VACCINES AND DIAGNOSTICS

COVID-19 INITIATIVES

**DR. SIDI BENCHERIF** has developed a biomaterial-based vaccine platform that could be leveraged for COVID-19 vaccine development. His strategy is based on an injectable biomaterial that could slowly release in the body as an adjuvant (one used in common U.S. vaccines), as well as SARS-CoV-2 antigens. The vaccine will therefore be engineered to recruit and activate immune cells against SARS-CoV-2 antigens, ultimately mounting a strong and long-lasting immune response against SARS-CoV-2.

**DR. JIAHE LI** is engineering an immune adaptor to enhance vaccines against influenza by targeting its receptor, STING, in humans. Coronaviruses can inhibit the STING protein to evade the immune system. Dr. Li proposes to engineer the STING protein with resistance to deactivation by coronavirus so that the STING proteins can become a more potent tool to augment our immune response against coronavirus replication.

**DR. LI** is also proposing research in quickly identifying areas and surfaces contaminated by COVID-19 to mitigate future need for diagnosis. Although disinfection on large suspected areas is effective, it is not practical or economical to apply this type of approach to disinfect all high-risk public areas, e.g., public transportation. Dr. Li proposes to develop a functional swab that can capture COVID-19 at low densities from a large surface area via COVID-19-specific binding peptides, perform an immune assay on the swab, and rapidly acquire results using smart phones with commercially available microscope lens (figure 1).

**DR. MING WANG** is proposing research on a rapid home test kit for COVID-19 detection. Current numbers show that a significant percentage of the population may carry the virus without symptoms, creating a need for a kit that may be used at home in addition to being available at all local clinics.

**DR. NIAN SUN** is developing new sensing techniques for diagnosing COVID-19 in air and solutions in a matter of seconds, rather than hours or days. Dr. Sun’s preliminary data shows that the virus can be detected in the air from the breath of a patient in approximately 1–2 seconds with nearly 100 percent specificity, which is a dramatic improvement from the current technology.

**DR. ED GOLUCH** has developed a diagnostic platform that can adapt to detect the surface spike protein of COVID-19 from a nasal swab from patients with symptoms in five minutes. The platform is simple enough for home testing, and once adapted, Dr. Goluch has already identified a company that can manufacture the test.

**FIGURE 1**

"Diagnosis on a Swab"

- High-affinity peptide specific for COVID-19
- CBD (cellulose binding domain)
- Cotton swab
- COVID19 capturing and concentration from small surface area
- COV19 detection antibody
- Chromophores or enzymes
- Cell phone equipped with microscope lens

Cotton swab
DR. JAMES BENNEYAN has developed a modeling tool, in partnership with the Lahey Hospital and Medical Center, to help hospitals produce their own projections and consider possible shortage scenarios up to 30 days in advance, as they prepare for potential waves of patients that could strain their facilities. Hospitals can run the tool with data specific to their facilities to project when the demand for hospital equipment is going to exceed the supply. It can also model the availability of hospital staff. This tool has been used by approximately 3,000 healthcare systems so far to date.

DR. JACQUELINE GRIFFIN has multiple projects focused on the response to COVID-19. First, in partnership with Massachusetts General Hospital, she is developing data-driven strategies to mitigate the effects of short-term drug shortages, while also researching strategies to increase long-term resiliency in the pharmaceutical supply chain. This work is in collaboration with OrbitalRx, the first software specifically designed to assist pharmacy managers with managing drug shortages.

Second, Dr. Griffin is researching new strategies for blood management in extreme shortage situations, as is currently occurring. Unlike other work in this area, her models integrate the consideration of blood type compatibility for assigning available blood units. Third, Dr. Griffin is analyzing how to manage limited bed capacity in hospitals and how different policies and protocols will impact health center operations and the patient safety/outcomes. She is proposing to build on her existing collaboration with local health systems and expand on the library of simulation models of outpatient facilities that she has created to develop a tool that can be deployed in assisting in identifying appropriate policies.

Finally, Dr. Griffin is investigating with colleagues how “crisis technologies” (software designed to support the public during emergencies) can better support vulnerable popu-
lations such as older adults and low-income households who are more likely to suffer poor health and economic challenges during emergencies. These technologies will also help racial and ethnic groups, such as individuals of Chinese descent, who face racism and xenophobia associated with COVID-19.

**DR. OZLEM ERGUN** has been asked by the Massachusetts Health Emergency Response Team to provide logistical planning to determine the location and support needs of 1,000 emergency hospital beds currently occurring. She is now part of the Governor’s Emergency Response Team and participates in daily calls. She and her team have shifted their work to near full-time on this project, which not only includes site recommendations based on population and spread projections, but also staffing projections and supplies for as many as 1,500 doctors and nurses.

These projections need to be updated and revised daily based on new information from her task force calls. She is the lead scientific author of “Strengthening Supply Chain Resilience,” commissioned and published in March by the National Academies of Science, Engineering, and Medicine. The U.S. Senate Committee on Commerce, Science, and Transportation has recently sought her advice and guidance on the current national emergency.

**DR. WEI XIE** is developing an interpretable artificial intelligence and risk-based process analytics and decision support platform that addresses critical needs in end-to-end biomanufacturing development and automation, especially monoclonal antibodies (including the bio-drugs for COVID-19). This platform can speed up the time to market and reduce the drug shortage.

**Dr. Ergun has been asked by the Massachusetts Health Emergency Response Team to provide logistical planning to determine the location and support needs of 1,000 emergency hospital beds currently occurring.**

---

**PHOTO: JESSICA GRIFFIN/THE PHILADELPHIA INQUIRER VIA AP**
Human-Machine Interaction

COVID-19 INITIATIVES

**DR. LEE MAKOWSKI** has started work with the University of Ghana focusing on medical facilities in Ghana as they begin to treat patients in respiratory distress with inexpensive tools and lightly trained staff. He has visited healthcare facilities in Ghana on two trips, most recently at the beginning of March. For devices to be used effectively there, they need to be simple to use, as well as deployable in settings with minimal logistical support. Working with two recent PhD students, Dr. Makowski is producing prototypes of a new respiratory assist device, with a goal of reducing needed ICU use (as Ghana cannot widely provide ICUs) by 25 percent.

Dr. Makowski is also working on another device for patients with more severe forms of the disease, and has been training several hospitals in methods to reconfigure their current ventilators, allowing them to serve two patients instead of one. The Korle Bu Teaching Hospital in Accra has already begun making those adjustments, with the head of their Department of Anesthesia preparing to test five prototype devices that Dr. Makowski’s lab has recently shipped.

**DR. JESSICA OAKES** is partnering with the Bill and Melinda Gates Research Institute to model airflow in instruments designed to provide non-invasive delivery of dry-powder aerosol surfactant for treatment of respiratory distress syndrome in pre-term infants.

**DR. RYAN WANG** has been developing virtual reality models to train non-medical essential personnel such as grocery store workers and warehouse workers. The VR environment (pictured) helps them learn how to safely practice social distancing and disinfection techniques, alerting them using vibration and other sensory feedback if they get too close to someone or miss an area needing disinfection.

**DR. TASKIN PADIR** is exploring how workers and robots interact and the greater importance of robots for the future of work in the era of social distancing. Dr. Padir is a national innovator in how robots can contribute to combating infectious disease, beginning with his involvements with research during the Ebola outbreak that began in 2014. He has significant knowledge to contribute to how to mitigate worker risk, particularly that of healthcare workers.
Harnessing Data
COVID-19 INITIATIVES

DR. AUROOP GANGULY is mapping post-disruption recovery of networked systems to study the ability of businesses and supply chains to recover effectively, reliably, and in a timely fashion from the current closure, ultimately to determine how well communities at large bounce back from COVID-19.

DRS. SARAH OSTADABBAS, RAYMOND FU, and DENIZ ERDOGMUS are exploring the development of a COVID-19 symptom monitoring framework that uses machine learning and RGB and passive infrared IR modalities to analyze video data of individuals quarantined inside a building (e.g., at home, in nursing facilities, or in hospital rooms) to provide ongoing remote risk assessment, early warning, and actionable information to medical service providers using markers of illness such as activity levels and sleep conditions (see image). The framework is also capable of tracking individuals in public indoor areas (e.g., at store checkout lines, in front of doctor’s office reception desks) and alerting them when social distancing is violated among people. This framework could easily be integrated to a wide variety of existing and emerging products including mobile apps, security systems, and special-purpose monitoring devices.

Doctors are exploring the development of a COVID-19 symptom monitoring framework that uses machine learning and RGB and passive infrared IR modalities to analyze video data of individuals quarantined inside a building.
DRS. MICHAEL KANE, OZLEM ERGUN, and others are extending their previous work funded by the National Science Foundation to understand how the COVID-19 pandemic will impact the algorithmic workplace, i.e., the gig economy.

DR. RYAN WANG is looking at mobility-related social distancing and dynamic travel decision-modeling to understand how pandemics can impact people’s mobility and energy resilience, particularly during power outages.

DR. BABAK HEYDARI is analyzing COVID-19 data with colleagues to see which social distancing policies are the most effective. Using the dates that states implemented various policies, the first thing he spotted was that people started staying home in early March, even before they were told to. Algorithmically separating out voluntary actions from policies, his results showed that some policies worked much better than others—the stay-at-home order was six times more effective at reducing mobility than not doing it. Policies mandating the closure of non-essential businesses, as well as restaurants and bars, showed a smaller, but still significant, impact.

DR. HARISS KOUTSOPoulos is working on research relating to public transportation and disease spread. Public transportation plays an important role in urban mobility. However, various studies have indicated that it can also contribute to the spread of viruses. Dr. Koutsopoulos has begun combining models that have been proposed for infection transmission in indoor environments, using his own agent-based urban rail simulation model to study the relationship between operations and transmission risks.

DR. EDUARDO SONTAG and collaborators have developed a variation of the standard mathematical model of infections, so as to incorporate social distancing. This model is being calibrated to data, and will be used to make recommendations regarding the relaxation of shelter-in-place directives, as well as analyzing alternative scenarios of periodic (open loop) or adaptive (feedback) quarantine directives.

Dr. Sontag and collaborators have developed a variation of the standard mathematical model of infections, so as to incorporate social distancing.