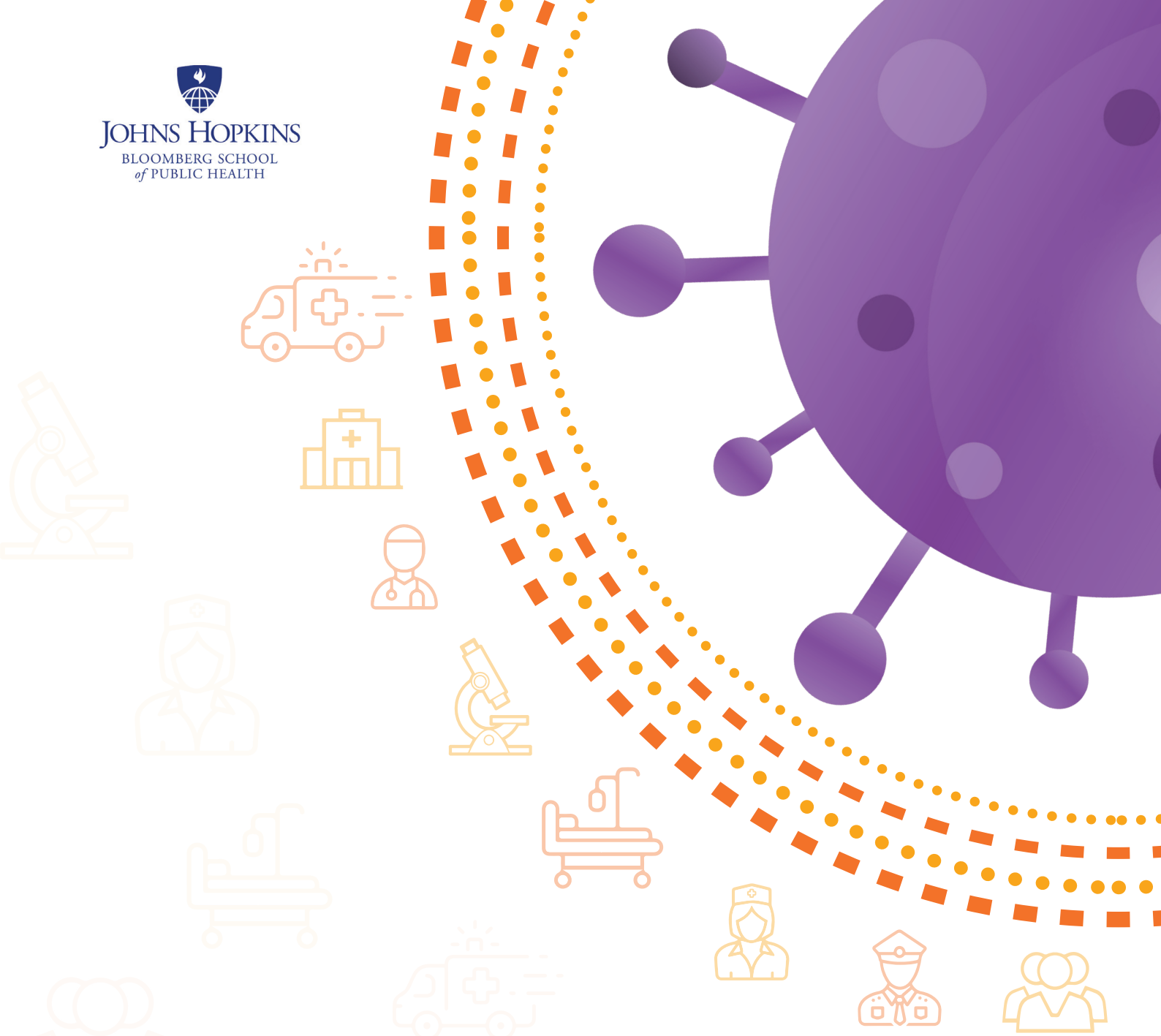

JOHNS HOPKINS
BLOOMBERG SCHOOL
of PUBLIC HEALTH

PREPARATION FOR AND RESPONSE TO COVID-19 IN A RESOURCE-CONSTRAINED SETTING

A CASE STUDY FROM UTTAR PRADESH, INDIA

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ABSTRACT

On 25 March 2020, India implemented the largest lockdown in the world in response to concerns over COVID-19. Given its historically fragile public health system and large population, concerns were raised early that COVID-19 might ravage Uttar Pradesh once lockdown measures were lifted. Many in the state were particularly vulnerable to the secondary effects of the lockdown, including decreased economic earnings and limited access to essential health services. Despite these challenges, Uttar Pradesh responded promptly with limited resources to address the COVID-19 epidemic. A case study approach was used, combining qualitative and quantitative data, to document the response to COVID-19 in Uttar Pradesh. Multisectoral approaches are increasingly acknowledged as a requirement for effective epidemic response efforts. Therefore, a modified version of the functions identified as necessary for an effective health emergency and disaster risk management effort was used. Several learnings from the state's response against COVID-19 were identified to strengthen the health systems toward greater responsiveness and resilience. The state government implemented a "whole-of-government" approach with a mix of top-down leadership and decentralized coordination and planning.

The response to COVID-19 in Uttar Pradesh has been led by the Chief Minister by convening all relevant departments, including health, to plan and execute various activities. Strict implementation of lockdown measures successfully reduced transmission of the virus affording the state critical time to establish clinical and public health functions. Uttar Pradesh increased testing and treatment facilities from almost nowhere to more than 150000 tests per day and approximately 150000 dedicated beds for COVID-19. The state developed an integrated digital platform which has been crucial for ensuring coordination at all levels of the government. Several government efforts to protect social wellbeing have been implemented providing INR ₹16 billion in funding for vulnerable poor households. The epidemic also presented several opportunities related to improved planning, coordination, training, and the expanded use of digital platforms. These opportunities could help further improve critical health indicators in the state and ensure a more resilient health system.

EXECUTIVE SUMMARY

On 25 March 2020, India implemented the largest lockdown in the world in response to concerns over COVID-19. Given its historically fragile public health system and large population, approximately 232 million people, concerns were raised early that COVID-19 might ravage Uttar Pradesh once lockdown measures were lifted. Many in the state were particularly vulnerable to the secondary effects of the lockdown, including decreased economic earnings and limited access to essential health services. Despite these challenges and limited resources, Uttar Pradesh responded promptly with limited resources to manage the COVID-19 epidemic. The mortality rate in the state was 3.7 per 100,000 population and the case fatality was 1.4% on 15 January 2021—both among the lowest in the world among countries where there have been a substantial number of cases. The response in the state was characterized by a rapid scale-up of testing and clinical capacity. In addition, the state has managed major influxes of migrants and worked rapidly to reinitiate routine health services. Most routine public health services have returned to pre-epidemic levels.

The aim of this case study is to document the actions taken in response to COVID-19 in Uttar Pradesh. While the epidemic in Uttar Pradesh continues, it remains imperative to assess response efforts in resource-constrained settings. Lessons from settings like Uttar Pradesh can also inform ongoing response efforts in similar settings. This case study therefore focuses on two time periods: (1) the preparation and early response phase beginning on 30 January 2020 when the first confirmed case was identified in India to 31 May 2020 when many lockdown measures were lifted in Uttar Pradesh and (2) the response phase after lockdown measures were lifted beginning from 1 June 2020 to 15 January 2021 when COVID-19 vaccination started in India.

The first confirmed case of COVID-19 in Uttar Pradesh was identified on 3 March 2020. Contact tracing efforts in the state identified several additional cases shortly thereafter, leading to the first cluster in Agra district of the state. The state government took early action to slow the spread of the virus. On 17 March 2020, prior to the national lockdown, the state closed all schools and colleges. On 22 March 2020, the state began lockdown measures in 16 districts. Additional districts were placed in lockdown on 23 and 24 March 2020. At the time, there were only 39 confirmed cases in the state. The central government initiated a nationwide lockdown beginning on 25 March 2020. Lockdown measures in Uttar Pradesh were rigorously implemented contributing to reduced transmission of the virus. The lockdown therefore afforded the state additional time to establish and strengthen critical response activities.

The state faced several population migration challenges during the lockdown. A large religious congregation that took

place in Delhi in March 2020 likely served as a super spreader event, as several hundred attendees of this event returned to Uttar Pradesh. Immediately upon learning of this event, the state activated the necessary mechanisms to track and quarantine many of these individuals and had placed approximately 17,015 in quarantine helping to control the further spread of the virus. This effort required the state and district administration and line departments working together to track and trace those who attended the event and their contacts. The lockdown also resulted in an immediate loss of income for workers in the unorganized sector and triggered a massive mass migration, including 3.5 million workers who returned to Uttar Pradesh. In anticipation, the state with support from partner organizations developed an online tracking system and established a community surveillance system through frontline health workers. Only 0.12% (n=4,140) of these migrants tested positive for COVID-19. A separate case study documenting the migrants response has also been prepared by the Government of Uttar Pradesh and Institute for Competitiveness.

National lockdown measures were gradually relaxed from 4 May 2020 and state governments were empowered to define lockdown activities from 18 May 2020. The national lockdown in India officially ended on 31 May 2020. Uttar Pradesh did not immediately relaxed its lockdown measures, and continued to restrict certain activities in the months following the end of the lockdown. Corresponding with the easing of lockdown measures, cases continued to increase from 1 June 2020 through 10 September 2020, with a marked increase beginning on 1 July 2020. Daily confirmed cases peaked on 10 September 2020 when there were more almost 7,000 cases reported. Peak of active cases occurred on 17 September 2020 when there were more than 68,000 active cases; however, only a fraction of these confirmed cases required hospitalization. A much-less pronounced increase in confirmed cases was observed in late November 2020 corresponding to several religious holidays earlier in the month. By the end of 2020, the state was reporting fewer than 1000 cases per day.

Multisectoral approaches are increasingly acknowledged as a requirement for effective epidemic response efforts. Therefore, a modified version of the functions identified as necessary for an effective health emergency and disaster risk management effort was used. Key findings include:

PLANNING AND COORDINATION:
Uttar Pradesh adopted planning and coordination approach to the response to COVID-19 that comprised both top-down leadership and decentralization of implementation. The overall response to COVID-19 has been led by the Chief Minister of Uttar Pradesh. These efforts were centrally coordinated by a committee know as Team 11 comprising senior bureaucrats representing diverse departments and chaired by the Chief Minister—indicative of a "whole-of-government" approach. The committee was established on 21 March 2020, less than three weeks after the first confirmed case was identified in the state. This committee focused on coordinating many of the critical health emergency response functions described in this case study.

At the district level, the COVID-19 response has been led by District Magistrates. While the mix of top-down leadership of the Chief Minister's office and decentralization of implementation powers to the District Magistrates have helped the state to

manage COVID-19 response across all 75 districts, this arrangement has not been without its challenges in some districts. For example, some respondents indicated that the recommendations of technical experts could have been better integrated into response activities. A strengthened health emergency plan could help in future epidemics and with other health emergencies. At the community level, Gram Nigrani Samiti and Mohalla Nigrani Samiti comprising various representatives from grass-root level have also played a crucial role in disease prevention and control activities.

HUMAN RESOURCES FOR HEALTH: The existing health workforce shortage in Uttar Pradesh was a concern of the state leadership from the beginning of the epidemic. However, frontline workers including ASHAs, AWWs, ANMs have played a critical role in awareness generation, community surveillance, and identification of symptomatic cases. In anticipation of surge capacity requirements, the state government implemented innovative administrative arrangements to expand the clinical health workforce. These included redefining roles of health workers, redirecting contractual workers from vertical programs for community surveillance activities, rapid recruitment against essential vacant contractual posts, and the redeployment of recently retired health workers for nonCOVID-19 services. In addition, the state government also prioritized the rational rotation of the health workforce during the epidemic to ensure adequate capacity in districts with high case loads.

Ensuring the health workforce in Uttar Pradesh had appropriate clinical training to effectively fulfill treatment guidelines required a massive COVID-19 training initiative by the state and its development partners. The state adopted a training-of-trainers model with master trainers reaching the frontlines through collaborations with the central government, multiple departments, and some development partners. The state also initiated several activities to protect the clinical workforce. These measures have largely been effective and only a very small proportion of health workers i.e., 12,646 health workers have been infected with SARS-CoV-2. Unfortunately, 109 health workers have died while performing their duties. Supportive supervision has been a hallmark of performance management in the state during epidemic, which was important for improving quality of healthcare service delivery, maintaining motivation of health workers, and obtaining accurate data.

HEALTH INFRASTRUCTURE AND LOGISTICS: To strengthen clinical capacity, the state government issued an order on 23 March 2020 to establish a three-tier pyramidical system of dedicated facilities for managing all clinical cases. Five days later, the central government issued similar instruction for all states. The tiered system allowed appropriate management of COVID-19 cases with the most severe cases being managed at L-2 and L-3 facilities where ventilators and specialist doctors are available. Although, the rapid scale up required extensive interdepartmental coordination, these facilities were largely activated by March and April 2020. Home isolation was allowed for asymptomatic and mild cases depending on eligibility criteria, thereby reducing the case burden on COVID-19 facilities. There were 176 L-3, 113 L-2 and 482 L-1 dedicated COVID health facilities in the state.

When the first case was documented in early March 2020, there was only one lab in the state equipped to conduct real

time polymerase chain reaction (RT-PCR) for SARS-CoV-2— the test used to diagnose SARS-CoV-2 infection. By rapidly scaling up laboratory capacity and supplementing capacity with rapid antigen tests, the state was able to conduct on average approximately 145,000 tests per day in September and October 2020 as cases peaked and maintained this level of testing through 15 January 2021 even as cases decreased dramatically. Test positivity remained largely below the 5% target indicated by WHO. Several policy decisions to relax regulations and procurement processes have accelerated access to critical commodities, including oxygen and ventilators. The government also coordinated with the private sector to enhance overall COVID-19 testing and treatment capacity of the state.

CORE PUBLIC HEALTH INTERVENTIONS:

Uttar Pradesh took early action to slow the spread of COVID-19. The state initiated strict travel restrictions, banned gathering of five or more individuals, and closed all schools and colleges, all before the national lockdown. While the lockdown was strictly implemented across Uttar Pradesh, some districts had implemented the lockdown more rigorously than others. The state government mandated face masks beginning on 8 April 2020, approximately one week before the central government. Hand hygiene and physical distancing have both been encouraged by the state government from the beginning of the epidemic through campaigns supported by development partners.

In Uttar Pradesh, routine surveillance activities at the community level have been conducted by frontline health workers. Many of these workers were trained before the reporting of any case of COVID-19 in the state. These workers have been equipped with pulse oximeters, thermometers, and smart phones to aid in contact tracing activities for COVID-19. Contact tracing that looks further back to identify the individual who infected the patient (i.e., retrospective contact tracing) was used initially and likely contributed to reduced epidemic growth in the state, specifically among migrants. From 22 May 2020, contact tracing activities focused on identifying contacts of confirmed and suspected COVID-19 cases and following them for 28 days to monitor for symptoms (i.e., prospective contact tracing). The state established a COVID-19 help desk in offices of all departments and also encouraged private sector to establish such desks so that the spread of SARS-CoV-2 infection could be prevented by early screening of symptomatic patients.

Another unique initiative of the state government is its massive targeted sampling across the state. Through this initiative, potential high-risk groups were quickly identified and tested for SARS-CoV-2 infection. The first round of targeted sampling was conducted in June 2020. Three additional drives were conducted in October, November, and December 2020 to further reduce transmission of the disease. In these drives more than 16.60 lakh targeted samples were collected and more than 15,000 samples were found positive for SARS-Cov-2.

In August 2020, the Government of Uttar Pradesh started to use ivermectin to prevent infection and to treat COVID-19 patients. This drug was distributed in the community through frontline workers and was administered to contacts and patients of COVID-19 and healthcare workers on a massive scale. The general public also purchased the drug over the counter following media reports.

India initiated the world's largest vaccination drive on 16 January 2021

with two manufactured in India COVID-19 vaccines. The state of Uttar Pradesh prepared for the delivery of COVID-19 vaccines based on its experiences with many public health and vaccination campaigns. To ensure the smooth introduction, two dry runs were conducted in all 75 districts: the first on 5 January 2021 at 853 sites and the other on 11 January 2021 at 3081 sites.

CONTINUITY OF HEALTH SERVICES:
Throughout India, routine services were heavily affected as a result of the COVID-19 epidemic and the national lockdown. Public facilities did not fully resume essential emergency clinical services, such as high-risk deliveries, neonatal services, dialysis, chemotherapy, and blood transfusion, until 11 April 2020. Most of these services are now being utilized at almost pre-epidemic levels. In addition, facility-based quality initiatives for improving clinical processes have also resumed.

Many outpatient and primary health care services were also reduced during the lockdown period. However, many services resumed from 28 April 2020 in public sector health facilities. Other primary health care services, including Village Health Nutrition Day (VHND) activities, where antenatal care services and immunization sessions are provided, have also resumed. These activities have been implemented in compliance with infection prevention and social distancing guidelines. The state government also continued implementation of massive door-to-door campaigns to control JE/AES. These *Sanchari Rog Niyantran* and *Dastak* campaigns, which were conducted thrice during the epidemic, were used to generate awareness and share messaging related to physical distancing and the use of masks. The resumption of many activities has been supported by strong supervision from state and district level officials and with support from several health partners.

SOCIAL PROTECTION INITIATIVES:
The national lockdown resulted in unforeseen consequences related to the migration of millions of migrants from large metropolitan cities and loss of livelihood of many daily wage earners. The state government took several actions to protect the lives and wellbeing of almost 3.5 million migrants returning to their villages in Uttar Pradesh from various parts of the country. With the involvement of Team 11 the state was able to mobilize significant resources to ensure availability of various social protection programs.

The state government also implemented a variety of socioeconomic relief programs targeting low-income families. Migrant workers and laborers received a one-time cash relief of up to INR ₹1,000. Likewise, the state government mobilized funds through paid-work days for more than five million workers in the state. The state government also ensured that vulnerable families and groups received timely pension payments and grain supply from public distribution system during the lockdown period. The public sector hospitals and laboratories are providing free of cost COVID-19 testing and treatment services to general public while Ayushman Bharat empaneled hospitals are providing free services to beneficiaries of the scheme. In addition, the state government has also covered the cost of COVID-19 treatment for all patients treated at private medical colleges/hospitals notified as dedicated COVID-19 hospitals. The state has also capped rates for COVID-19 diagnosis and treatment in private sector.

DATA AND KNOWLEDGE MANAGEMENT:
COVID-19 has created many opportunities for data and knowledge management

for health and other sectors. Early in the epidemic, surveillance related data was being managed through email and on Excel spreadsheets. The state government worked with the Uttar Pradesh Technical Support Unit (UP-TSU) to develop an integrated digital platform that was also integrated into the central government data portal. Sharing of information through the integrated digital platform has also improved collaboration between relevant departments.

The state has adopted several digital interactions in the form of trainings, webinars, continuing medical education, reviews and monitoring purposes which are more effective and economical in current situation and can help to improve communication in the future. An electronic COVID Care Support (ECCS) network has also been developed comprising teams of specialists from leading medical institutes to help hospitals in the management of seriously ill COVID-19 patients. Similarly, the department is also providing teleconsultation through its tollfree number as well as e-Sanjeevani. Uttar Pradesh is the state with maximum number of beneficiaries of e-Sanjeevani in the entire country.

RISK COMMUNICATIONS: To ensure that the people in Uttar Pradesh had access to accurate information about the status of the epidemic in the state and measures used to protect oneself, designated spokespeople from the state government conducted daily media briefings throughout the epidemic. In addition, the Chief Minister of Uttar Pradesh made frequent televised public addresses to the citizens of the state.

Individuals also accessed real-time information related to COVID-19 prevention, symptoms, and what to do if experiencing COVID-19 symptoms or if they are the contact of a confirmed or suspected COVID-19 patient through government hotline services managed from the Chief Minister's Office and the Department of Medical, Health, and Family Welfare in Uttar Pradesh. At the district- and village level, public information campaigns were implemented through social media, printed and televised news, radio, and community announcements. Development partners supported the state in preparing and disseminating many of these materials. The state also put in place several regulations on the sharing of information related to COVID-19 to mitigate the effects of misinformation shared through social media.

MONITORING AND EVALUATION: The monitoring of Uttar Pradesh's COVID-19 response is being primarily carried out utilizing new and existing digital data platforms with the real-time data and analytics. Team 11 as well as various committees, integrated COVID-19 command and control centers and control rooms of the state government departments monitored overall response activities in Uttar Pradesh on a daily basis, primarily using the integrated digital platform. In addition, the availability of human resources and other drugs and supplies are monitored through the routine Health Management Information Systems (HMIS), Human Resource Management Information Systems (HRMIS) and Drugs and Vaccine Distribution Management System (DVDMS) portals. Social protection measures and relief packages distributed by the state government were monitored through the routine data systems of related departments.

The central government also constituted a team for each state to interact with relevant departments and inspect preparedness and response activities. This team visited the state and some districts several times during the epidemic

in the state. Moreover, senior bureaucrats of the state were nominated as nodal officer for districts where they assessed overall response efforts and provided feedback to highest levels of governance. Similarly, the Department of Medical, Health, and Family Welfare (DOMHFW) also designated nodal officer for districts who resided in the concerned district and supervised overall efforts.

Although the state government quickly leveraged modern technologies and adapted a newly created command and control center to monitor the COVID-19 efforts, there have been reports of some districts consistently under-performing. The state government has been working to improve response efforts based on issues raised through independent and in-house monitoring and evaluation activities.

Uttar Pradesh has handled the unfolding COVID-19 epidemic using its existing health system capabilities in the face of substantial uncertainties. Incidence and mortality rates through 15 January 2021 are lower compared to several other Indian states and countries with comparable populations. The implementation of lockdown measures in Uttar Pradesh also afforded the state time to establish physical infrastructure (i.e., COVID-19 hospitals and laboratories), recruit critical health workers, and conduct essential trainings.

The COVID-19 epidemic has presented several additional opportunities to learn and utilize the lessons to improve the health systems. Such efforts have been emphasized with a recognition that a strong health system is not only the backbone of effective routine health services, but also ensures resilience during emergencies.

Lessons and opportunities for strengthening the Uttar Pradesh health system based on the experiences of state's COVID-19 response include:

- **Refine current health emergency planning:** Uttar Pradesh adopted top-down leadership and decentralized implementation approach to efforts against COVID-19. These efforts were centrally coordinated by a committee known as Team 11, comprising senior bureaucrats representing related departments and chaired by the Chief Minister of Uttar Pradesh— indicative of a "whole-of-government" approach. Existing health emergency and response plans in the state can be strengthened based on the experiences of the state in responding to COVID-19.

- **Strengthen coordination and collaboration further across relevant agencies:** Throughout the COVID-19 epidemic, the Uttar Pradesh leadership put significant efforts toward forging strong linkages with other sectors to manage variety of response efforts. Interdepartmental coordination has been a regular and distinct feature of successful public health efforts in Uttar Pradesh. The state has relied on these experiences to respond to COVID-19.

- **Continue to partner with community members in preparation and response activities**: The state used *Gram* and *Mohalla Nigrani Samitis* to ensure community involvement in many public health response functions. A well-established platform like this can support the community members to own and engage in mitigating the risks of emergencies and disasters.

- **Bolster disease surveillance through strengthened laboratory capacity**: Uttar Pradesh made great strides to establish new laboratories, upgrading

existing laboratories under DOMHFW and DOME, harnessing the capacity of laboratories of other sectors, promoting and facilitating private sector laboratories to increase overall testing capacity of the state during the epidemic. This enhanced capacity can be used for routine disease surveillance.

- **Expand integrated digital data platform to improve data for decision making**: To strengthen sentinel and public health surveillance in the state, learning and experiences from conceptualization to implementation and monitoring of the integrated COVID-19 data portal should be used. This data portal has proved its utility during the epidemic and thus can be permanently used in health information system of the state.

- **Develop strategy to expand and strengthen health workforce, including focus on public health and management:** The experience from Uttar Pradesh has also highlighted how strategic planning can reduce stressors related to the shortage and maldistribution of human resource on health system. These strategies should be continued and long-term investment should be made in developing core public health competencies of existing workforce.

- **Conduct surge capacity planning to meet with increased demand**: Health systems need to cope with unprecedented surge in demand during epidemics such as of SARS-CoV-2. Emergency and disaster planning need to develop a strategy to meet surge demands of public health as well as clinical needs such as spatial isolation infrastructure, physical beds, food, water, sanitation, oxygenation, mechanical ventilation, hospital infection control arrangements, and mental health services.

- **Identify opportunities to strengthen collaboration with the private sector**: The role of private sector should include, but must not be limited to expansion of laboratory services, clinical services, health workforce mobilization, management of critical infrastructure (e.g., water and food supply, transportation), and agreement on using standard protocols for preparation, surveillance, response, and information sharing and reporting.

MEETING OF TEAM 11 CHAIRED BY HON'BLE CHIEF MINISTER

LIST OF ABBREVIATIONS

AES	Acute encephalitis syndrome
ANC	Antenatal care
ASHA	Accredited social health activist
BDO	Block Development Office
BSL	Biosafety level
CB-NAAT	Catridge Based Nucleic Acid Amplification Test
CBE	Community-based event
CDC	United States Centers for Disease Control and Prevention
CHC	Community Health Centre
COVID-19	Coronavirus disease 2019
DDRT	District-level Disaster Response Team
DOME	Department of Medical Education
DOMHFW	Department of Medical Health and Family Welfare
ECCS	Electronic Covid Care Support Network
FGD	Focus group discussion
HBNC	Home based newborn care
HMIS	Health Management Information System
HRMIS	Human Resource Management Information System
ICDS	Integrated Child Development Scheme
ICMR	Indian Council of Medical Research
ICU	Intensive Care Unit
IDSP	Integrated Disease Surveillance Program
IEC	Information, education, and communications
IHAT	India Health Action Trust
IMS	Incident management system

INR	Indian rupees
JE	Japanese encephalitis
JHU	Johns Hopkins University
JHSPH	Johns Hopkins School of Public Health
KGMU	King George's Medical University
KII	Key informant interview
MCH	Maternal and Child Health
MOHFW	Ministry of Health and Family Welfare
NCD	Noncommunicable Disease
NCDC	National Center for Disease Control
NDMA	National Disaster Management Act
NHM	National Health Mission
NPI	Non-pharmaceutical intervention
PPE	Personal protective equipment
RMP	Rural Medical Practitioners
RT-PCR	Real-time polymerase chain reaction
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
SSU	State Surveillance Unit
TB	Tuberculosis
TOT	Training-of-trainers
UNDP	United Nations Development Program
UNICEF	United Nations Children's Fund
UPMSC	Uttar Pradesh Medical Supply Corporation
UP-TSU	Uttar Pradesh Technical Support Unit
US	United States
USAID	United States Agency for International Development
USD	United States Dollar
VBDC	Vector Borne Disease Control
VHND	Village Health Nutrition Day
WHO	World Health Organization

INTRODUCTION

After first emerging in Wuhan, China in late 2019,[1] severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes coronavirus disease 2019 (COVID-19), has spread rapidly throughout the world.[2] In its wake, the virus has placed unprecedented stress on health systems with demand for facilities and treatment services often outstripping availability even in the most well-resourced settings.[3,4] Given its large population, historically fragile public health system,[5,6] and limited infectious disease response preparedness,[7] concerns were raised early that health facilities in India would be rapidly overwhelmed following the relaxation of non-pharmaceutical interventions (NPIs) intended to abate transmission and reduce peak incidence, including restrictions on non-essential travel, mandated face masks, and the closure of all schools.[8-10] These concerns have been complicated by the secondary impact of NPIs on social welfare and routine health services in the country.[11,12] The most serious concerns related to the impact of COVID-19 and the effect of NPIs on vulnerable populations have been raised with regard to Uttar Pradesh, the most populous state in India.

Uttar Pradesh state is home to more than 232 million people across 75 districts. In 2011, when the most recent national census was conducted, approximately 78% of the population resided in rural areas where health services are often less accessible.[13] Literacy was low in the same year at 68%,[13] complicating risk communication activities.[14] Furthermore, roughly 50% of the population resided in households with more than seven individuals,[15] many of which are multigenerational, which could facilitate transmission of the virus that causes COVID-19.[16] Uttar Pradesh is also currently at the early stages of an epidemiologic transition, in which the prevalence of noncommunicable diseases—many of which are risk factors for severe COVID-19 outcomes[17]—is rapidly increasing alongside concurrent reductions in the morbidity of some infectious diseases (e.g., pneumonia) and the persistence of others (e.g., tuberculosis).[18] One potential mitigating characteristic of the state is the relatively young population—more than 40% of the population is less than 20 years compared to 25% of the population less than 20 years in the US— as most severe COVID-19 outcomes are believed to occur in older age groups (i.e., ≥ 65 years of age).[19,20]

There are several health systems challenges that have threatened to undermine COVID-19 response efforts in the state. The state had approximately 1.30 hospital beds per 1000 population in 2019 in the public and private sectors together—far below the global average of 2.89.[21] Less than one-third of hospital beds in Uttar Pradesh are in government hospitals. There were also a total estimated 0.02 intensive care unit (ICU)

COVID HELP DESK IN ALIGARH

beds in government hospitals and 0.05 ICU beds in private facilities per 1000 population before the epidemic in the state, raising concerns about the current infrastructure availability in the state. Uttar Pradesh, as in other states, has contended with a severe shortage of health workers and their maldistribution.[22] Currently, the density of skilled health workers (i.e., nurses, midwives, and doctors) in Uttar Pradesh is estimated to be 9.1 per 10,000 population, lower than the 44.5 standard set by the World Health Organization (WHO) and below the national India average of 11.5.[22,23] The severe shortage of specialists in the state, specifically anesthetists and pulmonologists, essential for many COVID-19 procedures, has also been of concern for response activities. As of 2019, there were only 11.6 specialists per million population throughout the state. There also remains shortages of paramedical and critical public health personnel in the state.

There are two departments responsible for the provision of critical public health and clinical functions in the state; the Department of Medical Health and Family Welfare (DOMHFW) and the Department of Medical Education (DOME). The former is responsible for the primary and secondary healthcare functions. The latter has a mandate to establish and maintain medical teaching institutions throughout the state that also serve as referral centers for peripheral facilities. Many of the advanced pathology laboratories in the state prior to the COVID-19 epidemic were based at medical colleges that fall under the administration of the DOME. Disease surveillance activities are primarily managed by the DOMHFW.

As in many states in India, Uttar Pradesh also receives technical and financial support from several government and non-government sources. The National Health Mission (NHM) is a distinct unit

within DOMHFW intended to aid health system strengthening efforts through enhanced staffing, finances, and program management support. Partial funding and oversight for NHM are provided by the central Indian government.[24] Support from donor agencies has also remained a feature of the health system in the state. The United States Agency for International Development (USAID), the World Bank, and the Bill & Melinda Gates Foundation have all provided funding to promote and establish partnerships intended to strengthen the delivery of health services. Technical expertise is also provided through partnerships with multilateral agencies, including the WHO, the United Nations Development Program (UNDP), and UNICEF.

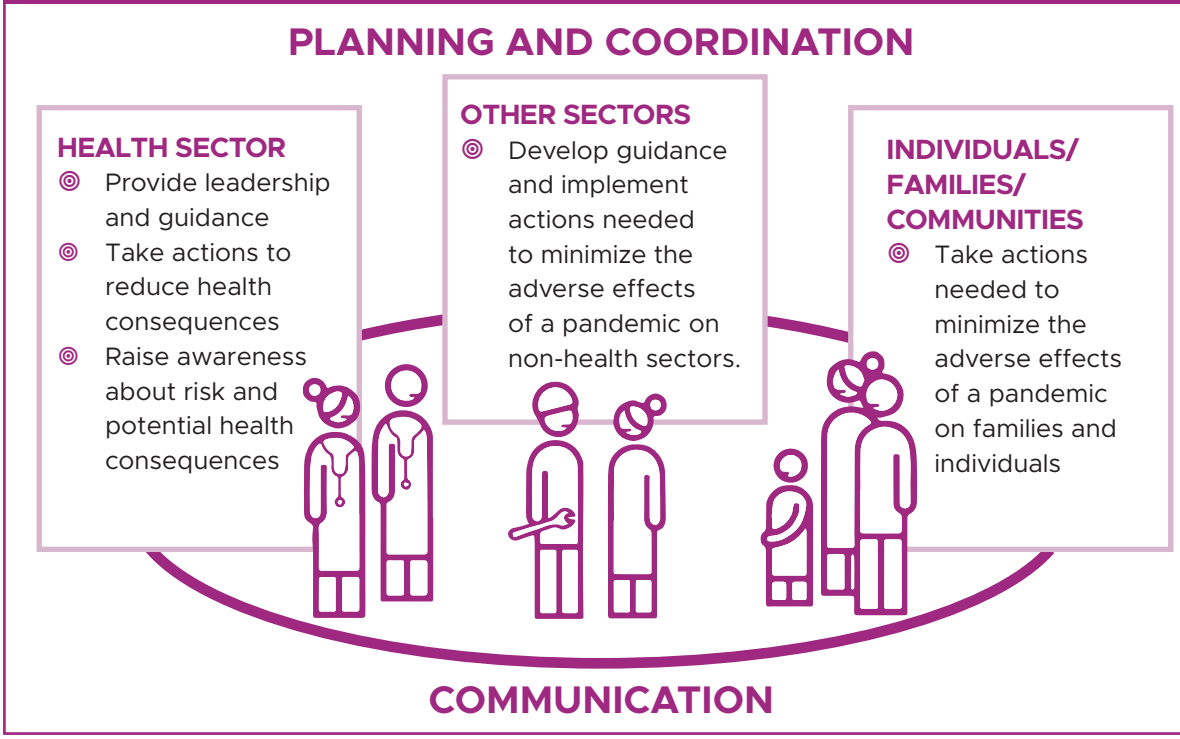
In this context, it is important to document and assess response efforts in settings like Uttar Pradesh.[25] Several COVID-19 response case studies have been published.[26-28] However, many of these case studies are primarily from high-income settings that differ in many ways from low- and middle countries.[2] Furthermore, many of these case studies have aimed to address the direct effects of the local epidemics and have not included social protection activities related to vulnerable individuals and communities. Multisectoral approaches are increasingly acknowledged as a requirement for effective epidemic preparation and response efforts. In the wake of the H5N1 pandemic, WHO has supported the adoption of a "whole-of-government, whole-of-society" approach that emphasizes the significant roles played by all sectors of society, including those across government.[29,30] It recognizes that governments hold the primary role to protect health but the responsibility should be shared with other stakeholders including local governments, the private sector, civil society, and communities.

In July 2020, the Government of Uttar Pradesh and the Johns Hopkins School of Public Health (JHSPH), with support from the Bill & Melinda Gates Foundation, partnered to prepare a case study on the COVID-19 epidemic response efforts in the state. A separate case study documenting the migrant worker response has also been prepared by the Government of Uttar Pradesh and the Institute for Competitiveness. The "whole-of-government, whole-of-society" approach framework was used to document and assess the activities aimed at reducing the transmission of infection, building and strengthening capacity to manage the increase in cases, and protecting the health and livelihoods of all citizens in the state, including from threats associated with the implementation of epidemic control measures. This case study focuses on the preparation and response phases of the epidemic with the goal of supporting ongoing epidemic response efforts.

METHODS

The following study adopted a case study approach, combining qualitative and quantitative data, to document the response to COVID-19 in Uttar Pradesh.[31,32] The aim was to identify lessons adopted during the epidemic that can support ongoing and future health systems strengthening efforts. The unit of analysis for this study was the entire state of Uttar Pradesh. This study used a modified version of the functions identified by WHO as critical to an effective "whole-of-government, whole-of-society" approach to health emergency and disaster risk management (see panel)—in this initial case study, a heavier focus was placed on governmental response efforts relative to community engagement.[30] Further efforts will be necessary to document community engagement activities in response to COVID-19 in Uttar Pradesh. At the time this case study was prepared, the epidemic was still underway in the state. Therefore, this case study focuses on two phases of the epidemic: (1) the "preparation and early response" phase beginning on 30 January 2020 when the first case was identified in India to 31 May 2020 when many lockdown measures were lifted in Uttar Pradesh and (2) the "response" phase from 1 June

FIGURE 1: "WHOLE-OF-SOCIETY, WHOLE-OF-GOVERNMENT" APPROACH—ADAPTED FROM WORLD HEALTH ORGANIZATION[33]



2020 to 15 January 2021 when COVID-19 vaccination was initiated in the state.

1. Epidemiologic and programmatic data

Routine epidemiological and health system data collected by the Government of Uttar Pradesh was analyzed. Data on confirmed cases, their contacts, and health infrastructure have been collected by frontline health workers and medical officers in the state. These data have been managed in an integrated digital platform that has served as the official single source of COVID-19 data for the Government of Uttar Pradesh since 8 May 2020. Data from the integrated data platform were used to characterize the epidemic in the state and the response measures.

To calculate period-specific incidence and mortality, district-wise population projections were used for 2020 based on 2011 census data and estimates of decadal growth. To calculate the effective reproduction number R_t, the method proposed by Cori, et al was used.[34] This statistic represents the average number of individuals each case is expected to infect at a specific point in time. This approach requires an estimate of the generation time which was obtained from previously published literature.[35] Case fatality was estimated as the number of COVID-19 deaths divided by confirmed cases. Reporting delays and preferential ascertainment of severe cases can introduce bias in estimates of case fatality during the

TABLE 1: FUNCTIONS FOR EFFECTIVE HEALTH EMERGENCY AND DISASTER RISK MANAGEMENT[30]

Function	Description
1. Planning and coordination	Structures, roles and responsibilities, and coordination mechanisms for epidemic preparation and response efforts.
2. Human resources	Planning for staffing and training across the spectrum of preparation and response capacities at all levels. Includes occupational health.
3. Health infrastructure and logistics	Establishment and strengthening of health facilities and other critical infrastructure to support preparation and response efforts.
4. Core epidemic response activities	Non-pharmaceutical interventions, testing, contact tracing, and isolation of identified cases/quarantining of potential cases.
5. Continuity of health services	Broad range of routine preventative and curative health services provided under routine circumstances.
6. Social protection interventions	Social and economic protection efforts aimed protecting the health and wellbeing, particularly among vulnerable groups (i.e., poor households, women, children).
7. Data and knowledge management	Efforts to expand or strengthen surveillance, information management, and availability of data.
8. Risk communications	Includes efforts to communicate effectively with the general public around health risks and how to mitigate them.
9. Monitoring and evaluation	Includes processes to monitor progress towards meeting preparation and response objectives.

course of an epidemic which have not been corrected for in this case study.[36] Basic descriptive statistics were used to analyze health facility data.

2. Document review

A total of 658 relevant government orders issued from the central Indian government and nine departments of the Government of Uttar Pradesh (see appendix A) were reviewed.[37] Two independent study members coded and synthesized each of these documents. Key themes and critical events were identified and discussed internally and were used to inform further data collection activities (see "Key informant interviews and focus group discussions" section). A public interest litigation refers to litigation undertaken to secure public interest in India. Such relevant litigations and mass media reports were also reviewed to identify any inadequacies in COVID-19 policies or their implementation.

3. Key informant interviews and focus group discussions

In July and August 2020, 21 key informant interviews (KIIs) and 6 focus group discussions (FGDs) were conducted with several government employees at the state, district, block and village levels, representatives from partner agencies working to support COVID-19 response efforts, and individuals from community-based civil society organizations. These individuals were selected given their direct and indirect involvement in preparation and response efforts. Individuals from districts based on the range of unique challenges faced by the state (e.g., internal migration, initial case clusters) were selected purposively. Eligible participants were identified from publicly available documents and information provided by the state government.

All KIIs were done by individuals from JHSPH in either English or Hindi depending on the preference of the study participant. KIIs with individuals in the capital city Lucknow were done in person. A distance of six feet was maintained during all in person interactions and study participants and research team members wore masks throughout these interactions. One FGD was conducted in person and the same physical distancing measures were implemented. The other five discussions were done virtually using the Zoom platform. If the study participants agreed, audio recordings of interviews were

TABLE 2: KEY INFORMANT INTERVIEW AND FOCUS GROUP DISCUSSION RESPONDENTS

Sector	Representative	Number of respondents (%)
Governmental	State-level politician	3 (6)
	State-level bureaucrat	9 (20)
	State-level technocrat	8 (17)
	District-level bureaucrat	3 (6)
	District-level technocrat	15 (42)
Non-governmental	Civil society	2 (4)
	International partner organization	6 (13)
Total		**46 (100)**

captured which were then transcribed into English. For those study participants who did not want to have interactions audio recorded, detailed handwritten notes were taken.

An internet-based, qualitative software program Dedoose was used to collate the thematic analysis of the qualitative data using the constructs adapted from the WHO health emergency functions (Table 1).[38,39] First, deductive codes were applied based on the description of each construct from Table 1. Additional codes were inductively identified based on emerging themes that were not previously included. A combination of qualitative data collection and analysis methods was used, using the KIIs, FGDs, and document review to comprehensively capture and triangulate our main findings.

4. Ethics

All study participants provided verbal consent in their preferred language prior to key informant interviews or focus group discussions. Ethical review was provided by the JHSPH Institutional Review Board and the research was determined to be a non-research activity (FWA #00000287).

5. Role of the sponsor

The sponsor of this study had no role in study design, data collection, or data analysis, writing of the report, or the decision to submit for publication. The sponsor provided interim feedback on the data interpretation; however, the sponsor had no role in the final interpretation of the data. BA, VA, RRP, HS, and BW had full access to the data used in the study and the corresponding author had final responsibility for the decision to submit for publication.

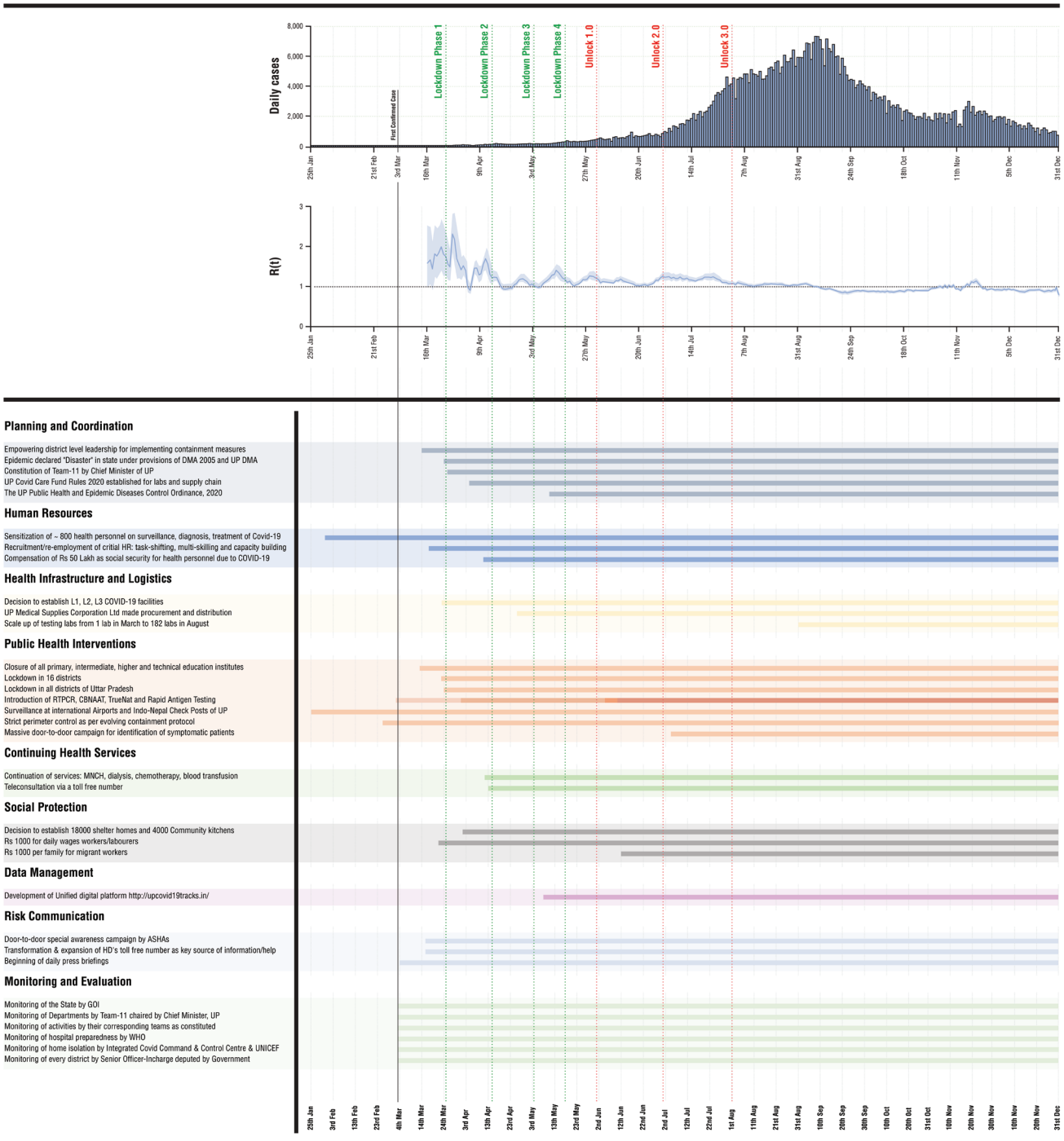
EVOLUTION OF THE COVID-19 EPIDEMIC IN UTTAR PRADESH

1. Preparation and early response phase (30 January 2020-31 May 2020)

Initial response activities aimed at identifying COVID-19 cases and slowing the spread of the virus in Uttar Pradesh initiated on 26 January 2020 following a formal communication from the central government. These early activities included symptomatic screening of international travelers from affected countries (e.g., China and Italy) and monitoring the 600km porous border with Nepal. The first confirmed case of COVID-19 in India was identified in Kerala on 30 January 2020 in an Indian national who had returned from studying at Wuhan University in China.[40] During the following month-and-a-half, several travel-associated cases were confirmed throughout the country in 12 states.[41] The first two suspects in Uttar Pradesh were identified on 27 January 2020. At the time, there were no laboratory facilities in the state equipped to perform real-time polymerase chain reaction (RT-PCR) used to detect the presence of SARS-CoV-2 genetic material. The samples were, therefore, sent to the National Institute of Virology (NIV) in Pune, Maharashtra where they were found to be negative. The first RT-PCR test for SARS-CoV-2 in Uttar Pradesh was done on 28 January 2020 and by the end of February 2020, the Microbiology Department at the

DISTRICT COORDINATION COMMITTEE MEETING AT AYODHYA

FIGURE 2: TIMELINE DAILY CASES, EFFECTIVE REPRODUCTIVE NUMBER, AND IMPLEMENTATION OF PUBLIC HEALTH AND RESPONSE INTERVENTIONS IN UTTAR PRADESH BETWEEN 28 JANUARY 2020 AND 31 DECEMBER 2020



King George's Medical University (KGMU) in Lucknow developed capacity to perform 60 RT-PCR tests per day to diagnose COVID-19.

The first confirmed case of COVID-19 in Uttar Pradesh was identified by KGMU on 3 March 2020 in an individual who returned from Italy to Agra. Contact tracing efforts in the state identified several additional cases shortly thereafter, leading to the first cluster in the state. On 17 March 2020, the state shut all schools and colleges. On 22 March 2020, the state government began lockdown measures in 16 districts. Two additional districts were placed on lockdown on 23 and 24 March 2020. At the time, there were only 39 confirmed cases in 11 districts. The central government stopped operation of all commercial flights from 22 March 2020 and initiated a nationwide lockdown beginning on 25 March 2020—the largest in the world.[42] Beginning on 16 April 2020, districts throughout the country were classified as green, orange, and red zones based on the number of cases.* Red zones were further demarcated into containment zones surrounded by buffer zones. National lockdown measures were gradually relaxed in non-containment zones from 4 May 2020. Beginning from 18 May 2020, state governments were empowered to define lockdown activities and the demarcation of various zones; however, Uttar Pradesh did not immediately relaxed its lockdown measures to avoid any potential transmission of infection due to return of huge number of migrants.

In the weeks prior to the national lockdown in March 2020, a large religious congregation took place in Delhi that likely served as a super spreader event. The event was attended by several individuals from Malaysia, Indonesia, and many Indian states—some of those who traveled from Malaysia had attended a similar congregation in Kuala Lumpur at the end of February 2020 and were infected with SARS-CoV-2.[43] By the time the event was identified as a potential cluster, several attendees of the congregation had already dispersed to various states throughout India, including several hundred who returned to Uttar Pradesh. In the weeks following the congregation, the state worked to track and quarantine many of these individuals and had placed approximately 17,015 in quarantine. Of those who had attended the event, 325 tested positive for COVID-19 and were associated with 176 secondary cases of the disease, suggesting that efforts to control the spread of the virus following the initial super spreader event have been successful.

There were other mass migration events that took place during the response phase that threatened to accelerate the epidemic in the state and undermine social wellbeing. The lockdown resulted in an immediate loss of income and employment for workers in the unorganized sector in India and triggered a mass migration of workers to their native states, including 3,528,227 migrants who returned to Uttar Pradesh—80% returned by special trains organized by the government. In anticipation, the state government supported by partner organizations developed an online tracking system and established a community surveillance system through frontline health workers. Only 0.12% (n=4,140), of migrants who returned to Uttar Pradesh tested positive

** Green zones = districts with zero cases to date or no cases within 21 days prior; orange zones = districts deemed neither a red zone nor a green zone by the central government; red zones = defined by the MOHFW based on case counts, doubling rate, and testing/surveillance findings; containment zones = areas within orange and red zones where cases have been identified.*

for COVID-19. In addition, approximately 10,500 students from Uttar Pradesh had been stranded in Kota, Rajasthan—a popular destination for national competitive examination training—following the lockdown. On 17 April 2020, Uttar Pradesh was one of the first states to initiate the return of students stranded in Kota when it sent 250 buses to retrieve these students. All students returning to Uttar Pradesh were tested after travel to Uttar Pradesh and were placed under home quarantine upon their return.[44]

At the implementation of national lockdown measures on 25 March 2020, R_t in Uttar Pradesh was 1.53 (95% confidence interval: 1.08, 2.08; Figure 2), indicating that each one confirmed case resulted on average in approximately one-and-a-half additional cases—an indication of epidemic growth. The doubling time in the two weeks prior to the initiation of lockdown measures in Uttar Pradesh was 4.1 days. During the lockdown, R_t increased initially to 2.28 (95% CI: 1.80, 2.81) on 27 March 2020, but declined thereafter and was briefly sustained less than 1 on 3 April, 18 April, and 4 May 2020. The doubling time increased to 10.8 days in the two weeks following the initiation of the lockdown. The decline in R_t and the increase in doubling time during the lockdown suggest NPIs were effective at reducing the overall transmissibility of SARS-CoV-2.

By the end of the lockdown on 31 May 2020, there were 8,869 cumulative confirmed cases reported in all 75 districts and 217 cumulative deaths from 45 districts, corresponding with a case fatality of 2.4%. The period-specific incidence of COVID-19 was 3.8 cases per 100,000 population. The highest incidence rates were in Gautam Buddh Nagar, Agra, and Hapur districts with 33.2, 18.0, and 13.9 confirmed cases per 100,000 (Figure 3)—Gautam Buddh Nagar and Hapur are in the proximity of Delhi and Agra is a popular tourist destination and the location of the first confirmed case in Uttar Pradesh.

2. Response phase (1 June 2020-15 January 2021)

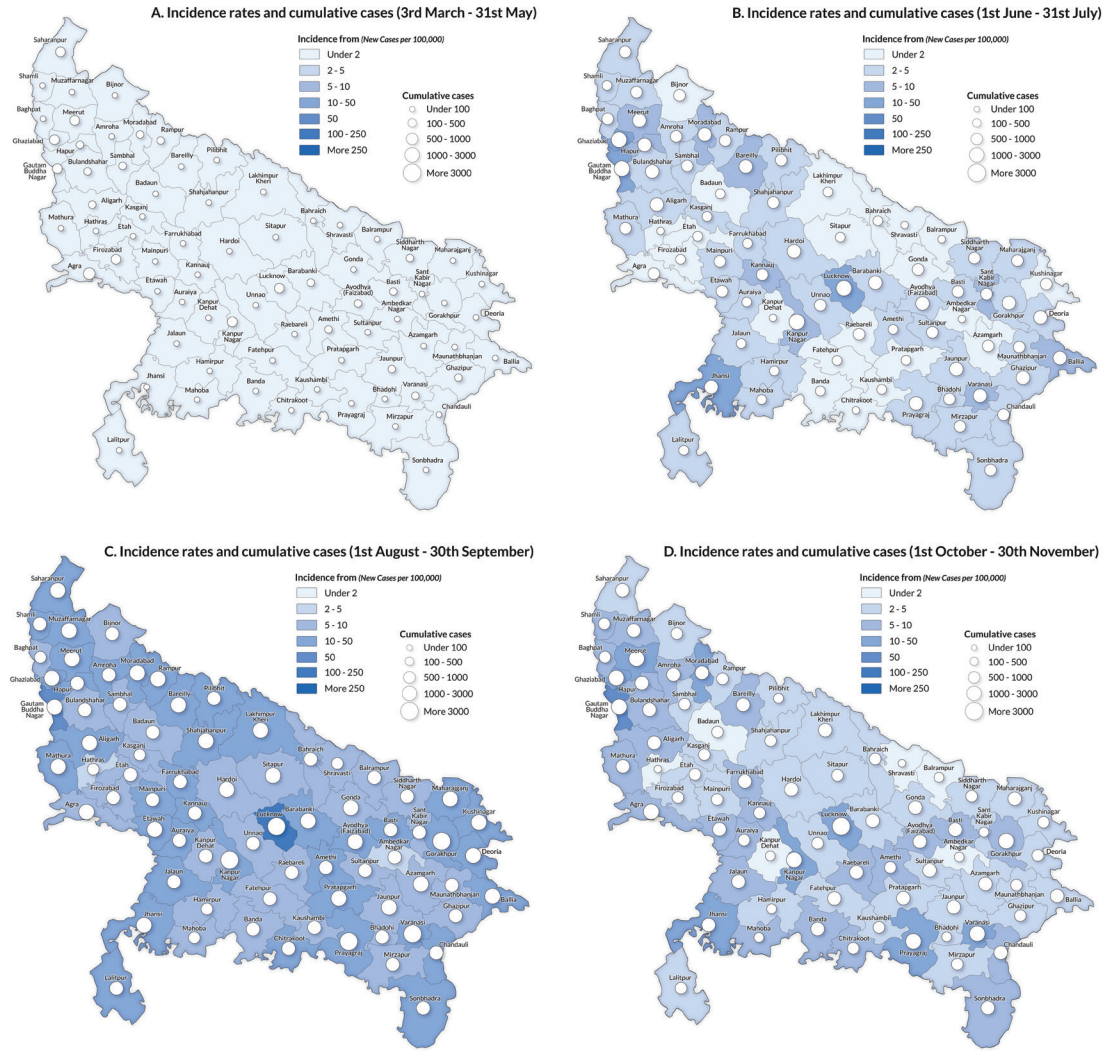
The national lockdown in India officially ended on 31 May 2020 and was followed by several relaxations termed "unlockdown" phases by the central government. However, the relaxation of some measures (e.g., movement for non-essential activities) was initiated prior to the end of the lockdown. Beginning on 18 July 2020 and continuing until 6 September 2020, Uttar Pradesh implemented weekend lockdowns mandating that all offices and commercial establishments remain closed on Saturdays and Sundays. Religious gatherings outside containment zones were allowed from 15 October 2020, ahead of several religious holidays beginning on 17 October 2020. Most educational institutions remained shut till 15 January 2021.

Corresponding with the easing of lockdown measures, cases continued to increase from 1 June 2020 through 10 September 2020 with a marked increase beginning on 1 July 2020 (Figure 2). The period-specific incidence of COVID-19 in Uttar Pradesh between 1 June 2020 and 31 August 2020 was 100.5 cases per 100,000 population. However, despite this increase, incidence in the state was less than half the national incidence (258.5 cases per 100,000) during the same timeframe. In addition, R_t in the state during this period was sustained below 1.5 through the end of August 2020 and ranged from as high as 1.24 (95% CI: 1.13, 1.35) on 30 June 2020 to as low as 1.00 (95% CI: 0.99, 1.02) on 10 August 2020. The promotion of hand hygiene and mandated facemasks—though adherence was variable—together with other public

health measures likely contributed to lower R_t. Daily confirmed cases initially peaked on 10 September 2020 when there were approximately 7,000 cases reported. Cases began decreasing thereafter with an average of 1946 daily cases reported during the last week of October 2020. R_t in the state was also maintained below 1.00 after 10 September 2020 through the remainder of the study period.

After 1 June 2020 and through 30 October 2020, there was substantial geographic heterogeneity in confirmed cases (Figure 3). The highest period-specific (i.e., three month) incidence occurred in the most populous and densely populated urban districts in the state, including Lucknow, Gautam Buddh Nagar, and Kanpur Nagar—all among the most densely populated districts in Uttar Pradesh (i.e., > 1200 people/km^2). Reported incidence rates in each of these districts were greater than 200 confirmed cases per 100,000 between 1 June 2020 and 31 August 2020 (Figure 3). These districts, together with Ghaziabad, Meerut, and Varanasi, also had the highest period-specific incidence between 1 September and 30 November 2020. However, the incidence of confirmed

FIGURE 3: PERIOD-SPECIFIC INCIDENCE AND CUMULATIVE CASES BY DISTRICT IN UTTAR PRADESH DURING THE PREPARATION AND EARLY RESPONSE PHASE (A) AND THE RESPONSE PHASE (B, C, D)



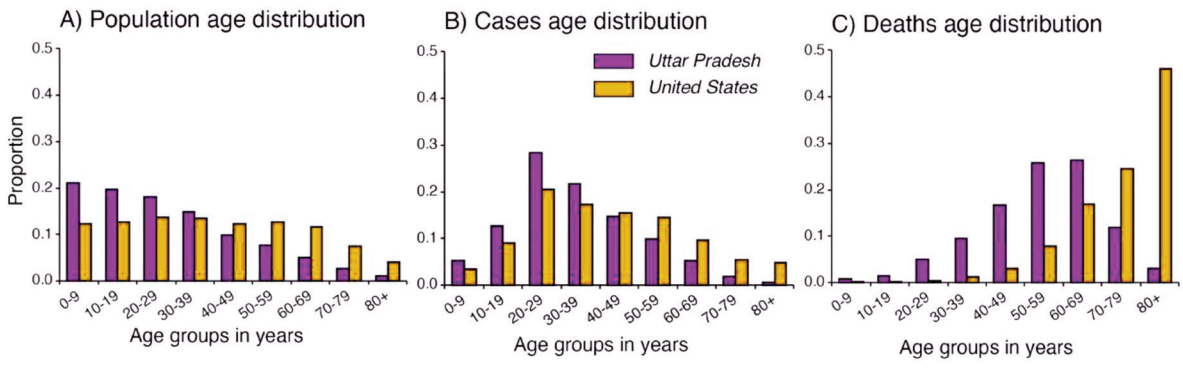
cases in some urban districts was relatively low compared to these districts between 1 June 2020 and 31 August 2020. For example, in Agra, where the first cluster of cases in the state was identified, the incidence was only 45.1 confirmed cases per 100,000 population between 1 June 2020 and 31 August 2020— the lowest in the state. This early success was attributed to thorough household surveillance, extensive contact tracing, and the provision of door step delivery of essential items to individuals within containment zones. However, between 1 September 2020 and 30 November 2020, the incidence of confirmed COVID-19 cases in Agra increased and was once again among the highest in the state.

A seroprevalence study was conducted in September 2020 by the state government with support from KGMU in 11 districts. The seroprevalence study intended to assess what proportion of the population had been exposed to the virus and therefore might have some natural immunity. In the survey, which comprised 1,450 people from each of the 11 districts (n=15,950), 22.1% had antibodies to SARS-CoV-2. The districts in which survey was conducted include Lucknow, Agra, Baghpat, Ghaziabad, Gorakhpur, Kanpur, Kaushambi, Meerut, Moradabad, Prayagraj, and Varanasi.

3. COVID-19 Epidemic at the end of the study period

By 15 January 2021, there were approximately 595,963 cumulative confirmed cases of COVID-19 in Uttar Pradesh and 8,569 cumulative confirmed deaths corresponding to a mean case fatality of 1.4%. The national case fatality during the same period was also 1.4%— one of the lowest in the world among countries with more than 100,000 confirmed cases.[45] Among all confirmed cases during the study period, the age distribution in Uttar Pradesh was slightly younger than that of cases reported in the United States (US) by September 2020, where overall case fatality was 3.3%.[46] The case fatality in Uttar Pradesh standardized to the US age distribution was 2.4%, indicating that the differences in case fatality are only partly explained by age structure in the two settings (Figure 4). This relationship has been observed in other Indian states and could be attributable to underestimates of cases among younger adult age groups in India.[16,47-49] Furthermore, the relationship between age and risk of death in Uttar Pradesh might also be confounded by socioeconomic status.[50] The overall case fatality for men (1.5%) was higher than that for women (1.3%).

FIGURE 4: POPULATION AGE DISTRIBUTION (A), COVID-19 CASE AGE DISTRIBUTION (B), AND COVID-19 MORTALITY DISTRIBUTION (C) COMPARING UTTAR PRADESH AND THE UNITED STATES



HEALTH EMERGENCY PREPARATION AND RESPONSE FUNCTIONS

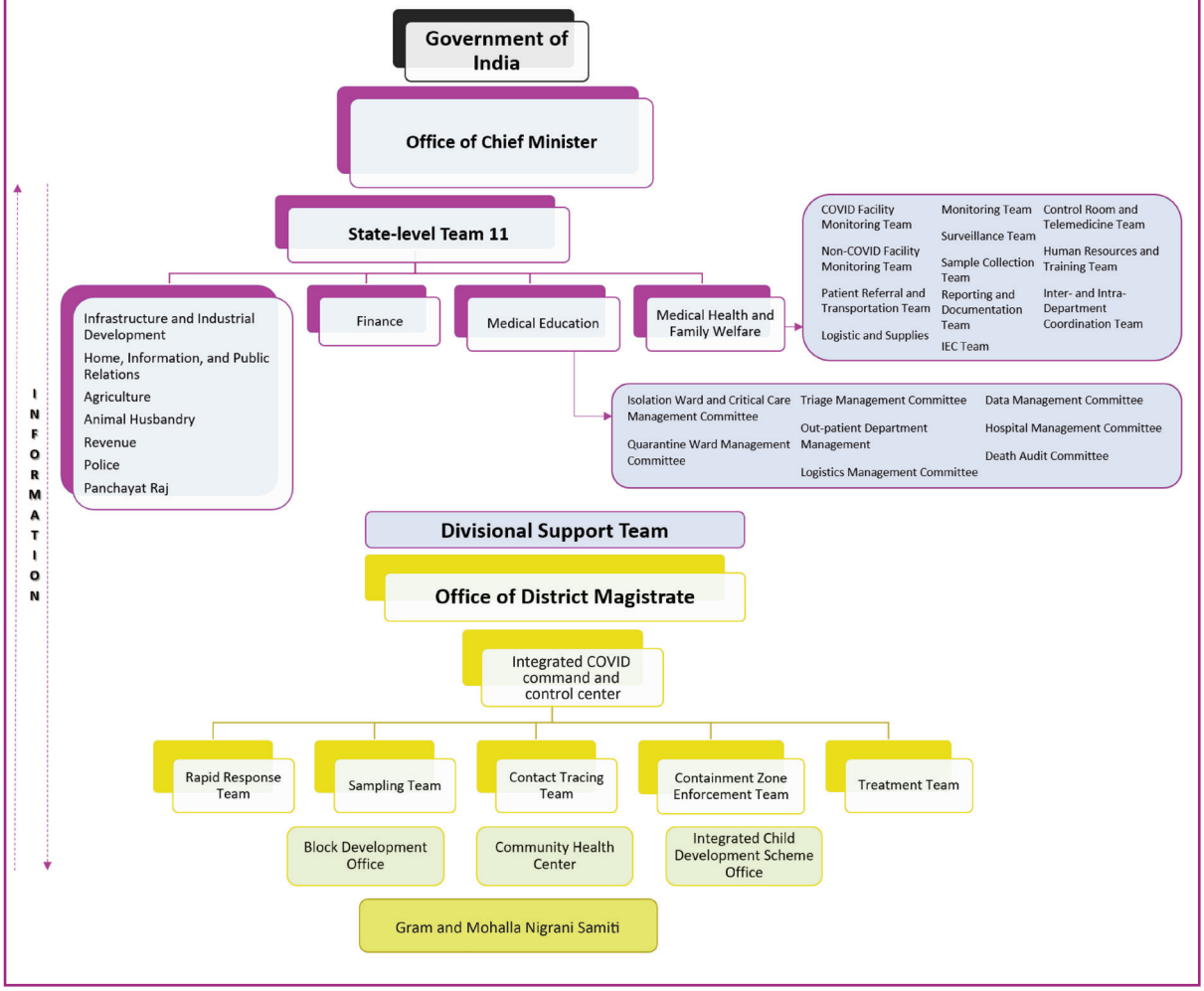
1. Planning and coordination

COVID-19 has been a highly complex challenge for all governments, requiring strong leadership and appropriate emergency response structures to manage an effective response. The WHO has called for a "whole-of-government, whole-of-society" approach to managing the response to COVID-19.[29,30]

In Uttar Pradesh, the response to COVID-19 has been centrally coordinated by a committee know as Team 11 (Figure) comprising 11 senior bureaucrats representing 9 departments selected by the Chief Minister, the head of the state government. The committee is also chaired by the Chief Minister and was established on 21 March 2020, less than three weeks after the first confirmed case was identified in the state. The committee comprises representatives from relevant departments responsible to ensure lockdown measures, public health, and social protection activities. Team 11 has held meetings daily since 25 March 2020 to discuss and make relevant decisions, including those related to health and issues of broader social protection. This committee focused on coordinating many of the critical health emergency response functions described in this report. The committee also enabled the rapid mobilization of financial and human resources across various departments for COVID-19 response. During the preparation and early response phase, Team 11 ensured INR ₹2.89 billion (USD $28.0 million) for the procurement of medical supplies and infrastructure and

DISCHARGING COVID-19 PATIENTS FROM COVID FACILITY, DISTRICT AMROHA BY GIVING GIFTS

FIGURE 5: STRUCTURE OF GOVERNMENT COVID-19 PLANNING AND COORDINATION EFFORTS IN UTTAR PRADESH



INR ₹16.00 billion (USD $213.6 million) for social protection programs. An additional INR ₹9.66 billion (USD $128.8 million) was provided by the central government under the State Disaster Risk Management Fund.[51]

In many cases, new management structures may need to be established to effectively respond to a large-scale health emergency. For example, during the west African Ebola virus epidemic in 2013-2015 Africa, the establishment of an incident management system (IMS) in affected countries was critical for the management of responses efforts.[52,53] Such entities help to ensure a clearly defined chain of command and organizational structure, effective resource management, and advanced planning. The DOMHFW established a COVID-19 control room on 18 March 2020 led by the Additional Chief Secretary of Health who represents health in Team 11 meetings. As the department managing the public health response, DOMHFW has also managed response operations through 10 intradepartmental teams that have specific mandates, including testing, contact tracing, treatment, coordination, and documentation (Figure 5). The DOME also manages several intra-departmental

teams. Team 11 and the Chief Minister's office have worked to ensure greater coordination and collaboration through distributed leadership across relevant departments to support preparation and response efforts much like an independent IMS. Distributed leadership refers to a hub-and-spoke organizing principle that includes a relatively flat and interconnected series of adaptive teams working collaboratively to solve problems as they arise. This model is intended to allow for the dynamic learning and adaptation that a rigid command-and control model cannot manage.

At the district level, the COVID-19 response has been led by District Magistrates—the highest-level bureaucrat at that level. District Magistrates have been empowered as per the National Disaster Management Act (NDMA) to manage response efforts and serve as the head of the District-level Disaster Response Team (DDRT). District Magistrates are also supported by multisectoral teams of various departments. As shown in the Figure 5, each district typically consists of dedicated team with responsibility for rapid response, sampling, contact tracing, containment zone enforcement, and treatment of in-patients. The composition and responsibilities of such teams varied across all 75 districts; teams were constituted depending on the availability of human resources, skill-set and the characteristics of the epidemic in that district.

The state government set up an Integrated COVID-19 Command and Control Center (ICCCC) in each district on 18 July 2020. The coordination among teams and various activities related to COVID-19 management in all districts are being done by these centers, which include representatives from various departments, notified testing and treatment facilities, rapid response teams (RRTs), and emergency medical transport service (EMTS). These centers also serve to facilitate the prompt referral of COVID-19 patients to the appropriate facilities. The command center coordinates to ensure rapid movement of RRTs, prompt testing of symptomatic patients and contacts, intimation of laboratory result status, facilitation of transport and facility allocation in case of admission, and regular follow up of cases under home isolation.

COVID-19 activities at the block-level are managed by Community Health Centre (CHC)/Block Public Health Centres (BPHC) (government health facilities that provide referral services and specialist care) with support from other block-level functionaries.

Throughout Uttar Pradesh, thousands of monitoring committees known as *Gram* and *Mohalla Nigrani Samitis* have been empowered to undertake the responsibility of community-level COVID-19 operations such as contact tracing, symptomatic surveillance, household data collection, and enforcement of home isolation, and creating mass awareness within the community. These committees comprise *Gram Panchayat* (i.e., village council) representatives, urban local bodies representatives, other community leaders, and frontline workers.

The mix of top-down leadership of the Chief Minister's office and decentralization of implementation powers to the District Magistrates have helped the state to manage COVID-19 response across all 75 districts.[54,55] This arrangement has not been without its challenges in some

districts. Some respondents noted that open lines of communication facilitated open discussions among technocrats and senior officers at all levels.

2. Human resources for health

An effective epidemic response requires a strong, motivated, appropriately distributed and skilled health workforce. Given the health risks and emotional burden for health workers during the epidemic, governments need to support, protect and motivate the workforce.

The existing health workforce shortage in Uttar Pradesh was a major concern of the state leadership from the beginning of the epidemic. Each district formed several teams of doctors and paramedical staffs who were trained intensively and were rotated to address staff shortages and fatigue. When and where there was a need for additional health workers in a particular district, the state government had the flexibility to depute trained teams from adjoining districts. In anticipation of the surge capacity needs, the state government implemented several innovative administrative arrangements to expand the clinical health workforce in a short amount of time. These included redefining roles of health workers, redirecting contractual workers from various vertical programs (e.g., TB elimination program) for community surveillance activities, rapid recruitment against essential vacant contractual posts (i.e., epidemiologists and microbiologists) through NHM, and the redeployment of recently retired health workers primarily for non-COVID-19 services. In addition, frontline workers were essential for awareness generation, community surveillance, identification of symptomatic patients, and ensuring adherence to protocols.

Clinical and public health guidelines were issued early in the epidemic by the central government. Ensuring the health workforce in Uttar Pradesh had appropriate training to effectively fulfill these guidelines required a massive

TRAINING OF FRONTLINE WORKERS AT AYODHYA

COVID-19 training initiative. The state health leadership prioritized such trainings early. By the end of the study period, more than 165,000 health workers had been trained for COVID-19 activities in the state. Although some clinical and laboratory trainings were initially conducted in person these trainings later transitioned to virtual trainings by March 2020 and included mock drills on several clinical, laboratory, and surveillance measures. The state adopted a training-of-trainers (TOT) model with master trainers reaching the frontlines through collaborative effort of the DOMHFW, DOME, the central government departments and development partners such as UNICEF, WHO and UP-TSU. All frontline health workers, including accredited social health activist (ASHA) workers, participated in these trainings from their villages using smartphones provided by the state government.

To protect the clinical workforce from SARS-CoV-2 exposure, the state prioritized availability of personal protective equipment (PPE), established and activated infection control committees within each dedicated COVID-19 facility and public and private health facilities running outpatient and inpatient services during lockdown. Designated District Nodal Officers were mandated to inspect these facilities and activate infection control committees. The state also implemented shift management procedures wherein clinical providers were on duty for 14 days and off-duty for 14 days.[⌖] Many facilities were also equipped with close circuit television cameras to monitor attendance of health workers and ensure adherence to infection control measures. The state government also collaborated with local hotels to ensure the availability of well-equipped accommodation as well as quarantine and isolation centers for health worker, so as to prevent immediate exposure to close contacts. The provision of INR 5 million (USD $65,000) was made for the dependents of deceased personnel who died while engaged in the prevention, control, and treatment of COVID-19 in the state. Government employees diagnosed with COVID-19 were guaranteed paid leave while they recovered.

These measures were instrumental in protecting health workers from COVID-19 infection and only a small proportion of health workers (i.e.,12,646 health workers) belonging to both public and private sectors have been infected with SARS-CoV-2. Unfortunately, 109 health workers have died as of 31 December 2020. Development of a strong culture of quality healthcare followed by repeated trainings and stringent surveillance of infection control procedures is critical for the safety of patients as well as health workers. The state has also confronted the challenge of keeping fatigued health workers and essential government employees motivated, many who had been continuously working for many months. Health workers were deployed in rotations based on the case load of districts. When cases increased, health workers were shifted to address the burden.

Many individuals noted a shift away from punitive approaches to performance management approaches rooted in positive reinforcement. Supportive supervision practices were used to keep

⌖ *The off-duty days off have been updated to 7 days.*

QUARANTINE FACILITY IN A SCHOOL, SIDDHARTH NAGAR

health workers motivated during the COVID-19 response. One officer said, "I have an open line and anyone can call to discuss their challenges with me." There have been no wide-spread health workers' protest in the state as have been reported elsewhere.

3. Health infrastructure and logistics

To strengthen its clinical capacity, the state government issued an order on 23 March 2020 to establish a three-tier pyramidical system of dedicated facilities for managing the full spectrum of clinical cases. A similar recommendation was issued by the central government for all states in India five days later on 28 March 2020. This pyramidical structure and categorization of healthcare infrastructure have ensured a continuum of care for COVID-19 patients, the rational distribution of cases, and ensured efficient utilization of available resources.

L-1 facilities were intended for asymptomatic positive cases and were based at community health centers/ BPHCs within each block. L-2 facilities were established for mild positive cases and were housed within divisional hospitals, district hospitals, maternal and child health wings, or trauma centers. L-3 facilities were intended to treat severe positive cases based at state medical colleges. The state established L-1-attached facilities on 7 April 2020 for asymptomatic positive cases, after which L-1 facilities were intended for very mild positive cases. The details of these dedicated facilities are included in Table 3. All L-1, L-2, and L-3 facilities were equipped with oxygen and pulse oximeters since being established in late March 2020. In addition, once data indicated that a relatively large proportion of cases were mild or asymptomatic, the state government mandated the establishment of COVID Care Centres in hotels in all districts where if opted voluntarily then patients would bear the costs.

The state government partnered with the Bill & Melinda Gates Foundation and Tata Trust to convert 240 bedded district hospital in Gautam Buddh Nagar district and a 150-bed divisional hospital building in Gonda district into demonstration COVID-19 ready centers. Gautam Buddh Nagar is located in the National Capital Region (NCR) and had a high caseload

while Gonda is surrounded by many underserved districts.

By 30 November 2020, there was sufficient capacity to account for approximately 35,697 severe cases (Table 3). The rapid scale up of these facilities required substantial interdepartmental coordination and collaboration. Several respondents indicated that this was facilitated by Team 11 and the Chief Minister's office. Occupancy at all dedicated COVID-19 facilities has remained less than 50% for most of the study period. However, capacity of L-3 facilities in some districts reached around 95% during July and August 2020. Nevertheless, the government has considered moving health workers from some L-1 and L-2 where there was low occupancy. In addition, on 20 July 2020 home isolation of confirmed COVID-19 positive individuals who are asymptomatic or with mild symptoms if they could ensure a private room and a separate toilet at their home was permitted, among other things, to reserve bed capacity for more severe cases. In districts with low confirmed cases, COVID-19 patients were aggregated upwards from L-1 to L-2 and L-3 facilities.

When the first case was documented in early March 2020, there was only one lab in the state equipped to conduct RT-PCR tests to diagnose infection with SARS-CoV-2 and it could only conduct 60 tests per day. By 31 May 2020, more than 10,000 tests were being conducted on a daily basis in the state. By 15 January 2021, there were 126 labs in government sector and 106 labs in private sector in the state. A vast majority of these laboratories are biosafety level 2 (BSL2) laboratories.♦ The state also sought to establish biosafety level 3 (BSL3) laboratories in divisional hospitals in April 2020 when it allocated INR ₹649 million (USD $8.7 million). During the course of the study period, the median time to a diagnosis using RT-PCR was 2 days (IQR: 1, 3). RT-PCR is considered the gold standard for diagnosing COVID-19.

RT-PCR testing capacity in the state was supplemented by cartridge based nucleic acid amplification test (CB-NAAT) beginning on 29 March 2020 and TrueNat beginning on 5 June 2020, both typically used to diagnose tuberculosis. However, these tests together only account for

TABLE 3: COVID-19 HEALTH INFRASTRUCTURE CAPACITY AS ON 30 NOVEMBER 2020

	Admission criteria	Facilities	Available beds
L-1	Mild or asymptomatic positive case	482	115,085
L-2	Mild or moderate cases	113	5,648
L-3	Severe cases	176	35,697

♦ *BSL2 = Laboratories that are required for moderately hazardous pathogens. These laboratories are restricted behind self-closing doors, personnel require minimal PPE plus face shields, and many operations are performed within biological safety cabinets. Negative-pressure containment is generally advised but not often required. BSL3 = Laboratories that are required in the presence of potentially lethal pathogens. The lab is restricted behind two sets of doors. Workers may require immunizations and PPE with respirators are advised. All work is performed within a biological safety cabinet. Filtered room air must be exhausted.*

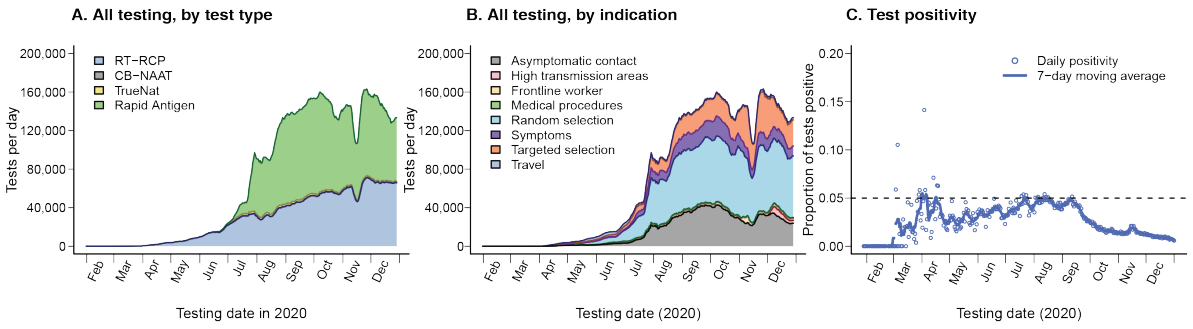
approximately 3.0% of all total tests administered during the study period. These tests provide faster results relative to RT-PCR tests. The median time to a diagnosis for CB-NAAT was 1 day (IQR: 0, 2) and 1 day (IQR: 0, 1) for TrueNat.

Rapid antigen tests were introduced on 22 June 2020 and contributed to the substantial increase in testing capacity in the state (Figure). By the end of the study period, 13 million rapid antigen tests had been administered, accounting for more than half (56%) of all tests administered in the state. In contrast to RT-PCR, CBNAAT, and TrueNat that can detect the presence of SARS-CoV-2 genetic material, rapid antigen tests can identify the presence of SARS-CoV-2 antigens indicating a current infection. These tests typically provide results within 20 minutes. The median time to a diagnosis for rapid antigen tests in Uttar Pradesh during the study period was 0 days (IQR: 0, 1). The rapid antigen test is thought to have lower sensitivity for SARSCoV-2 infection compared with RT-PCR potentially resulting in false negative test results. However, many experts are now advocating the use of imperfect tests that can provide results quickly, especially in clinical settings when triaging patients and need to separate them quickly. Emerging evidence suggests that rapid antigen tests might be more accurate[+] at detecting transmissible virus compared to RT-PCR.[56] All COVID-19 diagnostic tests in Uttar Pradesh have been provided free-of-cost to patients through public sector labs.

Overall, the state maintained test positivity largely below the 5% threshold that WHO has specified as being sufficient (Figure). By December 2020, the average daily number of tests per 100,000 population in the state was 65.0—among the highest in the region and higher than countries with comparable populations. In addition, there have been 34.8 tests per confirmed case, also among the highest with comparable populations. The United Kingdom reported 23.8 tests per confirmed case and the United States reported 14.8 tests per confirmed case.

In order to ensure timely procurement of medical supplies, the central and state governments relaxed several

FIGURE 6: DAILY TESTS (A), DISTRIBUTION OF TYPES OF TESTS (B) AND OVERALL TEST POSITIVITY OVER TIME IN UTTAR PRADESH



[+] *Accuracy is the ability to determine a correct diagnosis for a patient and is a factor of sensitivity, specificity, and disease prevalence.*

regulations. The Uttar Pradesh Medical Supply Corporation (UPMSC) was set up in 2018 to address previous procurement challenges in the state. During the epidemic, UPMSC was authorized to procure medical supplies for the entire state. Previously UPMSC only procured for DOMHFW and did not procure for DOME. Other regulations that were relaxed to accelerate the availability of critical supplies included allowing retail outlets to sell hand sanitizer without a license and permitting sugar mills and distilleries to operate during the lockdown to produce the alcohol used in hand sanitizers. The state government also promoted the local production of PPEs and as a result the number of suppliers increased from 1 prior to the lockdown to approximately 20 by the end of the study period. However, at the beginning of the epidemic, the rapid procurement of medical supplies was not without its challenges.

During the lockdown, informal private providers known as registered medical practitioners (RMP) were not permitted to remain operational, which was strictly enforced by the state government. All private health facilities otherwise were mandated to remain open during the lockdown period. However, there were media reports of some private sector facilities remaining shut during this time. While initially all dedicated COVID-19 facilities were public sector facilities, the state government began notifying private medical colleges as COVID-19 facilities beginning in April 2020. Only notified private facilities were permitted to treat COVID-19 positive patients and the cost was borne by the state government. Some patients preferred to get admitted in such facilities. Initially, integration with the integrated data platform also presented several challenges with regard to the private sector.

4. Core epidemic response interventions

Interventions that comprise a strong public health response to COVID-19 include NPIs and disease surveillance activities. Three categories of NPIs were implemented in Uttar Pradesh: (1) restrictions on movement, (2) contact restrictions, (3) and personal preventive actions.

Uttar Pradesh initiated strict travel restrictions in 16 districts on 22 March 2020 and expanded these restrictions in two additional districts on 23 and 24 March 2020. There were only 39 confirmed cases in Uttar Pradesh when these interventions were initiated. The central government stopped operation of all commercial flights on 22 March 2020, including to two international airports in the state. The national lockdown started on 25 March 2020 and restricted all interstate travel and non-essential movement within Uttar Pradesh. During this time, the state government permitted travel for migrants and students stranded in other states (see “Evolution of the COVID-19 epidemic in Uttar Pradesh”). Nonessential travel was allowed from 4 May 2020 with the exception of red zones and containment zones. From 30 May 2020, the state permitted unrestricted interstate travel; however, given the state of the epidemic in Delhi at the time, two bordering districts (i.e., Gautam Buddh Nagar and Ghaziabad) required e-passes. These additional restrictions were lifted on 30 June 2020. Non-essential travel in containment zones remained prohibited through the duration of the study period. However, the perimeter of containment zones gradually narrowed in accordance with central government guidelines as the number of cases increased in the state.

Uttar Pradesh shares a land border with Nepal that stretches for 600 km across

seven districts. For citizens of India and Nepal, the land border is open under normal circumstances and registration is not required to move between countries. Health posts with trained teams were deployed from January 2020 for the screening of suspects on the check-posts situated on the Indo-Nepal border. The closure of the India-Nepal border on 25 March 2020 stopped entry for all travels allowing only migrant workers from Nepal to return back to their country. Strict border surveillance was initiated following the closure and remained in place through the study period. However, District Magistrates of bordering districts were eventually authorized to make decisions about requirements for citizens of Nepal to enter into India.

The second category of NPIs implemented in Uttar Pradesh was aimed at reducing contact opportunities in the community. On 17 March 2020, the state called for the closure of all schools and colleges. The state placed 16 districts in lockdown on 22 March 2020 and two additional districts in the days following. During this period, the state banned gatherings of more than five individuals. The national lockdown was implemented on 25 March 2020. Initial national lockdown measures intended to reduce community contact opportunities included the closure of all schools, offices, gymnasiums, and non-essential commercial outlets. The essential services that remained operational throughout the lockdown period with mandatory operating hours and precautions include public and private health facilities, businesses related to the supply of food and dairy products, banks, and news outlets. The state government ensured establishment of COVID-19 help desks in offices of all departments and also encouraged private sector to establish such desk so that the spread of SARS-CoV-2 infection can be prevented by early screening of symptomatic patients. While the lockdown was strictly implemented across Uttar Pradesh, some districts had implemented the lockdown more strictly than others. In a government document dated 18 April 2020, 40 districts were identified as requiring stricter enforcement of lockdown measures, including Lucknow, Gautam Buddh Nagar, Ghaziabad, Bulandshahr, Prayagraj, Varanasi, and Kanpur districts.[57]

Lockdown measures were gradually eased from 4 May 2020 in non-containment zones and private offices were permitted to open with 33% capacity. A night curfew from 7:00pm to 7:00am was also instated at this time. Beginning on 8 June 2020, religious establishments, commercial outlets, and restaurants were permitted to open in Uttar Pradesh with limited capacity, thermal screening and mandatory face masks. Seating capacity in restaurants was limited to 50%. The night curfew was changed to between 9:00pm and 5:00am from 1 June 2020, between 10:00pm and 5:00am from 1 July 2020, and then ultimately lifted from 1 August 2020. Beginning on 18 July 2020, Uttar Pradesh implemented weekend lockdowns mandating that all offices and commercial establishments remain closed on Saturdays and Sundays. By 31 August 2020, large religious gatherings were still prohibited but allowed with certain precaution in the month of October 2020; however, most of educational institutions remained shut at the end of study period.

The third category of NPIs were personal preventive actions. These included mandated face masks in public, personal hand hygiene measures, and maintaining physical distance when in public. The state government required universal face mask usage beginning on 8 April 2020,

approximately one week prior to the national universal face mask requirement implemented on 15 April 2020. In contrast, the United States Centers for Disease Control and Prevention (CDC) recommended the universal use of face masks on 3 April 2020; however, many US states did not require their use until several months later. Similarly, the use of universal face masks was only recommended by the WHO on 5 June 2020. Despite being mandated, compliance has been variable and the state began fining individuals INR ₹100 for not wearing a mask on 8 June 2020, which was then increased to INR ₹500 on 10 July 2020. It is unclear how these fines have increased compliance. Hand hygiene and maintaining physical distance (i.e., two yards) have both been encouraged by the central and state governments from the beginning of the epidemic in India. Several information, education, and communications (IEC) campaigns have been implemented with support from several development partners, including UP-TSU and UNICEF (see "risk communications section").

Quarantining individuals who have been in contact with confirmed or suspected cases of COVID-19, who travelled from countries with an active epidemic, or who live in regions with high disease transmission, is an effective public health intervention for reducing disease incidence and mortality.[58] Beginning in February 2020, the state government worked to establish quarantine facilities in schools, hospice centers, and the Haj house (i.e., where pilgrims stay before embarking on Haj) near the international airport in Lucknow. Additional quarantine facilities were eventually instituted with support from the Revenue Department, Rural Development Department, Urban Development Department, and the Panchayati Raj Department. All travelers arriving in Uttar Pradesh from abroad were required to quarantine for two weeks beginning on 13 March 2020. Those who attended the large religious gathering in Delhi and all migrants who traveled back to the state were also required to quarantine for two weeks.

In Uttar Pradesh, routine surveillance activities at the community level are primarily conducted by frontline health workers, namely ANMs, ASHA workers, and AWWs. These frontline workers received virtual and in-person trainings for contact tracing from medical officers stationed in PHCs and CHCs. They have been equipped with pulse oximeters, thermometers, and smartphones to aid in contact tracing activities in their communities. From 22 May 2020, contact tracing activities have focused on identifying those individuals with whom confirmed and suspected COVID-19 cases have had contact and following them for 28 days to monitor for the onset of symptoms. This approach to contact tracing is known as prospective contact tracing as it aims to identify and isolate new cases. In contrast, retrospective contact tracing involves looking further backward with the aim of identifying the individual who infected the patient. Research from India has indicated that most secondary cases of COVID-19 result from a small proportion of primary cases—a phenomenon known as the overdispersion in susceptibility or "super spreading".[16] Initially, the state used retrospective contract tracing for all confirmed COVID-19 cases. This approach likely contributed to the limited epidemic growth resulting from the previously described migrations to Uttar Pradesh. However, retrospective contact tracing is difficult to implement in most settings and requires additional resources and therefore might be impractical in areas with a large number of cases.

Special house-to-house surveillance has been a feature of the response to COVID-19 in the state. For example, a special COVID-19 surveillance drive was conducted from 1-15 July 2020 by approximately 80,000 trained teams, reaching almost every house of the state and surveying more than 200 million. Through this surveillance, 180,000 symptomatic individuals were identified for testing. Another house-to-house survey was conducted in November 2020. During this surveillance, more than 70,000 surveillance teams surveyed almost 3.5 million household and identified an additional 10,605 symptomatic persons for testing.

Another unique initiative of the state government is its massive targeted sampling across the state. Through this initiative, potential high-risk groups were quickly identified and tested for SARS-CoV-2 infection. The first round of targeted sampling was conducted in June 2020. Three additional drives were conducted in October, November, and December 2020 to further reduce transmission of the disease. From 29 October to 12 November 2020 just before one of the largest festival in India, more than 800,000 samples were collected from rickshaw drivers, mehndi artists, beauty parlor employees, sweet shopkeepers, restaurant employees, people at places of worship, vehicle shop employees, street vendors, pharmacists and workers at nursing homes. Ultimately, almost 12,000 samples were found positive through RTPCR and rapid antigen tests. Test positivity was the highest (2.6%) for chemists and those working in nursing homes and lowest (0.7%) among those in restaurants. In targeted sampling done in November 2020, approximately 640,000 samples were collected from healthcare workers, teachers and school employees, office workers, those working in markets, railway and bus station employees, those in prisons (prisoners and employees), and street vendors. In total, 2605 tested positive for SARS-CoV-2 infection through RTPCR and rapid antigen tests. The highest test positivity was found at railways and bus stations while lowest positivity was detected among street vendors. In the first week of December 2020 during fourth drive, almost 220,000 samples were collected and 700 samples were found positive. These drives helped in prompt detection and isolation of individuals who might have, comparatively, contacted many people in a very short duration and thus reduced probability of dissemination of infection in the state.

The state government established institutional isolation centers in collaboration with private hospitals, schools, resident welfare associations, and hotels throughout the state to isolate all COVID-19 positive individuals at the initial phase of epidemic. Once the dedicated COVID-19 facilities were established, all confirmed cases were required to remain in a facility, even presymptomatic patients or if they remained asymptomatic throughout their infection.

In early July 2020, as the number of COVID-19 cases across the country was increasing, the Government of India allowed home isolation for confirmed cases as many proved to be asymptomatic and did not require specific medications. Subsequently, two weeks later on 20 July 2020 the Government of Uttar Pradesh also allowed home isolation for asymptomatic cases. Rigorous monitoring mechanisms were developed to assess cases that opted for home isolation through Integrated COVID-19 Command and Control Centers (ICCCC) led by District Magistrates in all 75 districts of the state. A protocol was developed to ensure an initial visit of the patient under home isolation by RRT led

SCREENING AND SAMPLING AT OLD AGE HOME, AURAIYA

by a medical officer. If the RRT found that the patient was asymptomatic, not suffering from any potential comorbidities, had a separate room and toilet, and was willing to download and upload information on home isolation and Arogya Setu application, then home isolation was allowed for the patient. RRTs were mandated to visit patient's home on three and seven days after diagnosis to assess the patient's health condition. Simultaneously, trained callers from ICCCC made daily calls to document the health status, development of any symptoms, and to assess where the patient need to be moved to a dedicated COVID facility. As of 15 January 2021, approximately 58.6% of all patients in the state were allowed home isolation. More than 99% of those who went through home isolation recovered from their infection. However, research using mathematical models has showed that home isolation is likely less effective at containing COVID-19 when compared to institutional isolation.[59]

In many countries, COVID-19 response intervention were implemented by relying on the surveillance infrastructure established during and following the H1N1 and SARS outbreaks.[27,60] Similarly, the response to COVID-19 in Uttar Pradesh has benefitted from previous public health surveillance activities, including the national polio surveillance program and surveillance programs for acute encephalitic syndrome (AES) and Japanese encephalitis (JE). One respondent indicated that household surveillance used "the pulse polio plan, whenever there is a positive [COVID-19] case reported from some area, these [frontline health workers] visit and they carry house-to-house survey." Efforts to address AES and JE in the state have also provided a strong framework for the public health response activities. Addressing annual outbreaks of JE has been a high priority for the political leadership in the state. The current Chief Minister gained experience addressing infectious disease outbreaks during his two-decade tenure as a Member of Parliament representing Gorakhpur—a district in Uttar Pradesh heavily affected by AES. Given the high political priority placed on AES, the work carried out in the JE and AES program has provided

good experience and fair understanding of public health measures to the technical leadership in the state. In addition, ASHA workers have been able to combine COVID-19 messaging with the annual *Dastak* ("door knock") campaign for AES. In July and October 2020, ASHA workers in all 75 districts visited every household communicating messages of ensuring social distancing, hand washing, and use of face masks.

In August 2020, the Government of Uttar Pradesh stated to use ivermectin to prevent infection and to treat COVID-19 patients. Ivermectin is an antiparasitic drug that is used to treat several neglected tropical diseases, including onchocerciasis, helminthiases, and scabies. The decision to use this drug for COVID-19 infection and treatment was based on anecdotal evidence from Agra district where members of the RRT there were given ivermectin to prevent SARS-CoV-2 infection and no member of RRT was ultimately infected with this virus. Based on this observation and findings of ongoing national and international research, the state recommended use of ivermectin for the prevention of SARS-CoV-2 infection and treatment of COVID-19. This drug was distributed in the community through frontline workers and was administered to contacts and patients of COVID-19 and healthcare workers on a massive scale. Simultaneously, the general public purchased the drug over the counter following media reports. Many state government officials believe that large-scale administration of ivermectin has provided protection against infection as well as reduced severity of illness in COVID-19 patients. However, current research does not indicate a protective or therapeutic effect of ivermectin with regard to COVID-19.

Finally, India initiated the world's largest vaccination drive on 16 January 2021 with two manufactured in India COVID-19 vaccines. The state of Uttar Pradesh prepared for the delivery of COVID-19 vaccines based on its experiences with many public health and vaccination campaigns. To ensure the smooth introduction, two dry runs were conducted in all 75 districts: the first on 5 January 2021 at 853 sites and the other on 11 January 2021 at 3081 sites. Among these sites, half were in urban areas and the other half in rural areas. The Chief Minister of Uttar Pradesh reviewed preparations at some session sites, including adverse event management in both dry runs.

SANITIZATION OF BUSES IN LUCKNOW

The purpose of these dry runs was to identify any potential bottlenecks in implementation and address them before the actual vaccine roll-out. Both dry runs witnessed active participation of state and district officials.

5. Continuity of health services

A health system that is shock-responsive should have the resources and capacities to maintain equitable access to quality health services. Throughout India, routine services were heavily affected as a result of the COVID-19 epidemic and the unavoidable national lockdown that was initiated on 25 March 2020. The state, with support from several partners, worked to reestablish these routine services as soon as possible in order to protect the health and wellbeing of those living in the state.

After declaration of the national lockdown on 25 March 2020, many health services of both public and private were disrupted as a result of sudden imposition of restrictions and lack of clarity on appropriate safety measures at the initial stage. Public health facilities did not fully resume essential emergency clinical services, such as high-risk deliveries, neonatal services, dialysis, chemotherapy, and blood transfusion, until 11 April 2020. Many respondents suggested that private services were not available consistently throughout the state. However, some critical health services were not affected during the lockdown. For example, 25% of deliveries occurred in a health facility. While this number is low relative to other states in India, it is virtually the same proportion as those during the same period in 2019. Facility-based quality initiatives for improving clinical processes have resumed. Training activities to improve labor room and operation theatre processes have been organized using digital platforms. As of August 2020, 20 sessions have been organized with approximately 250 participants.

Many outpatient and primary health care services were reduced during the lockdown period. For example, antenatal care (ANC) registration reduced to 8% and only 3% of pregnant women received an adequate number of visits (i.e., four or more visits). In addition, the percentage of age-eligible children who were fully immunized during the lockdown was only 1%. However, beginning on 28 April 2020, efforts to resume many primary healthcare services was initiated. Other primary healthcare services also resumed around the same time, including Village Health Nutrition Day (VHND) activities where ANC services, routine immunizations, and other nutrition and family planning services are provided, resumed with the exception of containment zones. These activities have been implemented in compliance with infection prevention and social distancing guidelines. In addition, home-based newborn care (HBNC) services were slightly disrupted during the lockdown but were resumed in May 2020 with instructions for conducting HBNC visits with no physical examination or weighing of the mothers and newborns. As HBNC services resumed, health workers also provided contraceptives and primary healthcare services in the state. The state government continued implementation of massive door-to-door campaigns to control vector borne diseases, Japanese Encephalitis and Acute Encephalitis Syndrome. This platform was also used to convey messages related to COVID-19 prevention and control. The resumption of these activities has been supported through strong supervision by the state and district officials and with support from several partners, including UP-TSU, WHO, and UNICEF

6. Social protection interventions

The national lockdown resulted in unforeseen consequences related to the migration of millions of migrant workers from large metropolitan cities and loss of livelihood of many daily wage earners. The state government took several actions to protect the lives and wellbeing of these daily wage earners and 3,528,227 migrants returning to their villages in Uttar Pradesh from various parts of the country.

With the involvement of Team 11 the state was able to mobilize INR ₹16 billion (USD $213 million) resources to ensure availability of various social protection programs. The state government mobilized various departments to arrange 1643 trains, 12,000 government buses, and 18,000 shelter homes for the migrants returning to Uttar Pradesh. Likewise, the state government was able to collaborate with civil society organizations to run 3,888 community kitchens that dispersed rations and cooked meals for migrants and daily wage earners. To reduce the risk of transmission of COVID-19 among vulnerable groups, the state government also ensured door-to-door delivery of essential food and medicines in containment zones, communities celebrating Ramadan, and families of at-risk groups, including elderly, women, and children.

The state government also implemented a variety of socioeconomic relief programs targeting low-income families during the lockdown period. Migrant workers and laborers received a onetime cash relief of up to INR ₹1,000 (USD $13) amounting to total of INR ₹3.4 billion (USD $44.8 million). Likewise, the state government mobilized INR ₹16.3 billion (USD $217.7 million) through paid-work days through the Mahatma Gandhi National Rural Employment Guarantee Act to 5,713,000 laborers throughout the state. The state government ensured that vulnerable families and groups received timely pension payments and grain supply from public distribution system even during the lockdown period. Besides, the state government is also protecting the people from catastrophic healthcare expenses for COVID-19 testing and treatment by determining specific rates for the private sector laboratories and hospitals. All COVID-19 related services provided through public facilities are free of cost to general public while *Ayushman Bharat*[**] empaneled private hospitals are providing free services to its beneficiaries who constitute the poorest of the poor.

7. Data and knowledge management

Usage of digital data is still in the initial stage in the health sector of Uttar Pradesh. Undoubtedly, COVID-19 has created many opportunities for data and knowledge management for health and other sectors. At the initial phase of epidemic, surveillance related data increased dramatically from district administrations, health facilities, and airports where symptomatic screening was taking place, through email on Excel spreadsheets. However, State Surveillance Unit (SSU) informed that additional capacity would be required for using data for decision making. During this time, the state government took timely decision to digitalize reporting architecture with support from UP-TSU. During several discussions and deliberations with SSU, UP-TSU conceptualized, designed, and

[**] *Ayushman Bharat is a central government program that aims to provide free access to healthcare for 40% of people in India. People benefitting from the program access their own primary care services. When a beneficiary requites additional care, then Ayushman Bharat provides free secondary health care for those needing specialist treatment and tertiary health care for those requiring hospitalization. The program is a centrally sponsored scheme and is jointly funded by both the federal government and states.*

ASHA PUTTING POSTER AT HOUSES, SAHARANPUR

developed a unified data platform over the course of one-and-a-half weeks. This integrated digital data platform was also integrated into the central government data platform managed by ICMR and MOHFW. Through this platform, patients can also access their report by using this portal.

Sharing of information through the integrated digital platform has also improved level of collaboration between the DOMHFW and DOME. A series of rigorous virtual trainings of health facilities, laboratories, field offices and administrators along with incorporation of practical suggestions from the field has quickly evolved this digital platform into a trusted and state-specific customized single source of information. The DOMHFW had limited capacity with respect to data scientists and professional epidemiologists to analyze, interpret, and extrapolate available data, but the state timely deputed many young medical officers who were trained in epidemiology or had fair understanding of data science and epidemiology. The state government received technical support from UP-TSU and WHO in this regard. The SSU gradually started to generate various analytical reports for decision making purposes on treatment facility and laboratory facility performance, cases, contacts and surveillance activities. The state government also prepared digital dataset of all migrant workers which was very useful for their health management at the time when they return to the state and also proved useful in skill mapping for their rehabilitation activities.

The state has quickly adopted digital interactions in the form of trainings, webinars, continuing medical education, reviews and monitoring purposes which are more effective and economical in current situation and may have huge impact future communication mode.

As a high priority for the Chief Minister, an electronic COVID Care Support (ECCS) network has been developed comprising teams of specialists from leading medical institutes to help hospitals in Uttar Pradesh in the management of seriously ill COVID-19 patients. Similarly, the department is also providing teleconsultation through its toll-free number as well as e-Sanjeevani.

The state also implemented online e-pass system and grievance redressal system to ease and address issues related to general public. Use of apps like Aarogya Setu and Aayush Kawach is being regularly promoted and monitored by the government to make people alert and aware against COVID-19. To facilitate

knowledge management, the department is also documenting initiatives, processes, strategies, plans, guidelines and protocols issued during current pandemic in the state.

8. Risk communications

The availability of reliable, trustworthy, and consistent source of information has been identified as one of the most critical aspects of managing public health emergencies.[61]

To ensure that the people of Uttar Pradesh have access to accurate information about the status of the epidemic in the state, measures used to protect oneself, designated spokespeople from the Health and Home departments conducted daily media briefings through the epidemic, beginning in April 2020. During the media briefings, the two senior government representatives shared the latest data on the number of new cases, the number of recovered cases, and the number of currently quarantined individuals. Any new policies and public health advisories from the state or central governments were also announced at these daily briefings. Local news agencies were invited to attend daily press briefings, which were also broadcast live on several news channels. In addition, the Chief Minister of Uttar Pradesh also made frequent televised public addresses to the citizens of the state.

Individuals in Uttar Pradesh also accessed real-time information related to COVID-19 prevention, symptoms, and what to do if experiencing COVID-19 symptoms or the contact of a confirmed or suspected COVID-19 patient through government hotline services managed from the Chief Minister's Office and Directorate of Medical and Health in Lucknow. At the district- and village-level, authorities and representatives conducted a variety of public information campaigns through social media, printed and televised news, radio, community announcement or distribution and display of information, education, and communication (IEC) materials. Development partners, including UNICEF, have supported the state

SERO SURVEILLANCE AT VILLAGE SEMRA KALPANA JASRA, PRAYAGRAJ

government in preparing and disseminating many of these IEC materials through a variety of community platforms in the state.

The effectiveness of these efforts in alleviating perception of fear and confusion of the mass or mitigating their risky behavior have been variable in Uttar Pradesh.[62] At the national level, companies such as Facebook have partnered with the central government to dispel misinformation spreading via WhatsApp messaging platform by limiting the number of message forwards and availing authentic COVID-19 information within the platform via chatbot and short-videos.[63] In this context, it was felt that Health Education Bureau and IEC Bureau of the DOMHFW could have played a critical role but missed the opportunity.

9. Monitoring and evaluation

The monitoring of Uttar Pradesh's COVID-19 response is being primarily carried out by utilizing new and existing digital data platforms with the real-time data and analytics. The leadership group of Team 11 as well as various committees and control rooms of the state government departments (described in Planning and Coordination) monitored overall response activities in Uttar Pradesh on a daily basis, primarily using the integrated Uttar Pradesh COVID-19 portal. Key epidemiological indicators monitored daily include: total positive cases, bed occupancy rate, recovery rate, total deaths, total number of tests performed (RT-PCR, rapid antigen test, and CB-NAAT/TrueNat), case fatality ratio, ventilator usage, total home and facility isolation cases, and total contacts traced per positive case among others. Team-11 also monitored quality of healthcare services provided by dedicated public and private health facilities and response to COVID-19 cases in terms of referral and allocation of facilities on a regular basis.

On 22 March 2020, the DOMHFW constituted 10 teams at state level to monitor COVID-19 facilities including quarantine centers, logistics and supply, human resource and training, patient transportation, media and IEC activities, control room, coordination with private sector, surveillance, inter-departmental and intra-departmental coordination. In addition, the availability of human resources and other drugs and supplies are monitored through the routine HMIS and HRMIS portal (Manav Sampada)/ DVDMS of the DOMHFW. A variety of socioeconomic protection measures and relief packages distributed by the state government were monitored through the routine data systems of related departments.

The state government has worked to ensure the quality of in-patient care provided by health professionals through measures such as the closed-circuit television monitoring and telephonic survey of in-patients through the State Call Center. The state government regularly collects feedback on the treatment, provider behavior, cleanliness, and overall patient satisfaction from the telephonic survey of patients admitted at the COVID-19 care facilities. On various occasions, state-level senior officials, including the Chief Minister and technical experts from academic, have visited highly affected districts to oversee the preparation and provide supportive supervision. The state government is monitoring the quality and cost of the services provided by the private sector facilities through the office of District Magistrates at each district. The state government has established a cut-off in-patient treatment rates for all the COVID-19 related treatment received by the public at private facilities.

The central government, civil society groups, and media have played active role in assessing the state government's response to COVID-19. The epidemiology of COVID-19, available resources and processes involved to reduce transmission and fatality are also being monitored and evaluated by the central government through MOHFW and organizations, such as the Indian Council of Medical Research (ICMR) and National Centre for Disease Control (NCDC). The state government uploads COVID-19 data on both cases as well as resource availability on the ICMR portal on a daily basis. The central government has continuously engaged with the state government in monitoring disease situation, providing technical and logistical support from the very beginning of the epidemic. The central government constituted a team for each state during the course of epidemic and the team constituted for Uttar Pradesh visited several times in the state to interact with state departments and also carried out inspections to ensure quality of response against COVID-19. The Chief Minister is closely monitoring the performance of various departments on the basis of feedback received through the Chief Minister's helpline and other sources. Media and civil society groups have also independently monitored the overall COVID-19 response of the state government utilizing the data from the Johns Hopkins University (JHU) Coronavirus Resource Center as well as some crowdsourced data platforms. Similarly, the WHO has evaluated facility preparedness for COVID-19 management in the state at the beginning of epidemic and UNICEF has evaluated adherence of home isolation protocols by patients and health system.

Although the state government quickly leveraged modern technologies and adapted existing command and control structure to monitor the COVID-19 efforts in such a vast state, there have been reports of some districts consistently under-performing during the COVID-19 response. Nevertheless, the state government departments have been working continuously to improve based on issues raised through independent and in-house monitoring and evaluation activities.

CONCLUSIONS AND OPPORTUNITIES FOR STRENGTHENING HEALTH SYSTEMS

Uttar Pradesh, like many other states and national governments elsewhere, has handled the unfolding COVID-19 epidemic using its existing health system capabilities and in the face of substantial uncertainties. The incidence and mortality rates through 15 January 2021 are lower compared to several other Indian states and countries with comparable populations. The strict implementation of lockdown measures in Uttar Pradesh also afforded the state time to establish physical infrastructure (i.e., COVID-19 hospitals and laboratories), recruit critical health workers, and conduct essential trainings.

By 15 January 2021, there were approximately 595963 cumulative confirmed cases of COVID-19 and almost 8569 cumulative deaths in Uttar Pradesh. Evidence from India and other countries indicates that SARS-CoV-2 will continue and the large-scale vaccination will take some time. [64,65] Given this reality, it is imperative that the government of Uttar Pradesh continues its ongoing efforts to control the epidemic. The COVID-19 epidemic has also presented several opportunities for the state to learn and utilize the lessons to strengthen the health system. Health system strengthening has been acknowledged as an important issue based on the recognition that a strong health system is not only the backbone of effective routine health services, but also a measure of resilience of health systems during emergencies.

Lessons and opportunities for strengthening the Uttar Pradesh health system based on the experiences of Uttar Pradesh's COVID-19 response include:

- **Refine current health emergency planning**
  Uttar Pradesh adopted top-down leadership and decentralized implementation approach to efforts against COVID-19. These efforts were centrally coordinated by a committee known as Team 11, comprising senior bureaucrats representing related departments and chaired by the Chief Minister of Uttar Pradesh—indicative of a "whole-of-government" approach. The committee was established on 21 March 2020, less than three weeks after the first confirmed case was identified in the state. This committee focused on planning and coordinating both the critical health emergency response as well as other functions required to mitigate effects of COVID-19 epidemic. This response proved effective for controlling the COVID-19 epidemic in Uttar Pradesh. Existing health emergency and response plans in the state can be strengthened based on these experiences of the state. Improvement should be done as soon as feasibly possible to avoid loss of individual or institutional memory.

- **Strengthen coordination and collaboration further across relevant agencies**
  Throughout the COVID-19 epidemic, Uttar Pradesh leadership put significant effort toward forging strong linkages with other sectors, including beyond health, to manage variety of response efforts. Ongoing collaboration efforts against AES and JE in the state have substantially contributed to these efforts. These efforts have particularly proved crucial in ensuring coordinated public health and clinical response efforts between DOMHFW and DOME. Uttar Pradesh should continue this coordination to address other issues that the state continues to face due to these two separate departments.[66] Similarly, an institutional integration mechanism among separate structures of the Health Department, such as the Directorate of Medical and Health (DOMH), Directorate of Family Welfare (DOFW), National Health Mission (NHM), and Uttar Pradesh Medical Supplies Corporation (UPMSC) at the headquarter-level can improve overall efficiency of the department. Interdepartmental coordination has been a regular and distinct feature of successful public health efforts in the state and thus, Uttar Pradesh has relied on experiences and understandings among departments to effectively respond to COVID-19.

- **Continue to partner with community members in preparation and response activities**
  Experience of Uttar Pradesh from ongoing fight against JE and AES suggests that it is critical to involve and engage with community members for awareness generation, surveillance, household preparation and improve acceptance of interventions implemented by the government. As community members are usually the first people to identify immediate risks, the state used *Gram* and *Mohalla Nigrani Samitis* to ensure community involvement in many public health response functions. Such well-established platform can enable communities to own and engage in mitigating the risks of emergencies and disasters. Moreover, IEC activities of the department can be improved and harnessed to design and implement behavior change communication programs involving community groups and leaders. Similarly, the risk communication strategy and interventions should be targeted to address any issues arising from false information particularly through social media.

- **Bolster disease surveillance through strengthened laboratory capacity**
  Countries that largely contained COVID-19 epidemic were able to do so by rapidly expanding testing and tracing capacities.[67] Uttar Pradesh made great strides to establishing new laboratories and upgrading existing laboratories under DOMHFW and DOME, harnessing the capacity of laboratories of other sectors, promoting and facilitating private sector laboratories to conduct SARS-CoV-2 testing and thus increase overall testing capacity of the state during the epidemic. This enhanced capacity could also be used for routine disease surveillance. To ensure quality of laboratory services, robust quality assurance mechanism and center of excellence can be designated.

- **Expand integrated digital data platform to improve data for decision-making**
  The integrated COVID-19 data portal has effectively facilitated a coordinated epidemic response across multiple departments and decision-making layers of the state government. It is noteworthy that government officials right from the state to the block-level rapidly adopted this new platform for decision making in the state. To strengthen sentinel and public health surveillance in the state, learning and experiences from conceptualization to implementation and monitoring of the integrated COVID-19 data portal should be used. As this state customized data portal has evolved through a series of horizontal and vertical consultations, therefore, it should permanently become part of health information infrastructure in the state. The recent National Digital Health Mission could support such efforts in Uttar Pradesh.[68]

- **Develop strategy to expand and strengthen health workforce, including focus on public health and management**
  The state utilized the potential of existing health workers during the COVID-19 response by protecting their health and enhancing their skills through continuous trainings and rational deployment. The experience from Uttar Pradesh has also highlighted how strategic planning can reduce stress related to the shortage and maldistribution of human resource on health system. These strategies should be continued and long-term investment should be made in developing core public health competencies of existing workforce.[69] Likewise, the existing workforce should also be provided continuous opportunities to refine and upgrade their skills and knowledge to effectively manage endemic and emerging diseases.

- **Conduct surge capacity planning to meet with increased demand**
  Health systems need to cope with unprecedented surge in demand during epidemics such as of SARS-CoV-2. Emergency and disaster planning need to develop a strategy to meet surge demands of public health as well as clinical needs such as spatial isolation infrastructure, physical beds, food, water, sanitation, oxygenation, mechanical ventilation, hospital infection control arrangements, and mental health services. Having a well articulated plan that provides direction at the times of uncertainty can help public health and clinical facilities managers to immediately start fulfilling the temporary demands either through stockpiles or procurement processes that are activated during emergencies.

- **Identify opportunities to strengthen collaboration with the private sector**
  The whole-of-society approach acknowledges that the government capacities alone are inadequate in meeting large surge in demands during health emergencies and disasters. The role of private sector should include, but must not be limited to expansion of laboratory services, clinical services, health workforce mobilization, management of critical infrastructure (e.g., water and food supply, transportation), and agreement on using standard protocols for preparation, surveillance, response, and

information sharing and reporting.[30] Flexibility of private sector can be particularly instrumental for rapid innovation and development of diagnostics, technologies, or treatment options to respond to emergencies like COVID-19. The Government of Uttar Pradesh collaborated with private sector healthcare providers to expand and strengthen testing and treatment capacity related to COVID-19 as well as to continue routine health care services during epidemic. This partnership with private sector should be continued during normal days.

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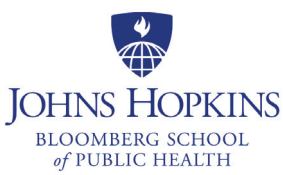
APPENDIX A

List of nine government agencies in Uttar Pradesh for which government orders and circulars were reviewed for this case study. In total, we reviewed 658 government documents in this review. All documents were available in the public domain.

1. Department of Medical, Health and Family Welfare
2. Department of Medical Education
3. Department of Information & Public Relations
4. Department of Revenue
5. Department of Urban Development
6. Department of Rural Development
7. Department of Home
8. Department of MSME
9. Department of Panchayati Raj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