Mission, Organization, and Future Direction of the Serological Sciences Network for COVID-19 (SeroNet) Epidemiologic Cohort Studies

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Received 11 January 2022; editorial decision 29 March 2022; accepted 22 April 2022; published online 27 April 2022.

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Open Forum Infectious Diseases© 2022

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Background. Global efforts are needed to elucidate the epidemiology of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the underlying cause of coronavirus disease 2019 (COVID-19), including seroprevalence, risk factors, and long-term sequelae, as well as immune responses after vaccination across populations and the social dimensions of prevention and treatment strategies.

Methods. In the United States, the National Cancer Institute in partnership with the National Institute of Allergy and Infectious Diseases, established the SARS-CoV-2 Serological Sciences Network (SeroNet) as the nation's largest coordinated effort to study coronavirus disease 2019. The network comprises multidisciplinary researchers bridging gaps and fostering collaborations among immunologists, epidemiologists, virologists, clinicians and clinical laboratories, social and behavioral scientists, policymakers, data scientists, and community members. In total, 49 institutions form the SeroNet consortium to study individuals with cancer, autoimmune disease, inflammatory bowel diseases, cardiovascular diseases, human immunodeficiency virus, transplant recipients, as well as otherwise healthy pregnant women, children, college students, and high-risk occupational workers (including healthcare workers and first responders).

Results. Several studies focus on underrepresented populations, including ethnic minorities and rural communities. To support integrative data analyses across SeroNet studies, efforts are underway to define common data elements for standardized serology measurements, cellular and molecular assays, self-reported data, treatment, and clinical outcomes.

Conclusions. In this paper, we discuss the overarching framework for SeroNet epidemiology studies, critical research questions under investigation, and data accessibility for the worldwide scientific community. Lessons learned will help inform preparedness and responsiveness to future emerging diseases.

Keywords. cohort; COVID-19; epidemiology; SARS-CoV-2; serosurveillance; SeroNet.

Coronavirus disease 2019 (COVID-19), an illness caused by infection with the severe acute respiratory coronavirus 2 (SARS-CoV-2), was first detected in December 2019 and designated a worldwide pandemic by the World Health Organization (WHO) on March 11, 2020 [1]. By April 2020, the danger that COVID-19 could overwhelm healthcare systems was apparent after propagated outbreaks throughout the world. Governments and public health agencies in many countries struggled to implement public health initiatives such as physical distancing, mask/face coverings, and, in some cases, stay-at-home orders in attempts to curb the number of infections or “flatten the curve”. Global efforts were launched to elucidate the epidemiology of this new disease, including its seroprevalence, risk factors, individual susceptibility, and long-term sequelae, in addition to developing effective therapeutics and vaccines.

In response to the COVID-19 pandemic, the US National Cancer Institute (NCI), in partnership with the National Institute of Allergy and Infectious Diseases (NIAID), Frederick National Laboratory for Cancer Research (FNLCR) and other parts of the National Institutes of Health (NIH), and the Department of Health and Human Services, established the Serological Sciences Network (SeroNet) as the nation's largest coordinated effort to study the human immune response to COVID-19 through a Congressional emergency appropriation of funding [2]. The overall goal of SeroNet is (1) to expand the nation's capacity for accessible and efficient SARS-CoV-2 serologic tests on a population-level and (2) to advance research on humoral and cellular immune responses to SARS-CoV-2 infection and vaccination among diverse and vulnerable populations. Another key objective is developing culturally targeted communication approaches to promote SARS-CoV-2 antibody testing and to better understand barriers that influence knowledge of and participation among minority communities in testing with the goal to address overall racial/ethnic disparities in COVID-19 susceptibility and outcomes. Lessons learned from SeroNet research can be applied immediately and may prove valuable both to (1) the development of vaccines and novel treatments and, (2) to inform future public health emergencies.

In this report, we discuss the overarching framework for the performance of SeroNet studies, and target outcomes of the consortium. By providing this foundational information, we alert the global scientific and medical community about data emerging from SeroNet studies to help drive the global response to the COVID-19 pandemic.

METHODS

Members of SeroNet

The NCI established 8 Serological Sciences Centers of Excellence to conduct research projects to characterize immune responses to SARS-CoV-2 infection and better understand predictors of protective immune responses and disease progression (Figure 1). In addition, 13 awards were granted to researchers to conduct projects on basic and applied serological research. Through the FNLCR, 4 subcontracts were awarded to research institutions as SeroNet Capacity Building Centers to expand the nation’s serology testing capabilities by increasing throughput, developing novel serological assays to test for SARS-CoV-2 antibodies, procuring reference serological samples, and conducting
serosurveillance studies. In total, SeroNet granted 25 awards to 23 of the nation’s top biomedical research institutions.

Evolving Research Questions

Upon establishment of SeroNet in October 2020 and naming the 25 awardees spread across 49 institutions (23 primary institutions, 26 additional collaborating institutions) overarching research questions were articulated. They focused on understanding susceptibility and diversity of exposures to SARS-CoV-2 including elucidating immune responses to infection in the general population and among high-risk and immunocompromised populations.

By December 2020, Pfizer-BioNTech [3] and Moderna/NIAID [4] had begun clinical trials in healthy populations on their respective mRNA SARS-CoV-2 vaccines, and they reported >94% short-term vaccine efficacy against hospitalization and mortality, with no evidence of increased incidence of major adverse events. These findings led to Emergency Use Authorization of the vaccines in Britain, the United States, the European Union, and several other countries. Soon thereafter, several other COVID-19 vaccines were approved by the WHO for use globally, including Johnson & Johnson/Janssen INJ-7843735/Ad26.COV2.S, Oxford/AstraZeneca AZD1222, Serum Institute of India Covishield (Oxford/AstraZeneca formulation), Sinopharm (Beijing) BBIBP-CorV (Vero Cells), and Sinovac CoronaVac [1, 5]. With over 20 SARS-CoV-2 vaccines now available around the globe [6], the SeroNet research infrastructure also supports questions focused on vaccine responses, including the durability of humoral and cellular immunity in immunocompromised populations compared with healthy individuals, and the frequency of breakthrough infections in vaccinated individuals.

In the coming months, the COVID-19 pandemic will no doubt continue to rapidly change both biologically, with emergence of new variants, and medically, with development of new vaccines and variations in vaccine perspectives, availability, and uptake across populations, and antiviral agents. Recommendations for “booster” (ie, subsequent dose vaccine administrations) and novel treatments for symptomatic disease are already changing the landscape. Public health policy will also evolve, with full US Food and Drug Administration authorization of vaccines and likely vaccine mandates by employers and communities. As such, SeroNet studies will continue to be refined to address research challenges that arise, including devising strategies related to vaccination uptake among hesitant and underserved populations (Table 1).

RESULTS
Scope of Epidemiologic Research

There is a broad range of research studies across SeroNet, including epidemiologic studies, basic investigational science, development and deployment of serologic diagnostic methods, mathematical and statistical modeling, and qualitative research
including focus groups, online surveys, and focus groups/qualitative interviews. Working groups were established to outline study design templates (Appendix A) to disseminate best practices within the network and broader community and to allow for future data harmonization. Among epidemiologic studies, the majority are prospective cohort studies with repeated measures focusing on various research questions across diverse populations, with strategic, real-world observational studies also included. Specific details on study aims and methodology for each SeroNet study involving human populations are outlined in Table 2 and Appendix B. The following subpopulations are being examined in SeroNet studies.

**Individuals With Immune-Mediated Inflammatory Diseases**

SeroNet studies are focused on populations with rheumatoid arthritis, systemic lupus erythematosus, and inflammatory bowel diseases (Crohn's Disease and ulcerative/indeterminate colitis). Adults with immune-mediated inflammatory diseases face significant concerns regarding infection risk, continuity in clinical care, and potentially suboptimal vaccine response. Additional concerns include disease exacerbation with either infection or vaccination and poor infection outcome, in both cases owing to heightened autoimmunity [7–10]. Key findings have been reported on (1) the frequency of adverse events after vaccination [11] and (2) the comparison of induced antibody responses across SARS-CoV-2 vaccine platforms [12], which help to inform clinical guidelines [13].

**Individuals With Cancer**

The SARS-CoV-2 infection continues to cause significant morbidity and mortality among vulnerable immunosuppressed cancer patients. For example, patients with lung cancer have a greater than 7-fold higher rate of becoming infected with SARS-CoV-2 COVID-19, a greater than 3-fold higher hospitalization rate with high complication rates, and an estimated case fatality rate of more than 30% [14]. The potential effects of malignancy and/or anticancer treatments on COVID-19 vaccine response as well as the impact of a vaccine on cancer treatment, incidence of adverse events, and progression are a main focus of some SeroNet studies. Several hundred patients with cancer, including hematological malignancies, solid cancers, and hematopoietic cell transplant recipients have been accrued and are being followed prospectively for endpoints of interest and impacts of various immunotherapies/cancer treatments. Key findings reported include perspectives and concerns regarding vaccination in cancer patients [15], and the reduced antibody
### Table 2. Description of Epidemiologic Studies in SeroNet

| Institution/Award | Project Title | Study Design | Study Population | Proposed Sample Size | Methods | Biospecimens and Assays |
|-------------------|---------------|--------------|------------------|----------------------|---------|-------------------------|
| Arizona State University, CBC21X089 | Multiplexed In-solution Serological Test for SARS-CoV-2, Human Coronaviruses, and Other Respiratory Pathogens | Prospective cohort study | □ HIV, cancer, and transplant patients and immunocompetent controls; □ All ages, M/F; □ Any race/ethnicity; □ Arizona/New York | 1125 immunocompromised; 375 controls; 500 postnatural infection | 3/2021–10/2025; Samples collected prevaccination and then 1, 3, 6, 12, 24 months postvaccination; Survey, medical records | Serum, PBMC, anterior nasal swab and saliva; MISPA to assay antibodies against the immunodominant antigens from SARS-CoV-2, other 6 human coronaviruses, and additional respiratory pathogens |
| Case Western Reserve School of Medicine and The Lerner School of Medicine, U01CA260513 | Pre-exposure Immunologic Health and Linkages to SARS-CoV-2 Serologic Responses, Endothelial Cell Resilience, and Cardiovascular Complications: Defining the Mechanistic Basis of High Risk Endotypes (CardioCOVID) | Retrospective cohort study | □ US veterans with COVID-19 receiving care within the Veterans Administration Health System; □ >18 yo, M/F; □ Any race/ethnicity; □ United States | 150 000 | 3/2019–12/2021; Medical records | Serum; Reactivity to the full-length S protein, the receptor binding domain (RBD) of the S1 protein and N protein, |
| Case Western Reserve University, U01CA260539 | Early Drivers of Humoral Immunity to SARS-CoV-2 Infections | Prospective cohort study | □ Individuals exposed to people known to have COVID-19; □ >12 yo, M/F; □ Any race/ethnicity; □ Northeast Ohio | 200 | 9/2021–present; Peripheral blood along with nasopharyngeal swabs, and saliva sampled on days 0, 1, 3, 7, 10, 14, and 28 and every 6 months for up to 3 years | Serum, Saliva and PBMC; Bead array assays to measure antibodies to S and N proteins and RBD in serum, S and N proteins and RBD-specific IgA and IgG in saliva relative to total IgA and IgG in saliva, Ag-specific B cells in peripheral circulation (flow cytometry and ELISpot) and isolating individual Ag-specific B cells to determine somatic mutations |
| Cedars-Sinai Medical Center, U54CA260591 | Diversity and Determinants of the Immune-Inflammatory Response to SARS-CoV-19 | Prospective cohort study | □ Healthcare workers including those recovering COVID-19 patients and their household contacts, cancer patients, patients with IBD; □ >18 yo, M/F; □ Any race/ethnicity; □ Los Angeles and surrounding areas | 2060 health workers, 1000 cancer patients, 175 IBD patients | 12/2020–9/2025; Samples collected pre- and postvaccination up to 5 years; self-completed questionnaires, medical records | Plasma, Buffy, PBMC; Antibody levels using Abbott assays for RBD and N protein; T cell repertoire using Adaptive; proteomics; metabolomics |
| College of Human Medicine, Michigan State University, U01CA260469 | Culturally Targeted Communication to Promote SARS-CoV-2 Antibody Testing in Saliva: Enabling Evaluation of Inflammatory Pathways in COVID-19 Racial Disparities | Randomized control trial | □ Black and white members of Flint Registry; □ >18yo, M/F; □ Black/African American and White; □ Flint, Michigan | 500 | 6/2021–6/2024, Baseline measures, Surveys | Saliva; Multiplex salivary antibody assay for anti-nucleocapsid, RBD, IgG, IgA, and IgM. Panel of inflammatory markers including IFN-γ, TNF-α, IL1β, IL2, IL5, IL6, IL7, IL8, IL10, IL12p70, IL13, IL17A |
| Emory University, U54CA260563 | Immune Regulation of COVID-19 Infection in Cancer and Autoimmunity | Prospective cohort study | □ Hospital inpatients newly admitted due to a positive SARS-CoV-2 RT-PCR test. Emphasis on patients with cancer, obesity, immune compromise, and other conditions that could affect the viral immune response. □ >18 yo, M/F; □ Any race/ethnicity; □ Atlanta and surrounding communities | 93 to date; plan to continue enrollment during each viral wave in Atlanta | 4/2021–present; Samples collected upon admission to hospital with positive test for SARS-CoV-2, at discharge, and then 3 and 6 months after discharge; survey, medical records | Serum, NGS of NP swab sample, flow cytometry, ELISpot viral neutralization, RNA-Seq, multiplex cytokine assays, metabolomics |
Table 2. Continued

| Institution/Award | Project Title                                                                 | Study Design               | Study Population                                                                 | Proposed Sample Size | Methods                                                                 | Biospecimens and Assays                                           |
|-------------------|-------------------------------------------------------------------------------|---------------------------|----------------------------------------------------------------------------------|----------------------|------------------------------------------------------------------------|-------------------------------------------------------------------|
| Feinstein Institutes for Medical Research, Northwell Health, CBC21X090 | Serological Sciences Network Capacity Building Center                        | Prospective cohort study  | □ Autoimmune Conditions (Systemic Lupus Erythematosus; Sjögren’s syndrome, rheumatoid arthritis) and immunocompetent controls; □ >18 yo, M/F; □ Any race/ethnicity; □ New York City metropolitan area | 700 controls and 400 with autoimmune disease | 6/2021–12/2021; Time 0, 2 months, 6 months, 12 months, 24 months; Medical records | SARS-CoV-2 antibody assays on serum or plasma; Roche Cobas Elecsys, DiaSorin LIAISON |
| *Icahn School of Medicine at Mount Sinai, U54CA260560 | Characterization of the Antibody Response to SARS-CoV-2 in Lung Cancer Patients | Prospective cohort study  | □ Lung cancer patients and controls; □ >18 yo, M/F; □ Any race/ethnicity; □ New York City metropolitan area | 2000                 | 10/2020–4/2024; At time 0, 3, 6, 12, 24 months; Survey, medical records | SARS-CoV-2 antibody assays on serum                                  |
| Icahn School of Medicine at Mount Sinai, CBC21X092 | Serological Sciences Network Capacity Building Center                        | Prospective, longitudinal study | □ Persons with Inflammatory bowel disease □ Persons with multiple myeloma □ Solid organ transplant recipients; □ Healthy controls □ >18 yo, M/F; □ Any race/ethnicity; □ New York City metropolitan area | 400                  | 02/2021–01/2023; 6 visits: 1 prevaccine (if feasible), and longitudinally at 3, 6, 12, and 24 months | Serum, PBMC, Mount Sinai/ Kantaro; Enzyme-linked immunosorbent assay (ELISA) |
| *Johns Hopkins University, U54CA260492-01 | Johns Hopkins Excellence in Pathogenesis and Immunity Center for SARS-CoV-2 (JH-EPICS) | Prospective cohort study  | □ HIV, cancer, and transplant patients and immunocompetent controls; □ All ages, M/F; □ Any race/ethnicity; □ Maryland | 2000                 | Prevaccine, 2 weeks postvaccine, then every 6 months; Hospitalized participants: Diagnosis (Day 0), Day 1, Day 3, Day 7, Weekly, Day 28, Month 3, 6, 9, 12, 18, 24/ Ambulatory Participants: Diagnosis (Day 0), Day 28, Month 3, 6, 9, 12, 18, 24 | Serum, plasma, PBMC, and nasal and oropharyngeal swabs; Mesoscale Discovery Assay (MSD) and ELISA to assay antibodies and antibody subtypes directed against SARS-CoV-2 proteins, MSD assays for cytokines and chemokines, metabolic immune cell flow cytometry, virus neutralization assays, antibody-dependent cellular cytotoxicity, complement-mediated cytotoxicity, complement fixations, ViraFEST and ELISpot |
| Kaiser Permanente Northern California, U01 CA260584 | SARS-CoV-2 Serological Antibody Testing for Disease Surveillance and Clinical Use | Serial seroprevalence surveys with built in longitudinal follow-up of a subset of participants | □ Kaiser Permanente Northern California members aged ≥7 years old; □ >7yo, M/F; □ Any race/ethnicity; □ Northern and Central California | Seroprevalence: 3000 per month x 24 months = 72 000; Longitudinal follow-up group: 1200 | 4/2021–3/2023; At time 0 and 3-month for seroprevalence survey; At time 0, 3, 6, 12, 24 months for longitudinal follow-up subgroup; Survey, medical records | Serum; Serum/ Diasorin LIAISON SARS-CoV-2 S1/S2 IgG test AND Siemens SARS-CoV-2 Total Assay on ADVIA Centaur Platform |
| Institution/Award | Project Title                                                                 | Study Design                      | Study Population                                                                 | Proposed Sample Size | Methods | Biospecimens and Assays |
|------------------|--------------------------------------------------------------------------------|-----------------------------------|----------------------------------------------------------------------------------|-----------------------|---------|------------------------|
| *Ohio State University, U54CA260582* | Center for Serological Testing to Improve Outcomes from Pandemic COVID-19 (STOP-COVID) | Prospective cohort study          | □ First responders, healthcare workers, and their household contacts; □ Any age, M/F □ Any race/ethnicity □ Central Ohio | 2500                  | 2/2021-8/2026; Time 0 and then every 180 days; Survey | Whole blood for serology; nasal swab for PCR, Saliva and biorepository specimens; anti-S (qual), anti-N (qual), trimeric anti-S (qual), unique S peptide alpha, unique N peptide alpha, unique S peptide beta, unique N peptide beta, unique S peptide SARS, unique N peptide SARS, common (cross-reactive) S peptide and N peptide, neutralizing titer(s) WT, D614G, B.1.1.7, B.1.351, P1, B.1.617.2, SARS, SARS QC coverage, SARS strain (Pango & GISAID), RSV A, RSV B, influenza A/H3N2, influenza A (H1N1), influenza B, human coronavirus HKU1, human coronavirus NL63, human coronavirus 229E, human metapneumovirus (HMPV), human adenovirus (HAdV), IFNB1 RNA, DXVX QC |
| *Tulane University of Louisiana, U54CA260581* | Tulane University COVID Antibody and Immunity Network (TUCAIN) | Prospective cohort study          | □ Adults living with solid and liquid cancers, adults with HIV, children with asthma, adults, and children with a history of SARS-CoV-2 infection or vaccination; □ >6 mo; M/F □ White, black, Hispanic □ Southeastern Louisiana | 1600                  | 04/2020–12/2025; Time 0, 1, 2, 4, 6 months then every 6 months after each immune event (eg, SARS-CoV-2 infection or vaccination); Survey and blood collection | Plasma, PBMCs; ELISA for anti-SARS-CoV-2 N, S and RBD Ab; Tcell epitope studies; pseudovirus neutralization assays, antibody function assays |
| University of Alabama at Birmingham, Heersink School of Medicine U01 CA260462 | Adaptive Immunity and Persistent SARS-CoV-2 Replication | Prospective cohort study          | □ Children undergoing cancer chemotherapy or other immunomodulatory treatment with COVID-19 □ Healthy children with COVID-19 as controls □ 3 months to 18 years, M/F □ White, non-Hispanic, black, Hispanic □ Alabama | 300                   | 9/2020–8/2024; 0, 1, 3, 6 months for blood samples; Weekly NP swab collection until 2 negative COVID PCR; In-person interview, medical record abstraction | Whole blood; Plasma ELISA for IgG binding antibodies, neutralizing antibody assays using ACE2 binding inhibition and pseudovirus particles; NP swabs—RT-PCR for the detection of SARS-CoV-2 RNA |
| University of Arkansas for Medical Sciences, Fay W. Boozman College of Public Health, U01CA260526 | The DISCOVER Study: Disparities in Immune Response to SARS-CoV-2 in Arkansas | Prospective cohort study          | □ Adult residents of Arkansas with COVID-19; □ >18 yo, M/F; □ White Non-Hispanic black/Hispanic, □ Arkansas | 600                   | 4/2021-12/2025; Time 0, 1, 2, 3, 6, 12, 18, 24, 30, 36, 42, 48 months; Telephone, video or in person interview; medical records | SARS-CoV-2 antibody assays on serum and dried blood spots |
### Table 2. Continued

| Institution/Award | Project Title | Study Design | Study Population | Proposed Sample Size | Methods | Biospecimens and Assays |
|-------------------|---------------|--------------|------------------|----------------------|---------|-------------------------|
| **University of Massachusetts Chan Medical School, U01CA261276** | Enhancing Racial and Ethnic Diversity in COVID-19 Immunology Research Participation Through Storytelling (COVIDStory) | Randomized control trial | □ Black and Hispanic community members; □ >18 yo, M/F; □ Black/African American or Hispanic/Latinx, □ Central Massachusetts | 1920 | 10/2021–8/2022 Survey in Qualtrics and RedCap; blood collection at Time 0. | Plasma; ELISA and/or LUMINEX screening for SARS-CoV-2 N, S, RBD IgG and IgA antibodies among other common viral infections such as the common human CoVs (OC43, LN63, 229E, and HKU1) influenza, EBV, and CMV |
| **University of Minnesota, CBC21X091** | Serological Sciences Network Capacity Building Center | Repeated measurement longitudinal cohort | □ HIV patients, cancer survivors, solid organ and hematopoietic transplant patients, and immunocompetent adults; □ >18 yo, M/F; □ Any race/ethnicity □ Minnesota | 600 in each of the immunocompromised groups and 300 in the immunocompetent group. | 06/2021–12/2022 Prevaccine, 1-month postboost dose, then every 3–6 months; Medical records | Serum, plasma, PBMCs/ELISA, automated immunoassay (Roche Cobas), University of Minnesota in-house developed spike total anti-RBD antibody method with IgG titers, and Roche nucleocapsid qualitative method (to assess for natural infection) |
| **University of North Carolina at Chapel Hill, U54CA260543** | North Carolina SeroNet Center for Excellence COVID-19 Household Transmission (CO-HOST) Observational Cohort of COV1-19 (OBS-C) COVID-19 in Farm and Food processing workers in North Carolina (COFF-NC) Covid-19 Convalescent Plasma Donor Biobank (CCP) Coronavirus-Inactivating Plasma (CoVIP) Recipient Biobank Adaptive Immune and Mucosal Responses in Covid-19 Recovered Individuals and SARS-CoV-2 Vaccinated Individuals (AIM-CoV) Hospital Remnant Study (HRS-CoV) UNC COVID Pathobiology study | Longitudinal cohort Cross-sectional cohort | □ Individuals with a positive test for SARS-CoV-2 infection (OBS-C); Households with persons with COVID-19 (CO-HOST); Farm and food processing workers (COFF-NC); Individuals with a positive test for SARS-CoV-2 infection who donated convalescent plasma (CCP) or received convalescent plasma (CoVIP) as part of a clinical trial; Individuals who have received a SARS-CoV-2 vaccine (AIM-CoV); NC-laboratory remnant samples from outpatient and inpatient clinics from April 2020 to June 2021 (HRS-CoV). □ All ages and sexes □ Any race/ethnicity □ Central North Carolina | OBS-C: 53, CO-HOST: 308 COFF-NC: 224 CCP: 201 CoVIP: 55 AIM-CoV: up to 200 HRS-CoV: 12,471 Pathobiology: 188 | 04/2020–2026; variable durations of follow up (28 days to 1 year); HRS-CoV was cross-sectional Surveys Medical record review | Serum; Plasma; Whole blood; Nasopharyngeal swabs; Anterior nasal turbinates swabs; Saliva; Throat wash; Sputum; Tracheal aspirate; Urine; Stool |
| **University of Puerto Rico Medical Sciences Campus, Puerto Rico Science, Technology and Research Trust, La Jolla Institute of Technology, U01CA260541** | SARS-CoV2 Correlates of Protection in a Latino-Origin Population | Cross-sectional study | □ COVID-19 patients in Puerto Rico and vaccinated patients; □ >18 yo, M/F; □ Any race/ethnicity □ Puerto Rico | 30,000 | 11/2020–7/2025; Baseline, 2 weeks; Survey, medical records | Nasopharyngeal swabs, whole blood; LDA ELISA-based IgM/ IgG tests |
### Table 2. Continued

| Institution/Award | Project Title                                                                 | Study Design                      | Study Population                                                                 | Proposed Sample Size | Methods                                                                                                           | Biospecimens and Assays                                                                 |
|-------------------|-------------------------------------------------------------------------------|-----------------------------------|----------------------------------------------------------------------------------|----------------------|-------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| Yale University, U01CA260507 | Immuno-Serological Assays for Monitoring COVID-19 in Patients with Hematologic Malignancies | Retrospective cohort study        | □ >18 yo, M/F; □ Any race/ethnicity and African Americans in the New Haven area □ New Haven County | ~300                 | 11/2020–10/2025; Samples will be collected at prevaccine, and 1 month, 3 months, 12 months and 24 months postvaccination | Microfluidic barcode chip for high-plex serology assay; Microfluidic barcode chip for high-plex plasma protein assay; CodePlex assay for multiplex cytokine assay commercially available at IsoPlexis; IsoCode assay of single-cell cytokine signature commercially available at IsoPlexis; Single-cell RNA-seq commercially available at 10x Genomics; Single-cell TCR/BCR sequencing available at 10x Genomics; CyTOF assay for multiplex immunophenotyping commercially available at Fluidigm |
|                   | Nonepidemiologic SeroNet Studies                                               |                                   |                                                                                  |                      |                                                                                                                  |                                                                                        |
| Beth Israel Deaconess Medical Center, U01CA260476 | Immunologic Signatures of SARS-CoV-2 vaccination and disease                   |                                   |                                                                                  |                      |                                                                                                                  |                                                                                        |
| Harvard T Chan School of Public Health, U1U01CA261277 | Causal, statistical, and mathematical modeling with serologic data             |                                   |                                                                                  |                      |                                                                                                                  |                                                                                        |
| La Jolla Institute For Immunology, U01CA260588 | SARS-CoV-2-reactive tissue-resident memory T cells in healthy and cancer subjects |                                   |                                                                                  |                      |                                                                                                                  |                                                                                        |
| *Stanford University, U54CA260517 | Mechanisms and duration of immunity to SARS-CoV-2                            |                                   |                                                                                  |                      |                                                                                                                  |                                                                                        |
| Wadsworth Center, U01CA260508 | High-throughput dried blood spot (HT-DBS) technologies in SARS COV-2 serology and vaccinology |                                   |                                                                                  |                      |                                                                                                                  |                                                                                        |

Abbreviations: Ab, antibody; Ag, antigen; BCR, B-cell receptor; CMV, cytomegalovirus; COVID-19, coronavirus disease 2019; EBV, Epstein-Barr virus; HIV, human immunodeficiency virus; HRS, Hospital Remnant Study; IBD, inflammatory bowel disease; IFN, interferon; Ig, immunoglobulin; IL, interleukin; NC, North Carolina; NGS, next-generation sequencing; NP, nasopharyngeal; PBMC, peripheral blood mononuclear cells; RT-PCR, reverse-transcription polymerase chain reaction; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; TCR, T-cell receptor; TNF, tumor necrosis factor; WT, wild type; yo, years old.

*Centers of Excellence (n = 8).*
response in cancer patients compared with healthy individuals [16, 17], in particular patients with selected hematological malignancies and those receiving specific anticancer treatments. For example, the seroconversion rate for patients with chronic lymphoblastic leukemia is as low as 50% compared with approximately 100% in the general population [18].

**Individuals Undergoing Solid Organ Transplantation**

Solid organ transplant recipients may receive a variety of immunosuppressive regimens to prevent organ rejection. Evaluating immune responses to different COVID-19 vaccines among solid organ transplant recipients is a specific focus of 2 SeroNet centers. Most transplant recipients evaluated in these studies include recipients who have received kidney, lung, heart, or pancreas transplantation. Detailed information on type of immunosuppressive medications and duration of immunosuppression is obtained from electronic medical records. Recent studies show substantially lower seroconversion rates among solid organ transplant recipients [19–22], and subsequent studies are focusing on both the initial rates of seroconversion and the durability of the immune response in these solid organ transplant recipients [23, 24].

**Individuals With Human Immunodeficiency Virus**

People with human immunodeficiency virus (PWH) are at an increased risk of COVID-19 and severe disease manifestations [25, 26]. The effects of antiretroviral therapy or human immunodeficiency virus (HIV)-related immunosuppression on vaccine response are unclear [27]. In addition, PWH who are not immunocompromised may have immunological features that result in different B-cell or T-cell responses compared with immunocompetent HIV-negative individuals [28–30]. Published studies on the immune response to SARS-CoV-2 vaccination in PWH demonstrate that PWH can respond to vaccination, but these are limited by nonrandomization approaches and lack of heterogeneity in sex, race/ethnicity, and age [27, 31, 32]. Therefore, further studies of humoral and cellular immunity and safety profiling after completion of the vaccine series in PWH are needed [31].

**Individuals at Risk Due to Occupational Exposures**

Healthcare workers (HCWs) have historically been on the front lines of epidemics [33]. The SARS-CoV-2 is a highly transmissible respiratory virus, making hospitals potential loci for outbreaks and placing HCWs at high risk of acquiring the infection and unknowingly transmitting the virus to others. To track seroprevalence or SARS-CoV-2 antibodies and vaccine-induced immune response in HCWs, SeroNet studies at major academic centers have recruited several hundred HCWs for longitudinal assessments. Key studies to date include understanding the magnitude of neutralizing antibody titers among polymerase chain reaction-positive HCWs, intensive care unit patients, and convalescent plasma donors [34] and the diverse impact of these neutralizing antibodies to different variants of COVID-19 [35].

**Pregnant Women**

Prevention and control of COVID-19 infection among pregnant women have been a major concern during the pandemic, primarily because pregnancy is a risk for more severe COVID-19 outcomes for both mother and baby [36, 37]. Studies are underway to investigate the clinical characteristics, outcomes, and vertical transmission (of infection or antibodies postinfection or postvaccine). In addition, studies are being conducted to determine the best time during pregnancy to administer vaccines to protect the mother and optimally transplacentally transfer antibodies to the baby.

**Children, Teens, and College Students**

Although several studies show children and adolescents are at lower risk of COVID-19-related morbidity and mortality [38], multisystem inflammatory syndrome in children is a serious health condition associated with SARS-CoV-2 infection [39]. Given the rarity of this condition, large consortium efforts involving SeroNet will be helpful in better understanding risk factors, clinical course of the disease, and immune response to vaccination. Recent studies have highlighted (1) racial and socioeconomic disparities of SARS-CoV-2 infection among the pediatric population [40] and (2) virological characteristics of hospitalized children with infection [41]. Children undergoing cancer chemotherapy or receiving other immunomodulatory treatments are being enrolled to understand the immune responses against SARS-CoV-2 after infection and immunization.

**Ethics Approval and Participant Consent**

The design of the work has been approved by local ethical committees for each individual study. This overview paper summarizing the consortium does not include factors necessitating patient consent.

**DISCUSSION**

**Health Disparities: Race/Ethnicity, Sex, and Age**

Health disparities among racial/ethnic minority groups are a persistent and growing public health concern. Although initially expected to be “the great equalizer,” COVID-19 has instead reinforced and exacerbated racial/ethnic health disparities in the United States [42]. The COVID-19 pandemic has emphatically demonstrated that minority populations are disproportionately exposed to infection and experience a greater burden of disease [43, 44]. Several reasons for these differences have been proposed, including a higher prevalence of comorbidities (eg, type 2 diabetes), greater social deprivation, large multigenerational
households, differences in occupational risk, misinformation, and inequitable access to COVID-19 resources and healthcare. To address these concerns, specific SeroNet studies are engaging community leaders and focusing on the recruitment and retention of ethnic/racial minority groups throughout the United States across a spectrum of socioeconomic levels in our research studies.

The pandemic has also revealed disparities based on age, sex, and gender [45–48]. Worldwide, people who are older aged or male sex are at greater risk of more severe outcomes from COVID-19 [48]. Age and biological sex also impact innate, humoral, and cell-mediated immune responses during infection [49–51]. This is further reflected in specific SeroNet study populations utilizing electronic medical records, with elevated inflammatory biomarkers explaining a majority of the sex differences in COVID-19 outcomes among hospitalized patients [51]. How sex and age intersect to alter immunity to SARS-CoV-2 infection and vaccination is being considered in SeroNet studies and collaborations.

Data Sharing
To accelerate data dissemination, SeroNet research results and data sets are made publicly available at the time a manuscript (“study”) is accepted for publication in a peer-reviewed journal. Rapid data sharing ensures transparency and accessibility and facilitates confirmation of the research findings, thus accelerating generalizability of the results. Furthermore, it promotes (1) new analytical strategies to answer other research questions and (2) the creation of harmonized datasets by combining data from multiple sources, with predetermined common data elements to facilitate meta-analyses. To ensure all data generated through the SeroNet program can be easily located, all studies will also be registered in the Immunology Data Portal, ImmPort [52], an immunology domain-specific data repository supported by NIAID. The ImmPort data model is designed to accommodate data and metadata from common types of immunology assays including enzyme-linked immunosorbent assays, flow cytometry, cytology by time-of-flight, chemiluminescence immunoassay, electrochemiluminescence immunoassay, Luminex, MesoScale Discovery, or IsoPlexis multiplex assays, and many others. ImmPort also allows linking data to other repositories, such as datatype-specific repositories, including NCBI’s dbGaP, SRA, or GEO. A SeroNet study record in ImmPort will contain the metadata and data deposited in ImmPort, as well as any links to data deposited in other public repositories.

DISCUSSION
Strengths and Limitations
The swift emergency appropriation passed by the US Congress in April 2020 provided funding within months that enabled the development of the SeroNet infrastructure. SeroNet is a unique network comprising a broadly based multidisciplinary consortium of researchers that fosters collaboration among immunologists, epidemiologists, virologists, clinicians, clinical laboratories, behavioral and social scientists, policymakers, and community members. By harnessing existing academic medical research centers and creating new relationships between institutions and investigators (eg, connecting infectious disease immunologists with oncology or autoimmune disease-focused immunologists or epidemiologists), this program is building long-lasting bridges and initiating a new vision for multidisciplinary research programs.

Within the network, we have defined (1) common data elements for self-reported data and clinical treatment/outcomes and (2) standardization of serological and cellular/molecular assays, thereby facilitating data harmonization for future consortium-wide efforts. All researchers pledged commitment to data sharing and accessibility using the F.A.I.R. (findable, accessible, interoperable, reusable) principles [53]. Moreover, the rapid dissemination of publications in OpenAccess format and the nimble and evolving nature of cohorts allow investigators to adapt to critical research questions. Furthermore, given the large size of the network, data can be pooled across studies to investigate rare exposures and outcomes.

Limitations of the network include the inherent heterogeneity across study methodologies. The network is also unable to investigate international variation and immune responses to vaccines not available in the United States. Finally, as the COVID-19 pandemic evolves, there will be a need for additional data collection not anticipated. However, the large infrastructure and diverse expertise of this multi-institutional effort should allow for sufficient nimbleness to address the ever-changing nuances of this pandemic.

Future Directions and Impact
The heterogeneity of clinical severity and the different manifestations observed after SARS-CoV-2 exposure suggest that both the viral pathogenesis and host responses are exceedingly complicated and will necessitate long-term studies. Furthermore, rapid deployment of different types of vaccines and changes in public policies, including the availability of vaccines, affect recommendations for the number of vaccine doses (and timing) needed to sustain immunological protection across various populations. SeroNet is in an optimal position to gather such data and answer critical scientific questions on these topics as they arise. Outstanding questions include understanding correlates of protection, identifying vulnerable populations for booster vaccinations, and alternative strategies for “poor responders.” Factors that increase the durability of vaccine-elicited immune responses in the general population and whether all persons require subsequent vaccination are unclear. Future priorities for investigation include
the following: (1) the potential benefit of heterologous vaccinations; (2) deep phenotyping of the spectrum of "at-risk" subpopulations with detailed clinical annotation to identify pathogenic mechanisms; (3) investigation into diversity of immune response across subpopulations and their respective roles in protection from infection and/or disease; and (4) interactions with other common respiratory pathogens and putative cross-protection.

CONCLUSIONS

In summary, SeroNet represents an ambitious effort to coordinate the study of this infection in real time. This publication brings information about this network forward, with the goals of articulating our framework for epidemiologic and immunologic study of SARS-CoV-2 and human populations and highlighting the value of creating a pan-national research network to combat the COVID-19 pandemic. The longitudinal studies of human populations already initiated establish critically important early benchmarks for tracking the host immunologic response to both the SARS-CoV-2 virus and to vaccination through time. The principles of making SeroNet datasets publicly available will help drive discovery and serve as a model for future research on both novel and existing diseases when multidisciplinary, collaborative research is desired in an evolving environment.

Supplementary Data

Supplementary materials are available at Open Forum Infectious Diseases online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Acknowledgments

We are grateful to all the studies participants and the many collaborators and staff supporting SeroNet studies. We thank Loraine Escobedo (Cancer Research Center for Health Equity at Cedars-Sinai) for assistance in creating the figure.

Financial support. This work was funded by US National Institutes of Health Grants U54CA260591, U01CA260584, U01CA260469, U54CA260543, U54CA260560, U01CA260541, U01CA261277, U01CA261277, U01CA260526, U01CA261276, U01CA260539, U01CA260513, U01CA260507, U01CA260462, CBC21X089, CBC21X090, CBC21X091, and CBC21X092.

Potential conflicts of interest. D. A. G. is founder and chief scientific and strategy advisor at Salimetrics LLC and Salivabio LLC. These relationships are managed by the policies of the committees on conflict of interest at Johns Hopkins University School of Medicine and the University of California at Irvine. R. F. is scientific founder and advisor of IsoPlexis, Singlelon Biotechnologies, and AtlasXomics. The interests of R. F. were reviewed and managed by Yale University Provost's Office in accordance with the University's conflict of interest policies. W. H. has been a consultant to Merck Vaccines and serves on the Scientific Advisory Board of Biobot Analytics. A. H. K. has received consulting fees from Roche. J. R. is a consultant to Secure Transfusion Services and was previously a consultant to CSL Plasma, Inc. J. R. is a cofounder, stockholder, and consultant for Cambium Medical Technologies, Inc. and Cambium Oncology, Inc. S. B. B. is a member of the cytomegalovirus vaccine advisory committees of Merck and Moderna and received research funding from Merck, Pfizer, and Moderna. A. B. K. is a consultant for Roche Diagnostics and has received research funding from Siemens Healthcare Diagnostics. J. S. receives royalties from Walters-Kluwer, Inc. and grant support from Merck & Co., Inc. A. M. holds a consultant or advisory role at Novartis and Morphophsys and has research funding from Amgen and Pfizer. K. L. R. has been a consultant for Amgen, Calithera, AstraZeneca, Blueprint, Boehringer Ingelheim, Daiichi Sankyo, EMD Serono, Genentech, GlaxoSmithKline, Janssen, Lilly, Merck KGaA, Mirati, Takeda, and Tesaro and nonfinancial support from Seattle Genetics. K. L. R. has research support to her institution from Calithera, Blueprint, Daiichi Sankyo, Genentech, Elevation Oncology, and Janssen outside the submitted work. M. Li. receives research funding through his institution from Pfizer, has received consulting/honoraria from Merck, Janssen, University of Virginia Miller Center, Sanofi Pasteur, Bristol Myers Squibb, and Peter Diamandis/Abundance Platinum, and has provided unpaid advice to Pfizer, Janssen, Astra-Zeneca, and COVAXX (United Biomedical). The Icahn School of Medicine at Mount Sinai has filed patent applications relating to SARS-CoV-2 serological assays (US Provisional Application Numbers: 62/994,252, 63/018,457, 63/020,503, and 63/024,436) and NDV-based severe acute respiratory syndrome coronavirus (SARS-CoV-2) vaccines (US Provisional Application Number: 63/251,020), which list F. K. as coinventor. Patent applications were submitted by the Icahn School of Medicine at Mount Sinai. Mount Sinai has spun out a company: Kantaro, to market serological tests for SARS-CoV-2. F. K. has consulted for Merck and Pfizer (before 2020) and is currently consulting for Pfizer, Third Rock Ventures, Seqirus, and Avimex. The Krammer laboratory is also collaborating with Pfizer on animal models of SARS-CoV-2. S. H. has been a consultant to FORMA Therapeutics. G. Y. M. has consulted for AbbVie, Arena Pharmaceuticals, Boehringer-Ingehelm, Bristol-Meyers Squibb/Celgene, Entasys, Janssen, Medtronic, Pfizer, Samsung Bioepis, Shionogi, Takeda, and Techlab and has received research funding from Pfizer for an unrelated investigator-initiated study. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

References

1. Lucire N, Seville M, Hatchett R, Halton J. Developing Covid-19 vaccines at pandemic speed. N Engl J Med 2020; 382:1969–73.
2. National Cancer Institute. Serological Sciences network to study COVID Immune response. Available at: https://www.cancer.gov/research/key-initiatives/covid-19/coronavirus-research-initiatives/serological-sciences-network. Accessed 2021.
3. Polack FP, Thomas SJ, Kitchin N, et al. Safety and efficacy of the BNT162b2 mRNA Covid-19 vaccine. N Engl J Med 2020; 383:2603–15.
4. Baden LR, El Sahly HM, Esmik E, et al. Efficacy and safety of the mRNA-1273 SARS-CoV-2 vaccine. N Engl J Med 2021; 384:403–16.
5. Mullard A. COVID-19 vaccine development pipeline gears up. Lancet 2020; 395:1751–2.
6. McGill COVID19 Vaccine Tracker Team. COVID-19 Vaccine Tracker. Available at: https://covid19.trackvaccines.org/. Accessed 2021.
7. Woodruff MC, Ramonell RP, Saini AS, et al. Relaxed peripheral tolerance drives broad de novo autoreactivity in severe COVID-19 [preprint], medRxiv 2021; [Preprint]. doi:10.1101/2020.10.21.20216192.
8. Knight JS, Caricchio R, Casanova JL, et al. The intersection of COVID-19 and autoimmunity. J Clin Invest 2021;131(24):1–9.
9. Woodruff MC, Ramonell RP, Nguyen DC, et al. Extrafollicular B cell responses correlate with neutralizing antibodies and morbidity in COVID-19. Nat Immunol 2020; 21:1506–16.
10. Wang EY, Mao T, Klein J, et al. Diverse functional autoantibodies in patients with COVID-19. Nature 2021; 595:283–8.
11. Botwin GJ, Li D, Figueiredo J, et al. Adverse events after SARS-CoV-2 mRNA vaccination among patients with inflammatory bowel disease. Am J Gastroenterol 2021; 116:1746–51.
12. Pozdnyakova V, Botwin GJ, Sobhani K, et al. Decreased antibody responses to Ad26.COV2.S relative to SARS-CoV-2 mRNA vaccines in patients with inflammatory bowel disease. Gastroenterology 2021;161(6):2041–2043.
13. Siegel CA, Melmed GY, McGovern DP, et al. SARS-CoV-2 vaccination for patients with inflammatory bowel diseases: recommendations from an international consensus meeting. Gut 2021; 70:635–40.
14. Rolfo C, Me shulami N, Russo A, et al. Lung cancer and severe acute respiratory syndrome coronavirus 2 infection: identifying important knowledge gaps for investigation. J Thorac Oncol 2022; 17(2): 214–227.

15. Figueredo IC, Ihenacho U, Merin NM, et al. SARS-CoV-2 vaccine uptake, perspectives and adverse reactions following vaccination in patients with cancer undergoing treatment. Ann Oncol 2022; 33(1):109–111.

16. Aleman A, Upadhyaya B, Tubal les K, et al. Variable cellular responses to SARS-CoV-2 in fully vaccinated patients with multiple myeloma. Cancer Cell 2021; 39:1442–4.

17. Oliver Van O, Gleason CR, Agte S, et al. Highly variable SARS-CoV-2 spike antibody responses to two doses of COVID-19 RNA vaccination in patients with multiple myeloma. Cancer Cell 2021; 39:1028–30.

18. Ribas A, Dhodapkar MV, Campbell KM, et al. How to provide the needed protection from COVID-19 to patients with hematologic malignancies. Blood Cancer Discov 2021; 2:562–7.

19. Prendecki M, Thomson T, Clarke CL, et al. Imperial Renal COVID-19 vaccine study group in collaboration with the OCTAVE Study Consortium. Immunological responses to SARS-CoV-2 vaccines in kidney transplant recipients. Lancet 2021; 398(10310):1482–1484.

20. Cucciardi D, Egri N, Bodro M, et al. Cellular and humoral response after mRNA-1273 SARS-CoV-2 vaccine in kidney transplant recipients. Am J Transplant 2021; 21:2727–39.

21. Marion O, Del Bello A, Abravanel F, et al. Safety and immunogenicity of anti-SARS-CoV-2 messenger RNA vaccines in recipients of solid organ transplants. Ann Intern Med 2021; 174:1336–8.

22. Boyarsky BJ, Chiang TF, Teles AT, et al. Antibody kinetics and durability in SARS-CoV-2 mRNA vaccinated solid organ transplant recipients. Transplantation 2021; 105:e137–8.

23. Karaba AH, Zhu X, Liang T, et al. A third dose of SARS-CoV-2 vaccine increases neutralizing antibodies against variants of concern in solid organ transplant recipients. Am J Transplant 2022; (4):1253–1260.

24. Karaba AH, Xianming Z, Benner SE, Akinde O, Eby Y, Wang KH, et al. Higher proinflammatory cytokines are associated with increased antibody titer after a third dose of SARS-CoV-2 vaccine in solid organ transplant recipients. Transplantation 2022; 106(4):835–841.

25. Yang X, Sun J, Rena C, et al. National COVID Cohort Collaborative Consortium, Associations between HIV infection and clinical spectrum of COVID-19: a population level analysis based on US National COVID Cohort Collaborative (NCC) data. Lancet HIV 2021; 8(11):e690–e700.

26. Karim F, Gazy I, Celie S, et al. HIV status alters disease severity and immune cell responses in beta variant SARS-CoV-2 infection wave. Elife 2021; 10:1–9.

27. Woldemeskel BA, Karaba AH, Gatliss CC, et al. The BNT162b2 mRNA vaccine elicits robust humoral and cellular immune responses in people living with Human Immunodeficiency Virus (HIV). Clin Infect Dis 2021; 74(7):1268–1270.

28. Chehimi J, Campbell DE, Azzoni L, et al. Persistent decreases in blood plasmacytoid dendritic cell number and function despite effective highly active antiretroviral therapy and increased blood myeloid dendritic cells in HIV-infected individuals. J Immunol 2002; 168:4796–801.

29. Donaghy H, Porni ak A, Gazzard B, et al. Loss of blood CD1c(+) myeloid and CD1c(−) plasmacytoid dendritic cells in patients with HIV-1 infection correlates with HIV-1 viral load. Blood 2001; 98:2574–6.

30. Parinitha S, Kulkarni M. Haemato logical changes in HIV infection with correlation to CD4 cell count. Australas Med J 2012; 5:157–62.

31. Ruddy JA, Boyarsky BJ, Werbel WA, et al. Safety and antibody response to the first dose of severe acute respiratory syndrome coronavirus 2 messenger RNA vaccine in persons with HIV. AIDS 2021; 35:1872–4.

32. Frater J, Ewer KJ, Ogbe A, et al. Safety and immunogenicity of the ChAdOx1 nCoV-19 (AZD1222) vaccine against SARS-CoV-2 in HIV infection: a single-arm substudy of a phase 2/3 clinical trial. The lancet. HIV 2021; 8:e474–85.

33. Nguyen LH, Drew DA, Graham MS, et al. Risk of COVID-19 among front-line health-care workers and the general community: a prospective cohort study. Lancet Public Health 2020; 5:e475–83.

34. Zeng C, Evans JP, Pearson R, et al. Neutralizing antibody against SARS-CoV-2 spike in COVID-19 patients, health care workers, and convalescent plasma donors. JCI Insight 2020; 5(22):1–14.

35. Zeng C, Evans JP, Faraone JN, et al. Neutralization of SARS-CoV-2 variants of concern harboring Q677H. mBio 2021:e025102.

36. Qiao J. What are the risks of COVID-19 infection in pregnant women? 2020; 395:760–2.

37. Sherrer ML, Lei J, Creisher PS, et al. Pregnancy alters interleukin-1 beta expression and antiviral antibody responses during severe acute respiratory syndrome coronavirus 2 infection. Am J Obstet Gynecol 2021; 225:301.e1–14.

38. Bhopal SS, Bagaria J, Obalis B, Bhopal R. Children and young people remain at low risk of COVID-19 mortality. Lancet Child Adolesc Health 2021; 5:e12–3.

39. Abrams JY, Oster ME, Godfried-Cato SE, et al. Factors linked to severe outcomes in multisytem inflammatory syndrome in children (MIS-C) in the USA: a retrospective surveillance study. Lancet Child Adolesc Health 2021; 5:323–31.

40. Dietrich ML, Norton EB, Elliott D, et al. SARS-CoV-2 seroprevalence rates of children seeking medical care in Louisiana during the state stay at home order. J Clin Virol Plus 2021; 1:100047.

41. Pinninti SG, Pati S, Poole C, et al. Virological characteristics of hospitalized children with SARS-CoV-2 infection. Pediatrics 2021; 147(5):1–10.

42. Okonkwo NE, Agowa UT, Jang M, et al. COVID-19 and the US response: accelerating health inequities. BMJ Evir Based Med 2021; 26(4):176–179.

43. Morales DX, Morales SA, Beltran TF. Racial/ethnic disparities in household food insecurity during the COVID-19 pandemic: a nationally representative study. J Racial Ethn Health Disparities 2021; 8:1300–14.

44. Reichberg SB, Mitra PP, Hghamad A, et al. Rapid emergence of SARS-CoV-2 in the greater New York metropolitan area: geolocation, demographics, positivity rates, and hospitalization for 46 793 persons tested by Northwell Health. Clin Microbiol Infect 2020; 71:3204–13.

45. Morgan R, Baker P, Griffith DM, et al. Beyond a zero-sum game: how does the impact of COVID-19 vary by gender? Front Sociol 2021; 6:650729.

46. Scully EP, Gupta A, Klein SL. Sex-biased clinical presentation and outcomes from COVID-19. Clin Microbiol Infect 2021; 27:1072–3.

47. Shapiro JR, Klein SL, Morgan R. COVID-19: use intersectionalizes to close gaps in outcomes and vaccination. Nature 2021; 591:202.

48. Chen Y, Klein SL, Garibaldi BT, et al. Aging in COVID-19: vulnerability, immunity and intervention. Ageing Res Rev 2021; 65:102105.

49. Takahashi T, Iwasaki A. Sex differences in immune responses. Science 2021; 371:347–48.

50. Klein SL, Pekosz A, Park HS, et al. Sex, age, and hospitalization drive antibody responses in a COVID-19 convalescent plasma donor population. J Clin Invest 2020; 130:6141–50.

51. Scully EP, Schumock G, Fu M, et al. Sex and gender differences in testing, hospital admission, clinical presentation, and drivers of severe outcomes from COVID-19. Open Forum Infect Dis 2021; 8:ofa448.

52. Bhattacharya S, Dunn P, Thomas CG, et al. ImmPort, toward repurposing of open access immunological assay data for translational and clinical research. Sci Data 2018; 5:180015.

53. Wilkinson MD, Dumontier M, Aalbersberg IJ, et al. The FAIR Guiding Principles for scientific data management and stewardship. Sci Data 2016; 3:160018.