changes by 1000 to 1500 years. This pattern of leads and lags supports the hypothesis that the North Pacific is not a passive recipient of North Atlantic climate changes, but rather is close to the source of millennial-scale climate perturbations.

Millennial-scale climate changes attributed to Northern Hemisphere atmospheric teleconnections also are observed in the Santa Barbara basin (7), the Gulf of California (8), and off Vancouver Island (9). However, these records lacked the resolution or detailed independent chronologies to definitively determine the phasing of tropical, North Pacific, and North Atlantic changes. Walczak et al. have the necessary archival resolution and chronological control to confidently assess this phasing. The authors' data provide evidence that globally recognized millennial-scale climate changes likely originated in the tropical Asian-Pacific region. Changes in heat and moisture transport via the western Northern Hemisphere jet stream likely explain synchronous rapid Northern Hemisphere warming during the last glaciation (10).

The atmospheric warming melted the Cordilleran Ice Sheet, producing glacial meltwater that may have provided freshwater (via the Bering Sea and Arctic Ocean) that slowed the AMOC (9, 12). Additional evidence from the circum-Antarctic Southern Ocean indicates that overturning driven by tropical atmospheric perturbations regulated glacial-interglacial CO₂ concentrations, rather than the AMOC (13). Taken together, paleoclimate and paleoceanographic records far from the North Atlantic argue that it is time to revisit this paradigm central to paleoceanography and paleoclimate studies since the first high-resolution ice core was drilled in Greenland (1, 3).

**REFERENCES AND NOTES**


**CORONAVIRUS**

**Public health during the pandemic in India**

Data from two Indian states give detail about variation in transmission and disease outcomes

By Jacob John and Gagandeep Kang

In March 2020, with coronavirus disease 2019 (COVID-19) threatening to overwhelm India’s fragile health care ecosystem, the country combined a stringent lockdown of its 1.37 billion population with a program of surveillance and containment of varied effectiveness across states. Testing and data management systems were set up, but the paucity of publicly available data, especially in the initial phase of the pandemic, limited understanding of disease epidemiology and transmission dynamics as well as the effectiveness of control measures. On page 691 of this issue, Laxminarayan et al. (1) present findings from government-implemented surveillance during the first 4 months of the pandemic in the two southern states of Tamil Nadu and Andhra Pradesh in India. They use data from, and after, the lockdown period to make important observations on the dynamics of infection, transmission, and risk factors. This collaboration between the state governments of Tamil Nadu and Andhra Pradesh and academic researchers is a valuable template for federal government agencies.

The public health response to infectious disease outbreaks is founded on the ability to mount a coordinated strategy that combines measuring and tracking cases to assess the efficacy of interventions. For COVID-19, testing, tracing, treating and isolating cases, as well as widespread mask wearing and social distancing, are, and are, the tools for transmission control. India’s population is second only to China’s...
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approximately 1.41 billion, in one-third of the land area, and so when severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) began its relentless spread outside China, there were concerns about the ability of low- and middle-income countries (LMICs) to deploy public health tools, given their limited health care capacity.

Although there were limitations in tracking in many parts of the world, the data from hospitals and laboratories were widely available, allowing modelers in academia and public health systems to use data from China and the industrialized world early in the pandemic to build predictive models based on the government strategies that were developed (2). Although useful, these models are sensitive to underlying assumptions about contact patterns and transmissibility of the infection, which are affected by population density, occupation, and social structures. In India and other LMICs, the lack of information sharing for analysis between government agencies with access to the data and academic groups with the skills to perform these analyses resulted in control strategies being widely debated because the evidence base for policy was unclear (3, 4).

Despite the perpetual underinvestment in public health in India, both Andhra Pradesh and Tamil Nadu have functional public health departments. Laxminarayan et al. describe scaling of contact tracing to reach more than 3 million exposed contacts and collect epidemiological and laboratory data from 575,051 contacts of cases in the first 4 months of the pandemic, when such extensive contact tracing was most likely to be beneficial. The surveillance was not perfect. There were variations in the effectiveness of screening across districts, with most cases having an improbable low number of exposed contacts. Testing strategies changed multiple times as the public health response adapted to emerging challenges, complicating analyses of infection rates and infection fatality ratios. Despite these limitations and the subsequent escalation in cases (see the figure), the authors have generated important insights.

The study highlights the importance of “superspreaders” in fueling the pandemic. Although there were limitations in contact tracing, and hence in the evaluation of secondary cases and of transmission chains, the finding that a minority of cases were associated with most transmission events (superspreading) is consistent with the emerging data across the globe (5, 6). The determinants of superspreading are not well understood, but it is likely to be a function of social interaction patterns of the infectious host, the environment, and biological characteristics of the infectious agent. Identifying the characteristics of settings where superspreading events are likely will help target control measures and screening for those settings to maximize limitation of transmission. However, focused control measures must be balanced against the potential for further stigmatization of individuals with COVID-19 beyond that already reported (7).

More than half the reported deaths in these two states occurred within 6 days of diagnosis compared with 16 days in China (12). There are several potential explanations. During the lockdown and with concerns about transmission, individuals who were ill may have come to health care facilities late in their illness. It is also possible that owing to limited capacity, testing was reserved for those who had more advanced symptoms and were potentially more likely to die. In the early phase of the pandemic, the treatment facilities may have been inadequately prepared, equipped, and staffed. The 26% improvement in mortality risk in recent months in these states (4) may partly be attributed to improved access to testing, treatment, and health care infrastructure over time.

The observation that traveling in proximity to a case for a long duration was a risk factor for transmission merits special consideration for India, where most interstate transport is by train, bus, and truck. Studies in other parts of the world on air travel have also documented spread (13). Most of these studies report data before widespread mask use, and experimental and real-world data obtained from using different modes of transport with well-described air circulation must be used to inform travel guidance (14). More studies from diverse settings at this stage of the pandemic, particularly including data from serosurveys, are needed to better understand factors determining transmission, plan interventions, and predict outcomes in LMICs.

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Cases and deaths in two southern states of India

Trends in case detection (7-day moving average is shown) and coronavirus disease 2019 (COVID-19) fatalities in Andhra Pradesh (●) and Tamil Nadu (●) highlight low case fatality and the effects of early interventions.

The contact tracing data suggests two important findings regarding transmission. First, there is an increased likelihood of cases infecting contacts of similar ages, and second, that children under 14 are active participants in transmission. These findings probably reflect prevalent social mixing patterns in India (8) but raise concerns about the possibility of enhanced transmission when poorly ventilated, crowded schools reopen (9). Children have been implicated in the transmission of other respiratory infections to the elderly when intergenerational contact is frequent (10). Careful monitoring of transmission by children will be vital to shield vulnerable older adults and those with comorbidities. At the other end of the age spectrum, the low mortality rate in the elderly as reported by Laxminarayan et al. indicates the need to better understand the composition of older age groups by socioeconomic status and comorbidities to clarify the contribution of the survivor effect. The lower death rates may also reflect that those who live longer in LMICs are more healthy than people of similar ages in high-income countries (11).
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