboratories as well as trained staff (89). Initially, samples had to be transported to Thailand (90) and laboratory capacity had to be upscaled from very low levels. Testing capacity was scaled up from one laboratory in March 2020 to seven in August 2020, and there was further expansion of testing capacity to 27 district hospitals by October 2020 (89). However test-positivity rates exceeded 10% after mid-October (87,89), suggesting substantial under-detection of community cases (89). The main contributing factors to the strained testing capacity included “dependence on other countries for testing kits, and shortages of human resources such as trained laboratory technicians and logistics and data managers”(87).

Testing policies were liberalised as PCR testing and particularly rapid antigen diagnostic test kits (RDTs) became more widely available. However, in some countries, once rapid antigen testing became more widely available, PCR testing in non-hospitalised individuals was skewed towards relatively low-risk groups who were required to undergo PCR testing for domestic and international travel, workplace requirements, or other factors, including testing conducted to meet surveillance performance targets. Self-administered and point-of-care administered RDTs were increasingly used for symptomatic cases outside of hospital settings, which represented an opportunity to considerably improve surveillance sensitivity, but RDT results were not consistently reported in many countries. In **Thailand**, key informants reported that a call centre was established during the ‘Living with Covid’ phase for cases to self-report their case status based on home testing with rapid antigen tests. This increased the sensitivity of surveillance through detection of mild cases that did not visit a health facility. Participation in the self-reporting scheme was incentivized through delivery of medicines and items need to support home isolation for cases who self-reported. Despite the increasing availability of testing over time, most countries faced significant challenges maintaining testing capacity particularly during the peaks of infection waves attributed to the Delta and Omicron variants of concern.

Given these challenges with ascertaining case incidence through case surveillance, countries used seroprevalence data to estimate the extent of under-ascertainment of COVID-19 cases through routine case surveillance. As noted in section 3.1.2, seroprevalence studies in some cases identified individuals with serological evidence of recent infection who had not been detected as a COVID-19 case (for example, in Sri Lanka in 2020 (47)). Most studies focused on estimating population-level exposure and contrasting the findings to case surveillance data, with studies across several countries consistently reporting higher ascertainment of recent infection through serology than through serosurveillance. However, limitations to the sensitivity of serosurveillance were also widely noted, including high drop-out rates for repeated cross-sectional studies, as well as evidence of waning immunity leading to confirmed cases subsequently testing negative by serology within a few months of recovering from the acute infection phase (for example, 42% of individuals who self-reported a history of COVID-19 in the Maldives were seronegative within 200 days of infection (44).

There were numerous and at times severe challenges to reliable ascertainment of COVID-19 deaths in many countries in the region. Some challenges estimating COVID-19 deaths were partly related to competing priority groups for COVID-19 testing amidst testing shortages. For example, in **Indonesia**, key informants reported that domestic travellers accounted for a considerable proportion of all COVID-19 tests, whereas lack of access to or prioritization of testing for suspected cases led to under-ascertainment of COVID-19 deaths in official datasets. Other challenges related to community support for COVID-19 testing, either during the course of illness or post-mortem. For example, in **Timor-Leste,** a review of COVID-19 surveillance noted some families refused post-mortem COVID-19 testing, hence the reported death rate may underestimate the true death rate (31).

Overall, sensitivity of surveillance for COVID-19 deaths was much more complete in countries and time periods where COVID-19 case incidence was low.

Accuracy and completeness

Accuracy and completeness of case surveillance was most often defined by resource constraints rather than testing strategy. A common challenge impacting accuracy of COVID-19 surveillance data was the lack of unique identifiers to link individuals to their test samples and other data. Duplicate reporting was identified as an issue as an individual could be tested multiple times during a single episode of COVID-19. For example, in **Nepal**, the health sector review of the COVID-19 response noted:

“There is currently no facility for identifying unique individuals through the testing system, so that reported case numbers may be artificially inflated where individuals have tested positive more than once in the course of a single illness episode.” (91)

Key informants in case study countries consistently reiterated challenges and limitations associated with data quality and completeness. In **Indonesia**, data quality issues identified by key informants included incomplete, conflicting, or ambiguous data, with difficulties establishing identity for some populations. In **Nepal**, key informants widely recognised that data was limited, late, and had poor coverage, but what was available was used – for example allocating healthcare workers to emerging hotspots, preparing new quarantine facilities, and allocating budget to hospitals and provinces based on case data reported in the IMU. Compared to case surveillance data, key informants in **Nepal** noted greater difficulties regarding the interpretation of mortality counts in **Nepal**, as there were multiple data sources for monitoring mortality, with conflicting data points and tensions noted between sectors and agencies with responsibility for different reporting systems. In **Thailand**, active case surveillance was scaled down when case incidence and pressure on hospitals peaked during Delta wave. Active surveillance teams shifted to promoting vaccination and home isolation as the priority response measures.

Linking hospital funding and reimbursement to COVID-19 reporting requirements improved the completeness and timeliness of COVID-19 surveillance data in **Indonesia** and **Nepal**. Additionally, in Nepal, private providers were incentivized with reimbursements for notified cases, and were required by legislation to submit case data. In Nepal, informants recognised that there were some challenges with the use of financial incentives for case reporting; incentives were necessary to get data but increased the risk of fake data submissions. Despite this risk, key informants reflected that incentives were essential for data sharing.

Timeliness

Regarding timeliness, countries aimed for daily reporting of COVID-19 cases and deaths for most of the pandemic period. Even where integrated data management systems became available, such as in **Indonesia**, timeliness was challenging amidst the extreme demands of the pandemic response. In Indonesia and elsewhere, key informants reported that surveillance teams at all levels of the health system made extraordinary efforts to continue compiling data for daily reporting, often working extremely long hours to do to ensure daily reporting deadlines were met. Thus, timeliness was maintained to a considerable extent for case surveillance. For other types of surveillance, reporting of surveillance data was delayed in many countries, especially mortality surveillance, serosurveillance, and genomic surveillance.

Flexibility

In most countries, pre-existing communicable disease surveillance systems lacked flexibility to readily incorporate COVID-19 surveillance, particularly surveillance types other than case surveillance, even in countries with well-established surveillance systems and processes. For example, **Thailand's** pre-existing national communicable disease surveillance system required each provincial office to report notifiable diseases to the Department of Disease Control (DDC) Department of Epidemiology once a week, typically using Microsoft Excel spreadsheets. These reports were then aggregated into a weekly situation report, a process that had been in place for over 30 years. However, there were multiple barriers to incorporating COVID-19 surveillance into this system. Some of the challenges included the switch to daily rather than weekly reporting, and substantial variation in surveillance and reporting processes (including data and spreadsheet formats) used by different provinces.

The flexibility of surveillance strategies also emerged as an important element of surveillance performance. Amongst the case study countries, **Thailand** demonstrated the clearest example of flexibility in surveillance strategy in response to the pandemic phase, which appears to have maintained and improved the overall performance of COVID-19 surveillance in the face of rising case incidence, spread of new variants of concern, and other significant shifts. In Thailand, there was clear recognition of the different phases of the pandemic response, with adjustment of measures and decision making according to the pandemic phase - and accordingly, prioritization of different types of surveillance. For example, as case incidence increased, Thailand moved from individual to cluster investigations, adopting the 'bubble and seal' approach through cooperation with the private sector to conduct and pay for workplace-based testing, prioritizing active case finding rather than contact tracing (as described in section 4.3.4), and de-prioritizing active case surveillance during infection peaks when resource constraints relative to response needs were most severe. Key informants reported that active case surveillance in late 2021, including rapid antigen testing outside bars and other high-risk locations, was thought to have delayed the peak of the Omicron wave by one month. During the transition phase, surveillance efforts were focused on high-risk settings (including aged care homes) and risk mitigation for returning travellers.

3.3.4. Monitoring burden of COVID-19 on healthcare capacity

The extent to which hospitalizations exceeded capacity varied substantially across countries and was driven at least as much by the effectiveness of the response as pre-existing hospital capacity. Effective surveillance and response averted pressure on hospitals, which in turn preserved resources to monitor the hospitalization rate and hospital capacity and respond accordingly.

Some countries in the region reported that hospital capacity was never severely exceeded:

- In **Bhutan**, pressure on hospitals was minimized through stringent measures to delay the onset of community transmission in the country, including closure of international borders and a 21 day quarantine period for permitted international arrivals (24), amongst many other preparedness measures. Hospital strain was further averted by stringent measures to protect healthcare workers from infection including pre- and post-deployment quarantine, regular testing, and training healthcare workers in surveillance of health systems and procurement of essential supplies for the response (25). By September 2021, there were no confirmed COVID-19 cases amongst healthcare workers (92).
- In **Timor-Leste**, health system capacity was reportedly never exceeded during the COVID-19 pandemic, in significant part due to the delayed onset of community transmission. Community transmission of COVID-19 was averted until March 2021 through stringent border control measures including restrictions on international arrivals, and mandatory quarantine of permitted travellers in government quarantine facilities (30). After the onset of community transmission, all confirmed cases were isolated in hospitals or dedicated COVID-19 treatment centres until July 2021, after which time home isolation was permitted as part of the strategy to manage rising COVID-19 incidence (31). These measures provided time to scale up testing, prepare treatment facilities, and other health system preparedness measures, as well the arrival of vaccines into the country and launch of the national vaccine program shortly after the onset of the first wave (31).

In some countries, modelling and forecasting of hospital capacity informed the rapid introduction of public health and social measures to suppress transmission – in these settings, the forecasted level of pressure on hospital capacities did not materialise, which was attributed to the effectiveness of the response measures implemented in part to avoid hospitals being overwhelmed. For example, in **Sri Lanka**, during a COVID-19 cluster among Navy personnel in April 2020, modelling was used in real time during the outbreak response to predict hospital admissions and effects on operational continuity of the Sri Lankan Navy (93). Ultimately, the reported number of cases was substantially lower than the projected number of cases. This 'prevented epidemic' was attributed to a series of rapid interventions in response to the outbreak, which were informed by the modelling (93).

By the mid-event phase and towards the transition phase, many countries had established integrated surveillance systems that included daily reporting of hospital bed availability, oxygen supplies, and other indicators of health system capacity for COVID-19 cases. However, the accuracy and timeliness of these surveillance data were constrained by data entry and reporting at hospital level, which often required manual (rather than automated) data entry into spreadsheets or other reporting tools. For example, in **Indonesia**, the SIRANAP information system was developed to collate and display hospital bed occupancy data, which was accessible to the public. This system aimed to support the public to view real-time hospital waiting lists and thus spread demand across hospitals with capacity remaining. However, the timeliness and completeness of this system depended on hospital data entry, which was delayed and incomplete especially during the Delta peak. Data entry relied on volunteers, who coordinated via a WhatsApp group within each hospital to share updated data on bed occupancy, which was then entered into SIRANAP from the chat logs.

Monitoring of hospitalizations and hospital capacity did not contribute to the performance of surveillance or the COVID-19 response overall when pre-existing health system capacity was insufficient to handle a health emergency. For example, in **Myanmar**, hospital capacity indicators reported before the start of the first wave (e.g. 1.04 hospital beds per 10 000 people; 0.71 ICU beds per 100 000 people; 0.46 ventilators per 100 000 people) were already considered insufficient to manage a medium size outbreak (87). Scarcity of medical staff contributed to pressure on hospitals in Myanmar, which was exacerbated by the high rate of infection of healthcare workers (about 10% of total confirmed cases in 2nd wave) (87).

3.3.5. Monitoring emergence and circulation of variants of concern

Early detection and monitoring of variants of concern was a key surveillance goal for countries in the region, most of which implemented and scaled up genomic sequencing capacities, as described in section 3.1.2.

Rapid sharing of sequencing data between **Thailand**, WHO, and China was essential for timely detection of Thailand's first COVID-19 case (and second country in the world to detect a case), noting that information sharing was facilitated through direct communications rather than via a formal bilateral mechanism or surveillance platform. As noted in section 3.1.2, wastewater surveillance contributed to surveillance for novel and circulating variants at local levels in key implementation sites in **India** where wastewater surveillance was implemented in collaboration with municipal health authorities.

However, at national level, genomic sequencing made a limited contribution to variant surveillance at country level in many settings and time periods, and had limited effect on the performance of surveillance overall. Factors that constrained the performance of genomic surveillance included that sequencing capacity was severely limited with substantial delays, with average time to results of approximately two months in some contexts (56), as described in Box 10. Though genomic sequencing was conducted in most countries in the region, it was mostly conducted sporadically and on a very small number of samples relative to the population size. Furthermore, key meta-data such as sample collection date, patient age, gender, comorbidities, and vaccination status were not often included in genomic sequencing databases.

For example, in **Indonesia**, key informants reported that the detection of the Delta variant of concern was inferred from case incidence, hospitalizations, and bed occupancy, before it could be confirmed by genomic sequencing due to delayed turnaround times. **Indonesia** also endeavoured to use genomic sequencing as part of the risk management strategy for several major international events during COVID-19, including performing genomic sequencing on test samples collected from international arrivals who were participating in major events. Management of COVID risk at these events was highly successful due to a range of measures taken, however, genomic sequencing results made limited contributions to the event risk management due to substantial delays. Key informants in **Thailand** also reported that genomic sequencing data was significantly delayed. **India** offers an illustrative example of common challenges for integrating genomic surveillance into decision making about the COVID-19 response in the region (Box 10).

Box 10: Factors constraining the performance of genomic surveillance for COVID-19 in India

In **India**, a consortium of government ministries and agencies established the Indian SARS-CoV-2 Genomics Consortium (INSACOG) in December 2020, which linked 10 national laboratories and 57 satellite laboratories into a genomic sequencing network coordinated by the Central Surveillance Unit of the Integrated Disease Surveillance Program, National Center for Disease Control (94,95). The goals of INSACOG included to understand super spreader events and outbreaks, and strengthen public health interventions to break chains of transmission (95). INSACOG set a target of 3-5% of all confirmed SARS-CoV-2 cases to be sequenced (56).

However, several critical gaps have been described that limited the utility of sequencing data collected through INSACOG to contribute to decision making about COVID-19. Firstly, sequencing capacity was limited and reporting substantially delayed; by October 2022, only 0.5% of all samples had been sequenced, with an estimated turnaround of 58 days (56). Though not formally evaluated, these results would have precluded the use of sequencing data for the stated goals of INSACOG. Secondly, available sequencing data underrepresented rural and low-income urban areas (in line with disparities in access to PCR testing), and key metadata such as sample collection date, age, gender, comorbidities and vaccination status were not captured (96). A review of India's genomic sequencing capacity presented several recommendations to strengthen genomic surveillance(56), including:

- Improving sample transportation, including ensuring adherence to cold chain and biosafety protocols;
- Sequencing samples from antigen-positive tests, which represent the vast majority of diagnostic tests conducted in the country;
- Optimising laboratory methods and quality assurance for efficient, accurate and cost-effective sequencing;
- Shifting towards a decentralized system to improve timeliness for sample processing and reporting (56).

3.4. Utility of surveillance for decision making

This section reviews the extent to which surveillance data informed decision making during the response to the COVID-19 pandemic. Relevant decisions include (but are not limited to) introduction or scaling back of PHSMs, allocation of healthcare and social protection resources, rollout of vaccination programs, domestic and international border restrictions, and movement restrictions, amongst others. Surveillance data and associated program data can also be used to inform decision making about the types of surveillance activities to implement. Finally, publicly available surveillance data can inform individual and community-level decision making related to health behaviours and compliance with public health measures.

3.4.1. Types of surveillance data used for decision making

Case surveillance data was the most widely used type of surveillance to inform decisions about key pandemic response measures, including decisions about domestic and international movement restrictions and border closures, implementation of mask-wearing policies, and other public health and social measures.

Data on hospitalizations and hospital capacity was less uniformly captured, but considered important for averting severe health system impacts across many countries. For example, in Jakarta, **Indonesia**, key informants reported that bed occupancy predictions were used to decide when to tighten public health and social measures in August 2020, and reinstated restrictions when full occupancy was predicted within the next seven days. Interpretation of hospitalizations data depended on the pandemic context and national policy settings. For example, early in the pandemic, **Thailand** admitted all confirmed COVID-19 cases to hospital for monitoring, when case incidence was low. Average length of hospital stay due to COVID-19 lasted longer in **Sri Lanka** than in many other countries, probably due to non-discharge policy until the symptoms were resolved and two negative tests were recorded (20).

In some instances, serosurveillance data was used for decision making about population-level pandemic restrictions and other measures. For example, key informants in **Thailand** reported several different uses of serosurveillance data in different populations. As part of the 'bubble and seal' policy, employees at key factories and other essential businesses were regularly tested for current SARS-CoV-2 infections, with testing funded by employers. If greater than 40% of workers at a single site tested positive, the business was 'sealed' into a bubble for four weeks. Manufacturing continued and workers resided on site. After several weeks, antibody screening was conducted. If greater than 85% of workers tested positive for SARS-CoV-2 antibodies, the bubble was re-opened. Later in the pandemic, data showing that greater than 90% of the population had antibodies to SARS-CoV-2 informed decision making to scale down the emergency response measures in **Thailand** in October 2022.

Overall, it appears that most countries made only modest investments in serosurveillance, with external funding provided to conduct a small number of serosurveys at different time points (**India** was an exception, where more than 50 seroprevalence studies had been conducted by August 2021 (49)). Prior to vaccines becoming available, these studies aimed to estimate the proportion of the population who had been infected with SARS-CoV-2 and contrast the findings with case surveillance data, as noted in section 3.3.3. At times, these data were also interpreted as reflecting the proportion of the population who were immune, at a time when re-infections were thought to be rare. Once vaccines became available, serosurveillance studies estimated the proportion of the population with infection or vaccine-acquired immunity, which was considered a key indicator for population-level susceptibility to severe disease or death, with implications for future health system demands. Some countries, including **Indonesia**, used findings from a modelling study based on national seroprevalence estimates to inform decision-making about reducing the stringency of PHSMs in late 2021, towards the end of the Delta wave but prior to the emergence of the Omicron variant of concern. These evolving purposes of serosurveillance, inherent limitations of serosurveillance studies, and varying interpretations presented some challenges for utilizing the available serosurveillance data for decision making, including:

- Serosurveillance was mainly conducted as research studies, with a significant lag to reporting of results. This prevented timely use of serosurveillance data to forecast case incidence or adjust pandemic response measures, but was likely adequate to compare the estimated cumulative population-level exposure to SARS-CoV-2 infection compared to case surveillance data at different time points.
- The quality of serosurveillance was limited by data quality issues, including false positive and false negative results due to limitations of antibody assays and test kits, as well as relatively high drop-out rates for repeated cross-sectional serosurveys in some settings. By 2021, waning immunity (whether infection- or vaccine-derived) was increasingly observed (97,98), which limited the utility of serosurveillance using traditional antibody-based serology tests as a population-based estimate of exposure to SARS-CoV-2 infection to contrast with case surveillance data.
- Given the initial absence of knowledge of the immunological characteristics of SARS-CoV-2 infections, and the emergence of new variants, it was difficult to interpret whether seropositivity conferred good protection against infection, or only conferred partial protection against severe disease and death at different time points in the pandemic. The protection conferred through vaccine-acquired immunity compared to infection-acquired immunity or

hybrid immunity was also a subject of ongoing research. These are inherent uncertainties for serosurveillance of an emerging pathogen, which at times challenged the utility of serosurveillance data. For example, countries reporting very high population-level seroprevalence for SARS-CoV-2 antibodies by the end of the Delta wave nonetheless experienced their highest case incidence of the entire pandemic during subsequent Omicron waves, though with lower relative severity. Nonetheless, seroprevalence estimates were used along with other sources of information to guide the withdrawal of PHSMs during the transition phase. For example, in **Thailand**, many pandemic control measures were scaled back in October 2022 once a nationally representative serosurvey estimated that greater than 90% of the population had evidence of vaccine-derived and/or infection-derived immunity, according to key informants.

Given the severe constraints to the performance of genomic sequencing for variant surveillance, as described in section 3.3.5, genomic surveillance had limited utility for timely decision making for much of the pandemic period. Exceptions included early case cluster investigations in the first weeks of the pandemic in some countries, and detection of the Omicron variant of concern leading to re-introduction of PHSMs in several countries, according to regional key informants. Genomic sequencing data was also used retrospectively to analyze the spread of some outbreaks.

Other types of surveillance explored in research studies and pilot projects, such as wastewater surveillance, were not typically used for decision making during the COVID-19 pandemic at national level. Instead, these studies provide evidence about opportunities to strengthen surveillance for future epidemic and pandemic responses. One exception is the use of wastewater surveillance in **India,** as noted in section 3.1.2.

3.4.2. Contribution of surveillance system performance to utility of surveillance

Across all types of surveillance, common limitations to the utility of surveillance data that relate to the performance of surveillance systems included:

- Pre-existing surveillance systems lacked the timeliness, sensitivity, and flexibility to enable effective surveillance of an emerging pandemic pathogen.

Countries established new, standalone surveillance systems and mechanisms for COVID-19 that functioned alongside pre-existing routine surveillance systems. The time required to establish and operationalise these new systems constrained the utility of surveillance data in the early weeks and months of the pandemic in particular.

> *"All of the COVID-19 surveillance systems including, the vaccination [surveillance system], we have written over that time period [during the pandemic]. At the start of the pandemic, everything was chaotic and ad hoc and temporary measures. We had to put things together and keep changing the program according to factors such as guidance from WHO and other agencies". (T.4)*

Furthermore, in some countries, including **Nepal**, there was no routine community-based surveillance for priority infectious diseases prior to the COVID-19 pandemic. Surveillance efforts were focused on detecting cases in hospital settings. In **Indonesia**, pre-existing routine community-based surveillance projects were operationalised as pilot projects and as a number of disease-specific surveillance programs. However, community-based surveillance systems for endemic infectious diseases were generally not utilized or scaled to support COVID-19 surveillance.

- Surveillance data lacked sufficient granularity to inform decision making.

As noted for several surveillance objectives in the previous section on surveillance performance, different types of surveillance data (e.g. case, genomic) were frequently missing key attributes, such as age, sex, comorbidities and other risk markers. For example, a published review of the health sector response to COVID-19 in **Nepal** noted:

> *"Routine surveillance data continues to lack important details that could be used for planning purposes, including the outcome of disease among vaccinated and unvaccinated individuals. There was also a lack of real time data on COVID-19 cases based on clinical features and treatment they have been receiving that could be useful for providing guidance for clinical decision making. Some of these are linked to long-standing issues in ensuring robust, and timely, reported from health facilities to the Ministry of Health and Population." (91)*

- Many types of surveillance data were substantially delayed, with lags of days to weeks commonly reported, as noted for case surveillance, deaths surveillance, serosurveillance, and genomic surveillance in previous sections.
- Key surveillance and health data were not linked across systems or levels of government.

Particularly in the first year of the pandemic, there was limited or no integration of EMRs, public health surveillance databases, laboratory information systems, and point of entry records.

Additionally, there were substantial challenges sharing data across subnational jurisdictions in the early part of the pandemic period. In **Indonesia** and **Nepal**, it was reported that there were often no formal mechanisms to coordinate data sharing and response (including contact tracing) horizontally between provinces for cross-provincial cases (e.g. commuters, migrants). This was instead managed through *ad hoc* communication between individuals and networks, for example using WhatsApp and other messaging software.

- A range of surveillance measures were needed to inform decision making, but this was beyond the capacity of surveillance units to produce, particularly in the first year of the pandemic.

For example, in **Indonesia**, the WHO Country Office initially presented the National Agency for Disaster Countermeasure, the agency coordinating the COVID-19 response, with eight indicators to guide response priorities, selected from an estimated 24 indicators proposed by WHO globally. However, due to the overload of competing demands and information sources for the response leaders, it was challenging to fully describe and interpret eight epidemiological indicators for a non-specialist group to translate into operational priorities in an emergency setting. This led to one indicator – population testing rate – being selected as the primary surveillance indicator to guide immediate response priorities. Key informants reported that this was successful in focusing efforts on increasing the population testing rate and enabling calculation of other indicators, however, may at times have incentivized over-testing of low-risk individuals (especially domestic travellers) in order to meet testing targets, which reduced the sensitivity and coverage of surveillance.

- Digital technologies could not overcome human resource bottlenecks and capacity limitations, but were most effective when developed in-country, and when surveillance, contact tracing, clinical, and laboratory data were integrated.

> *"I think with the data systems it's now time to get back to basics. Do the basics…These other tech they are cool… Maybe in this situation everything is chaotic. Everything is very fast. And the hospital setting and the hospital quality varies so much – maybe they don't have electricity all the time, and then high-level hospitals … you have to manage all that change, all that difference – taking everything back to basics and low tech as much simple as possible….Set up those basic things then we can talk about cool things next". (T.4)*

3.4.3. The role of leadership and governance in relation to utility of surveillance

The COVID-19 pandemic reinforced that the effectiveness of national responses can shift significantly with change in leadership of key ministries/institutions, and thus institutional effectiveness is still highly dependent on individual leadership as well as formal national policies, strategies, and resources. For example, in some countries, early cases in the alert phase were 'hidden' to avoid public panic, but this hampered the response significantly.

Prioritization of surveillance also depended on political leadership. In **Indonesia**, a change in ministerial leadership led to substantial investments in and support for improvements to the quality, coverage, and integration of COVID-19 surveillance data, including the development and integration of multiple information systems to support case surveillance, contact tracing, vaccination records, hospital burden, and other facets of the response. This transformation was in part enabled through the established of a new national agency to oversee the digitalisation of health data in Indonesia. Governance arrangements also interacted with trust in surveillance data. For example, in **Indonesia**, confidence in the accuracy of reported case numbers increased once decentralized province-based laboratory testing was established, after initial reliance on a single national reference laboratory to conduct COVID-19 testing.

Epidemic and pandemic literacy amongst decision makers had an outsize influence on the utility of surveillance data for informed decision making. Once community transmission was widespread, communications and information products based on surveillance data were not sufficient to influence political decision makers in some countries, who faced significant competing pressures, such as maintaining economic activity. Across the breadth of the qualitative data collection including region-wide sources, key informants at multiple levels and from several countries reported that non-health sector decision makers lacked epidemic and pandemic literacy, and this lack of epidemic and pandemic literacy at times hindered the appropriate implementation of PHSMs and other aspects of the response. However, these effects were not uniform – for example, in **Nepal**, though the implementation of lockdowns and other PHSMs was recognised as being politically sensitive (as in all countries), there was no perceived political interference in testing strategies and reporting of surveillance data. In **Thailand**, epidemic literacy at different levels of government was noted as a strength of the country's preparedness by key informants.

> *"This is one of the best experiences in using epidemiological data that I've ever seen, since [even] the prime minister also tried to understand the meaning of incidence and the actual number of cases". (T.10)*

3.4.4. Impacts of financing, resourcing, and private sector engagement on the utility of surveillance

Though not the focus of this project, financing and resourcing-related enablers and barriers for whole-of-society response to the COVID-19 pandemic were raised frequently in interviews and in the literature, with implications for surveillance as well as contact tracing.

The WHO SEAR is reported to have the lowest per capita level of health expenditure of all WHO regions, which was anticipated to substantially constrain capacity to respond to the COVID-19 pandemic (99). There is limited information available regarding how countries in the region mobilized and allocated funding specifically for surveillance and contact tracing, however it is notable that all SEAR Member States made COVID-19 tests available free of charge from early in the pandemic period (99). In practice however, severe constraints in supply chains and resourcing for COVID-19 tests in the first few weeks of the pandemic limited the effectiveness of provisioning COVID-19 tests free of charge (99). In some countries, non-citizens were ineligible for free testing; in countries where migrant workers constituted a high risk group, this likely undermined the effectiveness of surveillance efforts (99). In June 2020, the Government of **Bangladesh** introduced co-payments for public sector COVID-19 tests administered in health facilities (USD $2.40 co-payment) and at patients' homes (USD $5.90 co-payment); these fees were later reduced but maintained until at least March 2021 (99). Testing rates declined substantially in **Bangladesh** following the introduction of the co-payment policy, to the second lowest testing level proportional to population globally (99). The Government of **Nepal** first introduced a COVID-19 public sector test co-payment of USD $16.76 in October 2020, with exemptions for disadvantaged and vulnerable populations, and healthcare workers (99). The co-payment was removed within a month in response to rising case numbers, but re-introduced at a reduced rate in February 2021 (99). An analysis of over 30 low and middle income countries globally found that the epidemiological utility of surveillance data depends on testing policy, with open (unrestricted) testing policies far more effective than testing policies that constrain access by eligibility or cost (100).

SEAR Member States had a range of approaches to engaging the private sector in COVID-19 surveillance. The Government of **Thailand** rapidly integrated the private health sector into national case management and laboratory systems, including imposing the same reporting requirements on public and private health facilities (99) and requiring factories and other manufacturers to conduct regular employee testing through the 'bubble and seal' policy enacted during the second year of the pandemic. In contrast, the Government of **Bangladesh** initially prohibited private laboratories from performing COVID-19 tests. In **India**, there were pre-existing regulatory barriers to integrating the private sector into the response, requiring novel approaches to overcome – ultimately, 40% of hospitals authorized to provide free COVID-19 tests and treatment in 2020 were privately owned (99). Private health facilities in countries including **Bangladesh, India, Indonesia, Nepal** and **Sri Lanka** were reported to regularly charge above the agreed price cap for COVID-19 tests, indicating limited government capacity to maintain oversight of the private sector's engagement in the COVID-19 response (99).

Other challenges related to financing and resourcing were noted in case study countries. For example, the Government of **Nepal** had initiated a federalization process some years prior to the pandemic, with new levels of government and delegated responsibilities created. Key informants reported that there was a misalignment of funding between urban and rural areas in the new federalised structure, which affected COVID-19 testing capacities. In some settings, authorisation of operational costs, such as mobile phone data costs for health workers conducting surveillance activities, was centralized and slow to be approved. Lack of timely approval and release of funds constrained the implementation of activities.

3.5. Role of WHO in supporting surveillance

Information in this section is derived mainly from qualitative interviews in case study countries and at regional level, as well as from discussions during the regional validation meeting. Of note, key informants did not always distinguish between WHO Country Offices, SEARO, or WHO as a global entity when reflecting on the role of WHO in supporting surveillance. Therefore, in this section, responses are described as being related to 'WHO' in general, rather than specific WHO entities, unless noted.

Many key informants and discussion group participants reported that WHO played a very important role in supporting Member States to improve the performance and utility of surveillance during the COVID-19 pandemic, offering valuable assistance such as funding for additional surveillance officers, deploying technical staff to Member States' emergency operations centres, and a range of logistical supports. At Country Office level, WHO personnel were perceived as neutral bridges between Ministries of Health and key decision makers in national governments. In case study countries, WHO Country Office staff were perceived as approachable and responsive.

Despite these efforts, key informants across countries and levels expressed that WHO guidelines, data, and information products were delayed. Feedback emphasized the need for more timely support from WHO to enhance pandemic response at the national level. These delays often prompted reliance on other international compilations of surveillance data, which were noted by some key informants as including the Johns Hopkins COVID-19 data visualization dashboard, data and dashboards provided by the Institute for Health Metrics and Evaluation (IHME), and guidance on surveillance from the European Centre for Disease Control and Prevention, the United States Centers for Disease Control, and other partners. Senior key informants at national and regional level noted that traditional broadcast media and social media sources often provided the most timely and insightful information about the pandemic trajectory nationally, regionally, and globally. It was also noted that structured surveillance information as reported by Member States, SEARO, and WHO globally could not provide the same 'picture' of the pandemic context as these news and social media sources. While WHO's guidance was regarded as international best practice, this reputation sometimes inhibited the flexibility of national responses. For example, some key informants in some Member States reported that they sought greater support regarding flexibility and contextualisation when interpreting and applying WHO guidance to their national contexts, especially when implementing changes to case definitions and case isolation guidance, for example.

Country-specific experiences varied. In **Indonesia**, WHO formed part of the COVID-19 taskforce and provided personnel and technical assistance for surveillance data management, laboratory testing protocols, contextualising global surveillance guidelines and indicators, and planning for major international events, amongst other support. However, global WHO guidelines were sometimes perceived as being late. In **Nepal**, WHO's guidance was perceived as timely and adapted to local contexts, and deployment of WHO personnel to surveillance units supported and strengthened essential surveillance functions. However, key informants reported that there was some confusion at different levels of the health system when surveillance and related guidance and protocols frequently changed. Nepal faced challenges in accessing critical medicines and vaccines despite WHO support. In **Thailand**, key informants expressed a desire for more timely epidemic data from WHO to better respond to the emerging COVID-19 pandemic, particularly during the alert phase. Decision makers in Thailand often prioritized evidence and expert opinions from national sources rather than WHO, including their own case and outbreak investigation data, and experience responding to previous public health emergencies of international concern.

> *"For example, we wanted to see the epidemic curves. The pattern, how quickly it spread between cities and similar. This should have been available by March, April, May (2020), because many European countries like Italy and Spain had major outbreaks during that time. If this data had been available, other countries could understand what we are going to encounter in the future. But we could only watch the news - no one really made an epidemic curve at the time. We just knew there were high numbers of cases, high death toll, hospitals were over-occupied, they don't have enough medical supplies. But how can this type of information translate into knowledge for other countries to use for better preparation? Even though we had a short time - if you have one month lag you can do many things better, even though it's only one month." (T.10).*

4. COVID-19 contact tracing

This section presents findings related to the implementation, performance, and utility of contact tracing for COVID-19.

4.1. Description of contact tracing systems

There were many similarities in understanding and implementation of contact tracing across WHO SEAR, including the steps involved, the need for a surge workforce to sustain and enhance contact tracing capacity, and allocation of significant resources to the contact tracing effort. Contact tracing protocols were initially based on previous experience conducting contact tracing for outbreak-prone infectious diseases, and revised and updated several times in response to shifting transmission dynamics and priorities during the COVID-19 pandemic.

The key steps involved in contact tracing included:

- *Contact identification as part of case investigation*: Most countries conducted case investigations and contact tracing for laboratory confirmed COVID-19 cases detected through case surveillance. Suspected cases, or cases that tested positive through self-administered rapid antigen tests, were less often or rarely the subject of a case investigation including contact identification. Some countries set targets for the number of contacts per confirmed COVID-19 case.
- *Contact tracking and notification*: This step relies on timely tracking and notification of contacts and directing contacts to quarantine or testing sites (if applicable).
- *Contact follow-up:* This step included mandatory or advisory quarantine and/or (repeated) testing requirements, depending on the pandemic phase. In the first year of the pandemic, contacts were frequently directed to quarantine without undergoing testing, or prior to their test result being known, due to testing capacity shortfalls and backlogs.

In some countries, contact tracing commenced from the first detected case in the country, for example **Thailand** conducted a comprehensive case investigation to identify contacts amongst airline passengers and in-country community members for the first confirmed cases. In other countries, delays to official confirmation of the first case(s) in the country meant that contact tracing was not conducted for the earliest cases.

Common revisions to contact tracing protocols included changing the definition of a contact, testing requirements for contacts (including frequency and type of testing, e.g. PCR or antigen testing), quarantine location (home-based or facility-based), and quarantine duration.

Most countries commenced with manual contact tracing, with data captured in Microsoft Excel spreadsheets or similar tools. Digital technologies were increasingly integrated into the contact tracing workflow to scale contact tracing capacity and managing burgeoning datasets, as described in section 4.2.

4.1.1. Contact tracing objectives

Contact tracing was prioritized and implemented as part of national COVID-19 responses throughout the region. The objective of contact tracing was stated in some national contact tracing protocols to include early identification of contacts to prevent further transmission, in line with global guidance. In many cases, however, the objective of contact tracing was not specifically stated in national response plans or contact tracing guidelines. Instead, countries developed standard operating protocols focused on the implementation of contact tracing without explicitly stating aims, objectives, or desired outcomes.

Compared to surveillance, it is much less clear whether and how the objectives of contact tracing varied over different phases of the pandemic. Most countries maintained contact tracing, at least officially, as part of the national response strategy for most of the pandemic period. In contrast, in some countries, including **Thailand** and **Sri Lanka**, contact tracing was reportedly wound back or halted once caseload exceeded contact tracing capacity when community transmission was widespread, as described in section 4.3.4.

4.2. Contribution of digital technologies to contact tracing

Digital technologies were widely used to support contact tracing in the region. These included smartphone apps using Bluetooth proximity tracing, QR code venue check-in, and/or GPS functions intended for use by the general population to trace their exposure history, as well as smartphone or tablet apps and electronic information systems designed to replace paper-based data capture and analysis for contact tracing personnel, including formal health workers and health volunteers.

4.2.1. Contact tracing apps designed for use by the public

The COVID-19 pandemic was the first time that the public was directly engaged in contact tracing. Smartphone apps designed for use by members of the public to trace their location or contact history that were implemented in SEAR Member States during the pandemic are summarised in Table 3.

Table 3: Digital contact tracing apps for COVID-19 designed for use by the general population

Country	Name of digital contact tracing tool	Target population and geography	Launch year	Protocol/ technology for contact tracing
Bangladesh	Corona Tracer BD	General public, national	2020	Bluetooth proximity tracing
Bhutan	Druk Trace	General public, national	2020	QR code check-in
India	Corona Kavach (discontinued April 2020)	General public, national	2020	Bluetooth proximity tracing
	Aarogya Setu (replaced Corona Kavach)	General public, national	2020	Bluetooth proximity tracing GPS tracking
	Mahakavach	General public, Maharashtra State	2020	GPS tracking
	Corona watch	General public, Karnataka State	2020	GPS tracking
Indonesia	PeduliLindungi (later renamed as SatuSehat)	General public, national	2020	QR code check-in Bluetooth proximity tracing
Maldives	TraceEkee	General public, national	2020	Bluetooth proximity tracing
Myanmar	Saw Saw Shar	General public, national	2020	Bluetooth proximity tracing GPS tracking QR code check-in
Nepal	Covid NP	General public, national	2020	Bluetooth proximity tracing GPS tracking
Sri Lanka	MyHealth	General public, national	2020	GPS tracking
Thailand	Mor Chana	General public, national	2020	Bluetooth proximity tracing GPS tracking
	Thai Chana	Venue managers, national	2020	QR code check-in

Table 3 note: Unpublished data sourced from an ongoing systematic review of digital contact tracing apps globally, led by team member Dr Florian Vogt.

Despite their widespread use, no study or report could be found that evaluated the contribution of any digital contact tracing app to contact tracing effectiveness in WHO SEAR. This represents a significant evidence gap for the optimal use of digital contact tracing tools in the event of future epidemics or pandemics, and stands in stark contrast to the ubiquity of use of these apps in SEAR Member States during the pandemic. It is notable that evidence gaps are also apparent in other global regions, including the neighbouring WHO Western Pacific region (13). In the Western Pacific Region, where a small number of research studies and evaluations have been conducted, evidence suggests that there is little to no effectiveness of digital contact tracing apps designed for use by the public (13).

Key informants reported that apps intended for use by the general population were not integrated into subnational or national contact tracing systems and in many cases, informants were not aware of how to access data from these apps to support case investigation and contact identification or contact notification. Instead, some apps with contact tracing functions were mainly used to verify the COVID-19 case status of smartphone users when checking into venues such as shopping centres, movie theatres, or for domestic travel.

Studies addressing the acceptability and use of public-facing contact tracing apps reported significant concerns relating to data privacy and security, as well as technical and design flaws that impeded use. Overall, these factors constrained uptake and effectiveness of these apps across settings. For example, the Government of **India** launched the 'Aarogya Setu' digital contact tracing app on 2 April 2020. It used both Bluetooth and GPS for proximity tracing (101). Download and use of Aarogya Setu was mandatory for many public and private sector employees and in many public venues (102), which sparked controversy (103,104). An early analysis of the Aarogya Setu app published in August 2020 compared technical features with data privacy implications against other proximity tracing apps, and found that, while the Bluetooth/GPS features were similar to other apps, Aarogya Setu stored more personal data of its users (e.g., age, full name, profession, medical conditions, gender). The researchers concluded that the Aarogya Setu app, in its first version, raised concern on privacy as it stored data on a central server and information was not fully regulated (101). Researchers reported that these privacy concerns reduced acceptance of the app amongst the general public (101). In contrast, a different analysis concluded that the far-reaching data mining and privacy breaches of the app were justified by the circumstances, arguing that its mandatory nature increased uptake, thereby making it potentially more effective (102). These contrasting perspectives reflect the ambiguity regarding optimal models for digital contact tracing early in the pandemic period. Regional key informants advised that the privacy and security features of Aarogya Setu were updated in subsequent versions, including a change to the identification system and device-based storage rather than central server storage unless the user reported their case status or requested a COVID-19 test via the app. By February 2023, the contact tracing functionality of Aarogya Setu was discontinued, and centrally stored contact tracing data was deleted (105).

Concerns were also raised about the transparency regarding use of contact tracing app data in **Bangladesh**, against a background of increasing rates of data breaches and inadequate institutional and regulatory oversight (106). The Corona Tracer BD app was assessed to meet only two of five principles for ethical implementation of COVID-19 apps, namely voluntary use and limited data collection. A qualitative study reported that key informants familiar with the Bangladesh government's handling of COVID-19 app data identified gaps in legislation, regulation and practice regarding COVID-19 app data privacy and security (106). For example, government officials with key responsibilities for provincial-level data collection during the pandemic did not receive training or information about how data privacy and security were managed within the National Data Centre. Notwithstanding the significant stressors and competing priorities during the acute phases of the pandemic response, these gaps heightened the risk of significant data breaches and misuse for Bangladeshi citizens who adopted or used government-supported contact tracing apps (106).

In **Thailand**, a study of the useability of the Thai Chana contact tracing app was conducted from 15 December 2021 to 14 January 2022, corresponding to a surge in COVID-19 cases due to the spread of the Omicron variant of concern (107). This study is unique for being conducted in the late event phase of the pandemic when case incidence was at its peak. A survey of 800 Thai residents found that factors including intended use, actual use, perceived ease of use of the Thai Chana app were strongly associated with perceived useability. Perceived vulnerability, perceived severity of COVID-19 and understanding of the COVID-19 pandemic context were positively associated with intended and actual use (107). These represent plausible pathways towards the public health effectiveness of the Thai Chana app. However, key informants in Thailand reported that Thai Chana was not primarily used for contact tracing purposes; instead, it was mainly used for monitoring venue check-ins and compliance with venue capacity limits as determined by social distancing targets. Key informants reported that there was limited capacity to access and analyse data from Thai Chana, and that when data was accessed, there were delays and other barriers to effective use.

Key informants in case study countries universally reported that public-facing apps had very little or no utility for contact tracing. In **Indonesia**, key informants reported that while the PeduliLindungi app had functionalities to support contact tracing, it mainly functioned as a tool for monitoring individual case and vaccination status. Key informants in **Thailand** also reported that population uptake of the Mor Chana app, a Bluetooth proximity-tracing app, was extremely low – an estimated 10 000 users in a national population of 67 million.

4.2.2. Digital technologies to support contact tracing workflow

Digital contact tracing tools were also deployed to support health workers and health volunteers to conduct contact tracing, including case identification and investigation, contact identification and notification, and monitoring of compliance with quarantine/movement restrictions. Compared to digital tools designed for use by the general public, there is less published information available to describe the use of contact tracer-focused tools. Similar to digital technologies for surveillance, there was limited to no ongoing use of pre-existing specialist contact tracing data management software. For example, the WHO-developed Go.Data case investigation and contact tracing program was offered for use in several countries in the region. Some countries piloted Go.Data as part of national case investigation and contact tracing, including **Bangladesh, Bhutan, Indonesia, Maldives, Nepal, and Timor-Leste**. However, Go.Data was confirmed to have been withdrawn from use after initial implementation in Bhutan, Indonesia, Maldives and Nepal, with its ongoing use from 2021 mainly confined to research studies of transmission amongst healthcare workers in **Bangladesh** and **India** (108). There were several limitations that constrained its use, including difficulties retrieving data in field settings, lack of timely technical support, and other challenges, as reported in the literature (9) and by key informants in case study countries, as noted below. Instead, contact tracing data was initially often managed using generalist software such as Microsoft Excel spreadsheets, and gradually replaced by new software developed in-country to support contact tracing workflows and data management. Examples include:

- In **Sri Lanka**, the Suwapetha app was developed by the Western Provincial Ministry of Health and WHO Sri Lanka to support health workers to identify and manage cases and their contacts (109). The app integrates COVID-19 testing data from the national laboratory network provides feedback to the general public in the form of real-time high-resolution risk maps, updates/notifications and general information about COVID-19.
- In **Bangladesh**, a contact tracing app was designed and implemented specifically for use for contact tracing in Rohingya camps in Cox's Bazar (110). Government-imposed restrictions on internet access in the camps were incompatible with use of smartphone apps for contact tracing by the general population in the camps. Instead, community health workers conducted household visits as part of case investigation and contact notification and follow-up activities. Between January and May 2021, approximately 250 000 individuals were screened in the camps, of which 431 suspected cases and 77 confirmed cases were identified (110). Data were entered into a bespoke contact tracing app designed adapted to the specific context of the camps, with key design features including:
    - The app went through several rounds of development and formative research to improve its utility in the local social and cultural context.

- Due to internet restrictions in the camps, the app was designed for use for community health workers to enter and manage contact tracing data offline, which was later automatically uploaded when internet connection was available.
- A key component of the app was incorporation of an education and information dissemination module to aid community health workers to address uncertainties, fears, concerns, and misinformation raised by community members.

Key informants in case study countries reported a range of innovations as well as challenges for using digital technologies to support contact tracing. In **Nepal**, contact tracing data verification was reportedly performed via Zoom calls between public health responders in the absence of a sufficiently granular data system to manage contact tracing and surveillance data. The WHO Country Office supported the rollout of Go.Data for contact tracing data management, but it was never widely used and was quickly replaced by a paper-based and Microsoft Excel spreadsheet system. Key informants described a range of limitations of Go.Data, including that field-level staff lacked permissions for accessing key contact tracing data. Even once the Information Management Unit data management system was developed, the modular design of the IMU did not allow for linking cases to contacts. Data loss and other technical issues also constrained its utility for contact tracing. In **Indonesia**, the 'Silacak' system was launched in November 2020 for contact tracing by a government team. Based on DHIS2, Silacak integrated with NAR, the surveillance information system developed for COVID-19 surveillance (see section 3.2) as well as the public facing PeduliLindungi app, linking data from multiple platforms via a single case identifier. This integration allowed for faster identification of cases and contacts than previously. Silacak was designed to be accessible on various devices and supported offline data access, which was key to its effective use in areas with limited internet connectivity. Silacak reported contact tracing performance indicators (case to contact ratio) which informed national zoning decisions.

Overall, key informants reported that digital technologies designed to support public health responders with contact tracing data entry and management reduced their workload and improved timeliness, but could not overcome the bottleneck of insufficient human resources to sustain contact tracing throughout the pandemic.

4.3. Performance of contact tracing

There were no effectiveness evaluations and relatively few published descriptions of contact tracing for COVID-19 in WHO SEAR. The available published studies mainly described contact tracing in the alert phase and early event phases only. Key informants in case study countries provided further information about the implementation and performance of contact tracing throughout the pandemic. Overall, there were severe challenges contact tracing for most of the pandemic periods, from contact identification through to contact follow up and quarantine.

Some countries established and monitored contact tracing performance indicators, but these indicators were almost always process indicators, such as the number of contacts identified per case, rather than outcome indicators relating to prevention of further transmission.

4.3.1. Contact tracing performance over different pandemic phases

Contact tracing during the alert phase

Studies and reports from the alert and early event phases indicate that contact tracing was effective in many settings when case incidence was low. In several countries, early outbreaks were contained, and contact tracing was recognized as a key contributor to the effectiveness of the response. Crucially, contact tracing was one of several response measures implemented when outbreaks were successfully contained, with measures including active surveillance and movement restrictions also contributing to success. In some countries, contact tracing was introduced and utilized in the early stages of the pandemic to interrupt transmission, but at times, negative community perceptions led to hesitancy and limited cooperation with contact tracers.

For example, the capacities of health authorities to implement contact tracing during the Alert phase have been described in a report on contact tracing and associated control activities for the first cluster of COVID-19 cases in **Bangladesh** in March 2020 (111). The index case for the cluster was a Bangladeshi resident who had recently travelled from Italy. Of the 163 contacts listed for the index case, 34 (21%) were identified and directed to quarantine at home. Of these identified contacts, 6 (18%) were confirmed COVID-19 cases, who tested positive when in home quarantine. Contacts that could not be identified or traced mainly related to exposure events on public transport. No digital contact tracing tool was available at this early stage of the pandemic. In addition to contact tracing, a containment strategy was implemented, with the containment plan adapted from a pre-existing WHO plan for responding to the H1N1 pandemic in 2009. A geographic risk zone around the index case and their contacts was defined, and entry and exit were restricted. It has been reported that COVID-19 case incidence remained low in the area where the containment strategy was implemented for several weeks (111).

Contact tracing during the event phase

There was a clear consensus across case study countries that contact tracing was ineffective once case incidence exceeded contact tracing capacity, even with a surge workforce to support contact tracing. Case incidence exceeded contact tracing capacity early in the event phase in several countries, well before peak incidence was reached. For example, in **Indonesia**, contact tracing initially relied on centralized data integration, but this approach could not keep up with the sudden surge in cases during the first wave (39). By mid-2020, there were concerns regarding delayed initiation, coverage of positive cases and of contacts screened, unclear procedures, variation in implementation at the local level, and uncertainty regarding coordination and resources needed as caseload continued to increase (112).

There was considerable variation in how key informants perceived the importance of maintaining contact tracing activities when capacities were overwhelmed. In some settings, contact tracing was perceived as a vital activity throughout the pandemic response, and significant efforts were made to at least partially sustain contact tracing despite stretched resources. Others perceived contact tracing to be ‘meaningless’ during the peak of the Delta and Omicron waves. These informants often reported that they felt that they had no influence over decision making to sustain contact tracing as official policy, despite its perceived ineffectiveness. Some of these informants were aware of WHO guidance regarding contact tracing, noting that it was difficult to advocate for the suspension of contact tracing due to its ineffectiveness in the local context, when this was in apparent contradiction to WHO guidance. For example, during periods of high case incidence in **Nepal**, contact tracing was maintained as national policy, despite high awareness amongst health responders that they had poor to no capacity to implement contact tracing effectively. Instead, contact tracing was *de facto* deprioritised, with public health responders focusing more on vaccination and other aspects of the response. In **Indonesia**, public health responders continued contact tracing in accordance with national policy, but with an awareness that contact tracing was no longer effective given few contacts were traced within a time frame consistent with reducing risk of onwards transmission.

In **Thailand**, provinces had different approach to contact tracing. Despite challenges harmonizing contact tracing data, this was considered an advantage as the national risk matrix approach allowed for contact tracing to be conducted in context-appropriate ways, and was continued in areas with lower case incidence even when contact tracing was no longer being pursued in urban areas (see section 4.3.4). This approach was enabled by considerable delegation of responsibilities as well as resources to district and provincial level governments.

Contact tracing during the transition phase

It appears that most or all countries had ceased contact tracing by the transition phase. Amongst countries that sustained contact tracing for much of the pandemic, the timing of official withdrawal of contact tracing policies varied, but there is no evidence that contact tracing was prioritised beyond early to mid-2022.

4.3.2. Health workforce and surge capacity to conduct contact tracing

In several countries, it took time to develop contact tracing protocols and familiarise healthcare workers with implementing contact tracing. For example, in **Nepal**, key informants reported that contact tracing protocols were not available at local health system level by the time of the first lockdown. By the time protocols were fully developed, case incidence was already too high for contact tracing to be effective.

Multisectoral collaboration to create a surge workforce for contact tracing expanded capacity but introduced other challenges. In particular, military and police personnel (hereafter 'security services') were considered an important part of the contact tracing surge workforce in many countries. In important respects, the security services effectively enabled contact tracing capacity to be scaled up. Informants described key attributes of security services that positively contributed to scaling up capacity, including that security services personnel are familiar with working under hazardous conditions, had previous experience responding to natural disasters, were able to be rapidly mobilized and directed to work throughout the country, and operated under clear chains of command that enabled timely operations. In some settings, security services also supported healthcare workers to engage with businesses that were initially refusing to participate in contact tracing.

However, there were limitations and disadvantages associated with engaging the security services across settings. For example, in many cases it appears that security services lacked sufficient familiarity with public health principles and ethics to implement contact tracing effectively. Security personnel were often more focused on meeting targets by identifying the required number of contacts, rather than contacts at highest risk and/or vulnerability. At times, informants reported that security services adopted tactics akin to policing rather than public health responses when identifying and notifying contacts, including descriptions of security services in effect "apprehending" contacts in some instances.

Community volunteers, community health workers and occupational health staff were able to effectively support contact tracing in some settings, including mobilizing social support for contacts in quarantine, however they were not consistently mobilised, compensated, or resourced.

Sustaining contact tracing skills and capacities as part of the formal healthcare workforce and surge workforce was particularly challenging during and after the most severe COVID-19 waves that overwhelmed health systems. For example, key informants in **Nepal** reported that the recruitment and training of contact tracers was halted towards the end of the Delta wave, due to pandemic fatigue and exhaustion amongst healthcare workers. Furthermore, the same healthcare workforce was responsible for administering COVID-19 vaccines as well as contact tracing; and the vaccination campaign was prioritised.

4.3.3. Community engagement in contact tracing

Support for contact tracing was mixed in communities in the three case-study countries. Support for contact tracing was higher in settings where the effectiveness of early containment measures including contact tracing demonstrably led to prevention of further transmission and/or easing of some restrictions, as was reported in **Thailand**. In Thailand, health responders perceived that the community was generally very compliant with public health measures including contact tracing. Celebrity and media communications also supported participation in contact tracing.

There was ongoing support amongst some communities for contact tracing during the pandemic. In **Indonesia**, public health responders reported that cases were self-presenting and seeking guidance for their contacts, including during the Omicron wave, by which time home quarantine arrangements and shorter duration of quarantine had reduced some compliance challenges. Public health responders felt strongly compelled to respond and deliver case management and contact tracing despite stretched resources to in these situations.

Communities were engaged in contact tracing in **Thailand** from the outset. When cases were low, contact locations were advertised via media outlets to encourage contacts to self-report. When contact tracing capacity amongst the public health workforce was overwhelmed, the approach changed to encourage cases to self-notify their case status to their contacts. Contacts were encouraged to self-test with a rapid diagnostic test if they were aware that they were a contact, and they could self-report their case status if positive via a national hotline.

In general, lack of support for the daily needs of people in quarantine and their families, from whom quarantined contacts were sometimes separated, led to under-reporting of cases and non-compliance with quarantine. In all three case study countries, it was consistently reported that engagement with contact tracing was limited when people perceived their livelihoods were threatened, in particular for migrant workers with unresolved legal status, in illegally-operating businesses (e.g. gambling facilities), and amongst marginalised communities (e.g. sex workers). Countries also had challenges conducting contact tracing for international tourists, as they were not linked to national systems. In many of these populations, the security services were engaged to enforce compliance, however community trust and participation in the contact tracing process was hindered in many settings by the involvement of security services.

4.3.4. Alternatives to contact tracing

Alternatives to contact tracing were pursued in some settings. For example, in **Thailand**, active case identification was favoured over contact tracing in some contexts – for example, Thailand's VHVs were advised to conduct intensive and prospective case identification rather than retrospective contact tracing after detection of a confirmed case (50). Where contact tracing was conducted, it performed to a high level with the aim of suppressing or eliminating transmission. A modelling study estimated that the sensitivity of contact tracing to detect the contacts of index cases was 77.6% between January and June 2020 (113). The sensitivity to detect secondary cases amongst contacts of an index case was somewhat lower, at 67.6%. By the second year of the pandemic, when community transmission was widespread, **Thailand** largely switched from contact tracing to active case finding.

> *"The mindset changed during Delta wave in mid-2021. Delta came in April, but took around two months before rising sharply. At that time, we realized that contact tracing and containment strategies were no longer appropriate in a pandemic situation, so we changed strategy" (T.10).*

However, as the Delta wave receded, contact tracing was re-introduced to support early detection of high-risk unvaccinated contacts to prevent COVID-19 deaths amongst this cohort.

In **Sri Lanka**, from April 2020, contact tracing and active surveillance were integrated side by side at field level across 357 geographical/administrative areas (Medical Officer of Health units) (20). These units are part of the preventive care system and are the smallest public health administration areas in Sri Lanka, covering 60 000-100 000 people each (114). Combining surveillance and contact tracing at the grassroots level via the Medical Officer of Health units has been credited with keeping community transmission under control during most of 2020 in Sri Lanka (114,115). A modelling study suggested that contact tracing was among the single most effective non-pharmaceutical interventions in Sri Lanka (116). However, during the second wave (starting October 2020) the level of improvement necessary for contact tracing to suppress case numbers was no longer realistic if the goal was to contain the epidemic (116). Contact tracing was reportedly halted once community transmission was widespread.

4.4. Utility of contact tracing for decision making

Compared to surveillance, national public health units had far less oversight of contact tracing data. Contact tracing data was also not required to be reported to SEARO. In the case study countries, contact tracing data was mainly retained and used at provincial level. In **Indonesia**, high-level aggregate contact tracing data (namely case to contact ratios) were reported to the national level.

There are several examples of how contact tracing data was used alongside surveillance data for decision making about the COVID-19 response. For example, **Thailand** used contact tracing data early in the alert phase to inform their understanding of the epidemic and pandemic potential of the SARS-CoV-2 virus. There is an interesting case study in the **Maldives** for how contact tracing data can support decision making along with surveillance data. Contact tracing data provided key inputs into nowcasting models of COVID-19 epidemic spread in the first weeks of the outbreak in the Maldives (117). For example, in the absence of mobility data, the number of contacts per case was used as a modelling input to infer scenarios for near-term spread of COVID-19. In **Indonesia**, key informants at national and subnational level confirmed that contact tracing data was used along with surveillance data to classify the risk level of subnational zones. However, public health staff were not always comfortable with the integration of contact tracing data into zoning decisions, given inherent limitations and nuance required to interpret contact tracing data across subnational areas. Some informants suspected that manipulation of contact tracing data was being conducted in some provinces to ‘improve’ the zoning category, with attendant perceived economic and social benefits of fewer restrictions.

Overall, the utility of contact tracing for decision making was low from early in the event phase onwards in most countries, due to its low effectiveness at a population level once community transmission was widespread. Contact tracing strategy and resource allocation were not adapted effectively over the pandemic response phases in most countries, resulting in resource drain, with limited to no effective interruption of transmission chains.

Overall, there is still no generalizable and successful model to scale resources required to maintain contact tracing for COVID-19 when community transmission is widespread. There was a clear need for alternative strategies that would have made better use of scarce human and financial resources and more effectively reduced transmission.

4.5. Role of WHO in supporting contact tracing

Information in this section is derived mainly from qualitative interviews in case study countries and at regional level, as well as discussions during the regional validation meeting. As above, of note is that key informants did not always distinguish between WHO Country Offices, SEARO, or

WHO as a global entity when reflecting on the role of WHO in supporting contact tracing. Therefore, in this section, responses are described as being related to 'WHO' in general, rather than specific WHO entities, unless noted.

Across the region, most countries closely observed WHO guidance on conducting contact tracing for COVID-19 throughout the pandemic. This is reflected in the similarity of contact tracing protocols between countries, as noted in section 4.1. Unlike for surveillance, there was no standardized reporting of contact tracing data to SEARO. This meant that SEARO had limited visibility of contact tracing implementation, performance, and utility for decision making in Member States, though information was shared informally during meetings and included in situation reports where available.

Amidst severe pressures and the urgency of providing critical care during peak infection waves, particularly the Delta wave, several regional key informants observed that there was limited attention to the performance or effectiveness of contact tracing at national or regional level. In practice, this meant there was limited close attention to the impacts of maintaining contact tracing when caseloads exceeded contact tracing capacity, or proposing alternatives to contact tracing that could more effectively reduce transmission. As noted in section 4.3, some key informants perceived the need to maintain contact tracing to the extent possible despite clearly overwhelmed capacities, in line with WHO guidance.

To support interpretation of these reflections, it is instructive to review the timing and content of global WHO guidance on contact tracing in contrast to the experiences in Member States as described in section 4.3. Global WHO guidance was released and updated three times during the pandemic: the first guidance was released in May 2020 (118), the second guidance was released in February 2021 (119), and the third guidance document was released in July 2022 (120).The May 2020 guidance guided Member States on "establishing contact tracing capacity", by which time many Member States had already established or come close to exceeding contact tracing capacity amidst the first major waves of COVID-19. The February 2021 guidance continued to emphasise that contact tracing was a "key strategy for interrupting chains of transmission of SARS-CoV-2 and reducing mortality associated with COVID-19" and advised that where transmission was high, contact tracing could be focused on contacts at higher risk of exposure and/or severe disease. However, this guidance suggested a very wide range of contacts could meet these criteria, including household contacts, contacts in closed and crowded settings, contacts during a case's most infectious period, and contacts known to form part of a cluster of cases. As noted in section 4.3.1, most countries' contact tracing capacities were rapidly exceeded well before peak case incidence, already by mid-2020 in some instances. Therefore, several countries were already facing severe capacity limitations for contact tracing by the time this guidance was released in February 2021. By July 2022, global WHO guidance was updated once again, and advised Member States that in the context of widespread infection-acquired and vaccine-acquired immunity, it was appropriate to focus contact tracing efforts on high-risk contacts, rather than all contacts. However, by this time, most countries had already *de facto* deprioritized or withdrawn contact tracing policies. Of note, WHO guidance on contact tracing consistently included consideration of resource management, including assessing the impact of contact tracing relative to other health interventions. However, this advice does not appear to have led to major revisions of contact tracing protocols in most SEAR Member States, noting that key informants in **Thailand** and **Sri Lanka** did not refer to WHO guidance when describing decisions to transition away from contact tracing and focus efforts on other aspects of the response.

In summary, WHO contact tracing guidance lagged the pandemic realities in many SEAR Member States and was not perceived as providing timely guidance for countries. Given that contact tracing could not be implemented within time frames and coverage consistent with the goal of interrupting chains of transmission in most Member States for much of the pandemic period, global WHO guidance in effect hindered the most effective use of limited resources to suppress transmission during the pandemic in Member States where WHO guidance tended to be followed closely.

WHO offered other support to countries to implement contact tracing. WHO Country Offices supported salary costs for additional contact tracers in **Indonesia** and **Nepal**, which was considered by key informants as an essential support to address workforce gaps during peak periods. SEARO offered support to countries to implement digital technologies to support contact tracing, with varying outcomes. In **Indonesia**, WHO provided key inputs into the design of a contact tracing data management system that became ‘Silacak’, which was integrated with surveillance and other data sources (section 4.2.2). From early in the event phase, SEARO offered training in Go.Data software. However, as previously noted, WHO was not able to respond quickly to technical issues and flaws with Go.Data, and in **Nepal**, it was eventually dropped in favour of manual and Microsoft Excel-based data management, until the national IMU system was developed.

5. Summary of key findings and recommendations

This report presents evidence regarding the implementation, performance, and utility of surveillance, contact tracing, and associated measures supporting the COVID-19 pandemic response in the WHO South East Asia region. Public health responders throughout SEAR made extraordinary efforts amidst an unprecedented pandemic to conduct and maintain COVID-19 surveillance and contact tracing to avert transmission, deaths, and societal impacts of the pandemic. SEAR Member States achieved system-wide transformations and innovations that improved the performance and utility of COVID-19 surveillance, including the development of new, integrated information systems by in-country agencies during the height of the pandemic response. Similarly, countries made effective use of contact tracing along with other measures to contain and interrupt transmission for several clusters and outbreaks, especially early in the pandemic period. Countries also found a range of mechanisms to scale contact tracing capacity through multisectoral collaboration, even if capacity was ultimately overwhelmed by surging case incidence.

Despite these achievements, there is a risk that critical lessons learned, and capacities developed during the COVID-19 pandemic are already being lost (Box 11).

Box 11: Are lessons learned from the COVID-19 pandemic at risk of being lost?

Key informants in all three case study countries consistently expressed a range of concerns indicating that countries are still not well prepared to implement surveillance and contact tracing for another pandemic rapidly and effectively, and that lessons learned are being forgotten. For example, there are concerns that lessons learned from COVID-19 may be lost due to pandemic fatigue and institutional turnover.

"I'm afraid that the government itself is going to be forgetting all the experiences, it's like a kind of like a leaky glass... I'm not involved in that anymore, in the health preparedness... Maybe we were too tired facing the pandemic and then we don't move forward." (I.6)

Adaptable and flexible surveillance systems are still not in place, constraining the likelihood of early detection and response to another pandemic-prone emerging pathogen.

> *“But still, if you think, if any event is going to happen in a community, there is still not a mechanism that will allow that event – for example if there is a case, or if there are contacts in the community - that the system still doesn't allow us to report that.” (N.1)*

As health systems and financing are reverting to non-emergency levels, there is a risk that momentum towards multisectoral integrated surveillance will be lost due to budget constraints.

> *"We were so lucky that every kind of hospital connected with us at the time... We hope that they remain connected in the post COVID world, but they have to work it out from their own budget because if they're going to connect with us, they have to hire the staff and they have to allocate some budget to that. So, in COVID it was okay but post COVID? Maybe not all will remain connected to us, but we will hopefully have as many as possible.” (T.4)*

This project identified significant challenges and evidence gaps pertaining to surveillance and contact tracing for COVID-19. To support ongoing efforts to sustain and strengthen pandemic preparedness in WHO SEAR, this section presents evidence-based recommendations for strengthening surveillance and contact tracing for outbreak and pandemic-prone infectious diseases. Recommendations are offered for SEARO as well as for SEAR Member States. Key limitations and constraints that affect interpretation of this evidence and recommendations include:

- This project aims to support pandemic preparedness efforts, but the findings derive from country experiences during the COVID-19 pandemic only. Future pandemics may be caused by pathogens with different epidemiological and clinical characteristics, and in different social and economic contexts.
- Methodological limitations including the retrospective nature of the project, risk of recall bias for interview participants, lack of quantitative analysis of surveillance and contact tracing performance, reliance on published literature and technical reports for countries that were not visited.

5.1. Surveillance

Surveillance for early detection of emerging pathogens

Key findings

Pre-existing surveillance systems including EWARS had limited adaptability or flexibility to support early detection of COVID-19 cases at points of entry or in the community. Challenges included reliance on specific case definitions in EWARS that were oriented towards diseases with a different syndromic profile to COVID-19, inclusion of only selected sentinel hospitals and laboratories, lack of integration with point of entry surveillance, and lack of timely (daily or urgent) reporting. Instead, rapidly initiated surveillance specifically for COVID-19 was key to early detection and containment of COVID-19 in many settings. This included effective point of entry surveillance, rapidly scaled laboratory-based testing capacity, syndromic screening of higher-risk groups, and active case surveillance in the community. Countries that rapidly implemented and scaled COVID-19 surveillance in conjunction with other stringent measures reported low or zero COVID-19 incidence for extended periods in the first year of the pandemic.

Recommendations for SEARO

1. Critically review the approach to early warning surveillance, recognizing the need for multiple types of surveillance to enable early warning and detection of emerging pathogens, including strengthened subnational and national EWARS designed for detection of emerging pathogens in addition to known epidemic diseases, event-based surveillance, point of entry surveillance, and others as appropriate (potentially including wastewater surveillance in some settings, for example). Review and harmonize case definitions, guidance on implementation sites, and flexibility across these systems with early warning capacities to ensure rapid detection and integration of emerging infectious diseases into existing surveillance systems.
2. Further explore the potential for types of surveillance other than case-based surveillance to complement and strengthen early warning surveillance. This may include wastewater surveillance to detect and confirm the presence of a pathogen that has emerged in another country or region. Note the potential for wastewater surveillance for pathogen detection is still an active area of research, and that the effectiveness of wastewater surveillance is linked to genomic sequencing capacity, which was shown to be limited in many SEAR Member States.
3. Reduce barriers to recruit surge capacity rapidly and flexibly at regional level to provide timely and comprehensive support to Member States, including technical assistance, from early in the alert phase.

4. Develop comprehensive guidance and advice regarding surveillance and other measures at international points of entry, as well as providing guidance for surveillance at domestic air and seaports and land crossings where it may be feasible and effective to screen domestic travellers.

Recommendations for SEAR Member States

5. Critically review the approach to early warning surveillance, recognizing the need for multiple types of surveillance to enable early warning and detection of emerging pathogens, including subnational and national EWARS event-based surveillance, point of entry surveillance, and potentially wastewater surveillance, including case definitions, implementation sites, and flexibility to integrate emerging infectious diseases into reporting systems.
6. As part of national preparedness measures, plan for and rapidly implement multiple types of surveillance early in the alert phase of an emerging epidemic, including surveillance at points of entry and in recently returned travellers, active case surveillance in communities, and complementary surveillance methods, potentially including wastewater surveillance, syndromic surveillance, or risk-based surveillance, depending on the epidemic context.

Utility of different types of surveillance for decision making

Key findings

Key findings and recommendations related to the role of different types of surveillance include:

Case surveillance

Case reporting was by far the most widely used surveillance type to inform decision making. However, the sensitivity, timeliness and completeness of case surveillance data were often constrained. Health ministries and public health responders generally made best use of available data despite these limitations. However, sensitivity and coverage of case surveillance was undermined by introduction of testing fees, exclusion of subgroups including migrants and residents with irregular status, and limited access to testing outside of urban areas. Major COVID-19 outbreaks were attributed to delayed case and cluster detection due to these factors.

Surveillance of hospitalizations and hospital capacity

In many countries, there were no pre-existing data linkages between surveillance databases and hospitalization databases including EMRs. It is notable that countries that introduced monitoring of hospitalizations and hospital capacity within the first few weeks of the pandemic, in conjunction with a range of other stringent early response measures, had delayed onset of widespread community transmission and lower peak incidence during COVID-19 waves. This suggests that early incorporation of monitoring of hospitalizations and hospital capacity may have been an indicator of effective pandemic response planning as well as directly supporting the response, including by supporting decision-making about timely introduction of PHSM to avoid hospitals being overwhelmed, and timely allocation of resources to hospitals anticipating or responding to high caseloads.

Serosurveillance

Serosurveillance was implemented in several countries, though mainly in the form of cross-sectional surveys and research studies rather than routine continuous surveillance. Results from surveys and other studies were often reported with considerable time lags and several data quality issues were noted, which delayed utility for decision making in many settings. Serosurveillance was most useful for comparing estimated proportions of the population exposed to SARS-CoV-2 infection compared to estimates derived from case surveillance, and for comparing exposure to infection amongst different population subgroups. There were inherent uncertainties affecting the interpretation of serosurveillance data for an emerging pathogen, which constrained the utility of serosurveillance for forward planning. For example, the likelihood and observation of new variants of concern, for which immune escape characteristics are initially unknown, means that seroprevalence studies can only provide tentative estimates of the proportion of the population considered immune to infection, or at low risk of severe disease, as part of forward planning.

Genomic surveillance

Genomic surveillance capacities were substantially increased throughout the region during the COVID-19 pandemic. Genomic surveillance was useful for variant surveillance and cluster investigations if results were available within days, rather than weeks as was commonly reported to have occurred. In many countries, genomic surveillance did not contribute to variant surveillance in practice due to the substantial time lags in obtaining sequencing results and limited and non-representative sampling, which in turn were caused in part by funding and supply chain constraints. Furthermore, lack of meta-data on patient demographics or clinical outcomes accompanying sequencing results constrained interpretation of genomic surveillance.

Other types of surveillance

Wastewater surveillance was implemented through research studies in several countries, and implemented in collaboration with public health authorities in several major cities in India. These studies and projects demonstrated considerable potential for wastewater surveillance to support early detection of impending infection waves and variant surveillance, as long as resources are available for timely analysis and reporting, and wastewater surveillance is aligned with overall surveillance objectives. Population-level mobility data released by global technology companies provided a novel source of data to monitor compliance with PHSMs and informed qualitative and quantitative forecasting of COVID-19 incidence following changes in mobility patterns in several instances.

Recommendations for SEARO

7. During non-emergency settings, continue to support Member States to strengthen case surveillance for priority infectious diseases, especially testing capacity, increasing sensitivity and coverage of testing, and timeliness of reporting.
8. Support continued interoperability of hospital and clinical databases with public health surveillance and associated epidemiological datasets. Prioritize early monitoring and reporting of hospitalizations and hospital capacity from the alert phase onwards.
9. Critically review lessons learned and guidance to countries regarding the role of serosurveillance for emerging and pandemic-prone pathogens.
10. Support continued strengthening of genomic sequencing capacity at national and subnational levels (especially in larger Member States) to improve turnaround times, expand sampling capacity and develop targeted sampling strategies for different surveillance objectives, and enhance surge capacities, including the flexibility to pivot to newly emerging pathogens.

Recommendations for SEAR Member States

11. Continue to expand laboratory and point-of-care testing capacity for use in health emergencies through strengthening routine surveillance for endemic, epidemic and pandemic-prone infectious diseases. Prioritize open testing policies with testing offered free of charge to all residents (including non-citizens and residents without formal status) for priority

infectious diseases to increase sensitivity of case surveillance and timeliness of outbreak detection.

12. Maintain operational capacity and mechanism to link hospitals and other healthcare facilities with surveillance data during and after health emergencies.
13. When planning and revising surveillance and response strategies, allocate sufficient resources to serosurveillance activities to ensure that results are timely, samples are representative of well-defined target populations, and serosurveillance activities are conducted in response to a specific surveillance objective.
14. Continue to strengthen genomic sequencing capacity, with the aim of continuous improvements in timeliness of sample collection and reporting. To support capacity strengthening, regularly document and evaluate the utility of genomic surveillance to inform national and regional guidance on the most appropriate use cases for genomic surveillance.

Integration of multiple data sources to improve utility of surveillance

Key findings

Progress towards integration of multiple types of surveillance was achieved in many countries, operationalized through integrated information systems developed in-country specifically for COVID-19 surveillance and with the goal of supporting decision making during the response. However, many key types of data remained outside of public health surveillance systems or were poorly integrated, especially data from private sector hospitals, healthcare clinics, and laboratories, and data from COVID-19 apps developed outside of the health sector. Linking reimbursement for services delivered by public and private sector providers to completeness of reporting appeared to be effective in some settings.

Recommendations for SEARO

15. Prioritize continued investments to improve the performance of basic case surveillance systems and other foundational components of surveillance systems.
16. Introduce and promote collaborative and integrated surveillance approaches in selected Member States where foundational aspects of surveillance, including case surveillance capacities, are well established. In Member States where foundational aspects of surveillance require strengthening, prioritize supporting investments in core surveillance functions while gradually introducing collaborative and integrated surveillance approaches, commencing with high priority infectious diseases or use cases.

Recommendations for SEAR Member States

17. Prioritize strengthening the foundations of surveillance systems, including reviewing surveillance objectives, streamlining surveillance activities to respond to surveillance objectives, identify gaps and priorities actions to strengthen the performance and utility of surveillance, emphasizing data quality, timeliness, flexibility, coverage, and interoperability with key national systems.

Contribution of digital technologies to surveillance

Key findings

Most countries' pre-existing disease surveillance information systems could not be rapidly adapted to incorporate COVID-19 surveillance. Instead, most countries reverted to familiar, generalist tools for managing data and communications, like Microsoft Excel or WhatsApp, amongst public health responders in the alert phase of the pandemic. In some cases, generalist tools were used throughout most of the pandemic, at least at some levels of the health system. Many countries achieved rapid and remarkable transformations of their surveillance information systems, mainly by developing new, custom solutions in-country with public and private sector involvement. Some countries are now expanding pandemic-era COVID-19-specific surveillance information systems to support surveillance and data integration for a wider range of health conditions and events. Despite their widespread use, uncertainty persists about the effectiveness of different types of digital technologies to support decision making during the pandemic response. This includes the appropriate balance between encouraging subnational-level innovation in digital health data management and capacity, whilst retaining interoperability and capacity for rapid integration at national level when required.

Recommendations for SEARO

18. Prioritize supporting Member States to enhance national capacities to develop fit-for-purpose surveillance and information systems and other digital technologies that are interoperable with other national systems.
19. Recognizing that nationally developed information systems were preferred and better suited to national needs, support Member States to establish robust surveillance information systems in-country, and apply caution before offering or supporting piloting of externally developed specialist surveillance software during an acute epidemic or pandemic response.
20. Advocate for enhanced technical support for maintaining and integrating familiar, widely used digital tools, including basic data management spreadsheets and communications platforms, into outbreak response workflows for immediate preparedness.
21. Support development and roll-out of user-friendly robust integrated surveillance information systems that retain capacity to integrate generalist and familiar tools rapidly and flexibly to strengthen outbreak responsiveness. Specialist tools and systems can substantially benefit the response to health emergencies through automated and integrated data collection, analysis and visualization, but should be introduced gradually in non-emergency periods, ensuring ample resources for training and familiarizing users at all levels of the health system.

Recommendations for SEAR Member States

22. Continue to enhance capacity for the development of in-country surveillance information systems and associated digital technologies designed for use by the public health workforce.
23. Enhance capacity of routine surveillance systems to flexibly adapt to incorporate surveillance for a new pathogen, as well as integration of a range of surveillance types according to contextual needs.
24. Prioritize development of national surveillance platforms with capacity to be interoperable with multiple subnational reporting formats and databases, while moving towards interoperability standards for all digital health technologies and information systems developed and used in the country.

5.2. Contact tracing

Contact tracing before onset of widespread community transmission

Key findings

Contact tracing was initiated rapidly in some settings, and with some delay in others. Findings from a range of settings confirm that contact tracing is an effective intervention that can lead to interruption of transmission chains or even elimination of community-transmission, particularly when implemented with other supporting measures. Community support for contact tracing was higher when local elimination of transmission was achieved.

Recommendations for SEARO

25. Continue to strongly promote and support contact tracing as an effective strategy to interrupt transmission chains during outbreaks of directly transmitted epidemic and pandemic-prone infectious diseases, especially when effective countermeasures such as vaccines are not (yet) available, as part of comprehensive and rapidly initiated strategies to suppress transmission, avert the onset of widespread community transmission, and eliminate local transmission where possible.

Recommendations for SEAR Member States

26. Initiate contact tracing early and comprehensively during outbreak investigation and response for potential epidemic or pandemic diseases, recognising that contact tracing is highly effective when infectious disease incidence is low, and can be implemented amidst uncertainty about the epidemic or pandemic trajectory. To maximise the effectiveness of contact tracing, ensure data and operational linkages to surveillance.
27. Monitor capacities and mobilize surge workforces for contact tracing early, as part of a comprehensive effort to avert widespread community transmission.

Contact tracing during widespread community transmission

Key findings

Contact tracing objectives were often not clearly defined for different pandemic phases. Consistently across settings, contact tracing was ineffective at moderate to high COVID-19 case incidence, while absorbing substantial resources, across settings. Surge workforces did not allow contact tracing capacity to be fully maintained. Guidance from WHO was often interpreted as emphasizing the importance of continuing contact tracing despite overwhelmed capacity. This unduly increased the workload of public health responders at multiple levels of the health system in SEAR Member States, without supporting the effectiveness of the response overall.

Recommendations for SEARO

28. Develop clear guidance for Member States for a staged pathway from contact tracing through to transitioning to alternatives to contact tracing during periods when capacity to adequately perform contact tracing is exceeded. This includes guidance for appraising the likely effectiveness of alternative strategies, such as active case surveillance or prioritization of immunization programs and other countermeasures, compared to contact tracing in specific contexts.
29. Develop indicators for contact tracing performance that can be used to appraise in real time whether contact tracing efforts contribute to the goal of interrupting transmission chains over different pandemic phases.
30. During a health emergency, issue timely, flexible, and context-specific advice about alternatives to contact tracing to Member States, recognizing that contact tracing presents a substantial burden to the public health response that is potentially with little benefit in terms of interrupting transmission chains if not implemented in a timely manner and with a high degree of coverage and completeness.

Recommendations for SEAR Member States

31. Clearly define objectives and performance indicators for contact tracing activities as part of national strategic plans for preparing and responding to epidemics and pandemics, conduct trainings and strengthen the capacity the public health workforce to analyse and interpret contact tracing data in a timely manner, and invest in advanced planning for mobilization of contact tracing surge capacities, including establishing governance arrangements, training and supervision mechanisms.
32. When contact tracing is conducted, regularly review and adjust indicators of contact tracing performance to align with response objectives, engage the surge workforce early to maintain capacities, and monitor when capacities are at risk of being exceeded, to inform decision making about transitioning to alternative outbreak response strategies that may improve the public health effectiveness of the response overall, depending on the context.
33. When contact tracing capacity is overwhelmed despite early and sustained efforts to mobilize additional capacities, switch to alternative strategies that are anticipated to more effectively support the public health response given available resources and the epidemiological context.
34. Empower decision makers at different levels of the health system to make decisions about the implementation and utility of contact tracing in the local context and over different epidemic and pandemic phases, including transitioning to response strategies with higher anticipated public health effectiveness in the specific context.

Resources and collaboration required to effectively implement contact tracing

Key findings

Contact tracing is only effective if surveillance capacities are adequate and when contact tracing is implemented with a suite of complementary measures. This includes testing capacity, data systems to enable rapid identification, notification, and tracking of contacts and linking their test results, and capacity to provide social, logistical, and financial support for facility-based or home-based quarantine. Multisectoral collaboration went some way to addressing these requirements, and is essential as part of a comprehensive contact tracing strategy. However, multisectoral collaboration also introduced other challenges. For example, though military and police personnel were considered an important part of the contact tracing surge workforce in many Member States, the inclusion of security services at times undermined public health goals. Community volunteers and community health workers were able to effectively support contact tracing in some settings, including mobilising social support for contacts in quarantine. However, they were not consistently mobilised, compensated, or resourced. Despite efforts to mobilise surge workforces, there was no apparent model to sustain contact tracing capacity at high case incidence in any setting.

Recommendations to SEARO

35. Tailor guidance on contact tracing implementation to the range of contexts in the region, including settings where facility-based or home-based quarantining of contacts is challenging or infeasible to implement at scale, and where resources for social and financial support for contacts are limited.
36. Review and appraise lessons learned from global research into the performance of community-based contact tracing initiatives used during the COVID-19 pandemic that reduced the burden of contact tracing for the public health workforce.

37. Incorporate information about the inherent limits of contact tracing capacity during periods of widespread community transmission, and offer advice to Member States on pivoting surge workforces initially recruited for contact tracing to other activities to support health emergency responses, when necessary.

Recommendations to SEAR Member States

38. Strengthen opportunities for cooperation, preparedness planning, and training between public health agencies and security services outside of health emergencies, to strengthen the preparedness and capacities of security services to effectively implement contact tracing to support public health responses when needed.
39. Continue to develop financial and governance mechanisms and training packages to engage and support community health volunteers to support contact tracing prior to and during infectious disease outbreaks and health emergencies.
40. To maintain and increase community support for and engagement in contact tracing, prioritize developing mechanisms to offer adequate social and financial support for cases, contacts, and their households.

Contribution of digital contact tracing technologies designed for use by the public

Key findings

Despite their ubiquity, this project found no evidence for the public health effectiveness of exposure-tracking smartphone apps designed for use by the public to support contact tracing for COVID-19. This includes smartphone apps with proximity- and location-based tracing functions, as well smartphones with QR code venue check-in functions. Published literature originating from SEAR and other regions indicates significant concerns related to privacy, security, technical functions, and community trust when using contact tracing apps. Available data indicates that uptake and use of these apps was typically too low to meaningfully contribute to disruption of transmission chains at population level. Furthermore, contact tracing data from these apps was mostly unavailable to professional contact tracers. Apps with contact tracing features were more commonly used if they incorporated other features, such as displaying vaccination status. However, in these instances, contact tracing features were not widely known or used, thus they did not contribute to contact tracing performance.

Recommendations for SEARO

41. Future contact tracing guidance should reflect that there is no clear evidence to support the use of the current generation of digital contact tracing apps designed for use by the general public as part of contact tracing strategies. Barring major innovation, pronounced changes in community trust, and more scalable models for contact tracing in general, these tools are unlikely to support the effectiveness of contact tracing in future epidemics, and should not be prioritized for further investment.

Recommendations for SEAR Member States

42. Countries should document their experiences with and review the benefits, limitations and risks of COVID-19 contact tracing smartphone apps designed for use by the public and share their findings, to improve the availability of evidence for a widely deployed pandemic intervention.
43. Avoid further use of contact tracing apps unless substantial new evidence supporting their effectiveness becomes available, and/or where the use case or target population is different than during the COVID-19 pandemic.

44. If contact tracing apps are used in specific circumstances, conduct operational research during their deployment, or plan for post-deployment evaluations, to ensure lessons learned are captured.

Contribution of digital technologies designed for use by public health responders

Key findings

Externally provided specialist digital contact tracing software, including Go.Data, were not fit for purpose and were not widely implemented. In some cases, early efforts to pilot such systems absorbed significant resources with limited or no benefit amidst an unfolding health emergency. Many countries made considerable progress developing new data and information systems to support contact tracers and public health professionals to manage contact tracing data. These systems were most useful when fully interoperable with surveillance, vaccination, and other key datasets, including integration with routine health data systems such as DHIS2.

Recommendations for SEARO

45. Support Member States to enhance in-country capacity to develop and deploy contact tracing data management systems, which can be flexibly scaled and are interoperable with surveillance and other key systems, as a core element of public health response capacities.
46. Develop evaluation protocols that can be embedded into future deployments of digital contact tracing technologies for use by public health responders, to strengthen the evidence base for the contribution of digital technologies to contact tracing workflows and contact management and follow-up.

Recommendations for SEAR Member States

47. Ensure contact tracers have access to high-quality digital tools to support management of contact tracing workflows and data. Ensure contact tracers with field experience have opportunities to provide inputs into the design and refinement of digital technologies designed for use by public health responders.

5.3. Leadership and system capacities to support surveillance and contact tracing

Health system strengthening

Key findings

Prior investments in human resources, health system infrastructure, and pandemic preparedness were critical for COVID-19 surveillance and contact tracing. The COVID-19 pandemic underscored the need for enhanced health financing, streamlined data linkage and administrative processes within health systems, and regular workforce training to maintain effective response capabilities. Investments in digital technologies including interoperable information systems were important for strengthening surveillance and contact tracing for COVID-19, but digital technologies did not overcome human resources bottlenecks.

Recommendations for SEARO

48. Advocate for increased investment in human resources and stable health financing mechanisms post-pandemic, ensuring readiness for future health emergencies at both national and sub-national levels.

49. Strengthen the role of SEARO as a knowledge broker, ensuring timely data and information sharing, technical assistance, and timely and adaptive guidance that meets the evolving needs of Member States during health emergencies.

50. Strengthen WHO mechanisms (human resources, financial support, logistics support, etc) to support countries quickly and effectively within the first days and weeks of detection of an emerging or known priority infectious disease with epidemic or pandemic potential, including when uncertainty prevails about the magnitude of the threat. Early action has been clearly demonstrated to have the potential to substantially delay onset of community transmission – or achieve local elimination – in a wide range of settings, including settings with significant resource limitations.

Recommendations for SEAR Member States

51. Maintain and strengthen pandemic preparedness capacities at national level in accordance with the International Health Regulations. Where appropriate, this includes developing and implementing a national action plan for health security, and increasing investments in surveillance capabilities, including moving towards interoperable surveillance and information systems and multi-source surveillance.

52. Strengthen pandemic preparedness capacities at subnational level, recognising the importance of subnational government capacities to prevent, detect, and respond to health emergencies. Capacities may be strengthened at subnational level through activities including tabletop simulation exercises and expanding laboratory and surveillance networks, as well as strengthening mechanisms to enable responses, including rapid data and resource sharing, and reviewing financial disbursement mechanisms to ensure capacity for timely shifts in resource allocations during health emergencies.

53. Maintain investments in public health human resources and capacities at all levels of the health system.

Leadership within and outside the health sector

Key findings

Political considerations led to under-reporting or delayed reporting of COVID-19 cases in some contexts and time periods – demonstrating that timely outbreak and pandemic response goes beyond the performance of surveillance systems. Decisions made by government leaders enhanced or challenged the generation and utilisation of high-quality surveillance and information systems throughout the pandemic period. Epidemic literacy and public health awareness more generally amongst non-health sector decision-makers was considered a key determinant of the effectiveness of local and national responses.

Recommendations for SEARO

54. Establish mechanisms and platforms to routinely engage non-health sector leaders and decision-makers in existing pandemic preparedness activities, to strengthen epidemic and pandemic literacy beyond the health-sector. This should aim to strengthen institutional capacity, rather than strengthening capacities of selected individuals only.

55. Develop tailored training and professional development opportunities in epidemic and pandemic preparedness and response for health system managers and senior non-health sector senior government staff at national and subnational levels. Ensure training is offered and updated regularly, especially for newly appointed positions.

Recommendations for SEAR Member States

56. Regularly implement training and professional development opportunities for senior decision-makers within and outside the health sector at subnational and national level to maintain and enhance familiarity with epidemic and pandemic risks and responses within the country and in the region as part of ongoing pandemic preparedness activities. This should aim to strengthen institutional capacity, rather than strengthening capacities of selected individuals only. Training should include data literacy initiatives, such as familiarisation with interpretation of basic epidemiological and surveillance indicators.

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