



Original Article

Detection of Antinuclear Antibodies Targeting Intracellular Signal Transduction, Metabolism, Apoptotic Processes and Cell Death in Critical COVID-19 Patients

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Competing interests: The authors declare no conflict of Interest.

Abstract. Background and Objectives: The heterogeneity of the coronavirus disease of 2019 (COVID-19) lies within its diverse symptoms and severity, ranging from mild to lethal. Acute respiratory distress syndrome (ARDS) is a leading cause of mortality in COVID-19 patients, characterized by a hyper cytokine storm. Autoimmunity is proposed to occur as a result of COVID-19, given the high similarity of the immune responses observed in COVID-19 and autoimmune diseases. Here, we investigate the level of autoimmune antibodies in COVID-19 patients with different severities. **Results:** Initial screening for antinuclear antibodies (ANA) IgG using ELISA revealed that 1.58% (2/126) and 4% (5/126) of intensive care unit (ICU) COVID-19 cases expressed strong and moderate ANA levels, respectively. An additional sample was positive with immunofluorescence assays (IFA) screening. However, all the non-ICU cases (n=273) were ANA negative using both assays. Samples positive for ANA were further confirmed with large-scale autoantibody screening by phage immunoprecipitation-sequencing (PhIP-Seq). The majority of the ANA-positive samples showed "speckled" ANA pattern by microscopy and revealed autoantibody specificities that targeted proteins involved in intracellular signal transduction, metabolism, apoptotic processes, and cell death by PhIP-Seq; further denoting reactivity to nuclear and cytoplasmic antigens. **Conclusion:** Our results further support the notion of routine screening for autoimmune responses in COVID-19 patients, which might help improve disease prognosis and patient management. Further, results provide compelling evidence that ANA-positive individuals should be excluded from being donors for convalescent plasma therapy in the context of COVID-19.

Keywords: Autoimmunity; ANA; ICU; COVID-19; Coronavirus.

Citation: Nasarallah G.K., Fakhroo A.D., Khan T., Cyprian F.S., Al Ali F., Ata M.M.A., Taleb S., Zedan H.T., Al-Sadeq D.W., Amanullah F.H., Hssain A.A., Eid A.H., Abu-Raddad L.J., Al-Khal A., Al Thani A.A., Marr N., Yassine H.M. Detection of antinuclear antibodies targeting intracellular signal transduction, metabolism, apoptotic processes and cell death in critical COVID-19 patients. *Mediterr J Hematol Infect Dis* 2022,14(1): e2022076, DOI: <http://dx.doi.org/10.4084/MJHD.2022.076>

Introduction. The severity of COVID-19 is diverse, with a wide range of symptoms characterized from mild to lethal. A robust immune response is usually initiated upon viral infections, involving both the innate and adaptive immune systems to irradiate the virus.¹ Typically, viruses evade these immune responses through one of the following mechanisms; (1) Molecular Mimicry, (2) bystander activation, and (3) epitope spreading.^{1,2} In COVID-19 patients, several immunological impacts have been observed, including hyper-immune response, abnormal cytokine/chemokine production, T cells hyperactivation, increased monocytes, macrophages, and neutrophils count.^{1,3} The cytokine storm (i.e., abnormal cytokine secretion) is associated with fatality in COVID-19 patients, who usually experience a hyper-pro-inflammatory immune response leading to ARDS.^{1,3} These COVID-19 immune responses are quite similar to those observed in autoinflammatory and autoimmune conditions.^{1,4} It is known that infectious diseases trigger autoimmunity, specifically through molecular mimicry, and several viruses have been associated with autoimmune diseases.^{1,5,6} For example, enteric viruses have been associated with type 1 diabetes, and herpesviruses infections have led to the development of several autoimmune disorders, including multiple sclerosis, systemic lupus erythematosus, and rheumatoid arthritis.^{1,6,7,8} In addition, mice infected with murine coronavirus developed immune-mediated encephalomyelitis.⁹ Further, rhinovirus and coronavirus were shown to be the highest frequently detected pathogens in patients with psoriasis flares following respiratory tract infections.¹⁰

Severe COVID-19 patients have been suspected of developing autoimmunity. Several reports have suggested a link between SARS-CoV-2 infection and Kawasaki-like disease, acute inflammation of the blood vessels affecting children.^{5,11} Moreover, patients with severe COVID-19 pneumonia reported neutralizing IgG autoantibodies against type I IFNs.¹² In addition, other autoantibodies, such as anti-platelet autoantibodies (APA), were reported in COVID-19 patients, leading to immune thrombocytopenia.¹³ Accordingly, critically ill COVID-19 patients may experience elevated levels of other autoimmune antibodies, including antinuclear antibodies (ANA).^{14,15} High levels of ANA have been previously associated with several autoimmune disorders, such as lupus erythematosus (SLE) and rheumatoid arthritis (RA).¹⁶ This study investigates whether COVID-19 severe outcome could be associated with autoimmunity. We measured ANA levels in blood sera samples collected from COVID-19 patients with

different clinical severities (i.e., ICU "Severe" vs. Non-ICU "Mild or Asymptomatic"). We report a higher frequency of ANA in severe COVID-19 cases, suggesting a possible contribution of COVID-19 to autoimmunity and exacerbated disease outcome.

Method.

Sample Collection and Ethical Compliance. This study was approved by the IRB committees of Hamad Medical Corporation (MRC-01-20-145) and Qatar University (QU-IRB 1289-EA/20). Informed consent was obtained from all patients per the approved protocol, and informed consent was obtained from next of kin in case of death. The samples' numbers in **table 1** are only identifiable to the researchers and are not related to the national nor the medical IDs of the patients. Sera samples were collected from COVID-19 patients at different clinical stages and classified into two groups; (1) mild/asymptomatic (non-ICU, n=273), (2) Severe/Critical (ICU, n=126). Out of the 126 ICU patients, only 80 had sera extracted at different time points, assuming that ICU admission was on Day 1. For those with repetitive samples, at least two-time points were tested, and positive results were reported. All methods were performed following the relevant guidelines and regulations.

ANA IgG ELISA assay. All samples [mild/asymptomatic (non-ICU, n=273) & Severe/Critical (ICU, n=126)] were initially screened by ELISA. Sera samples were diluted 1:101 in sample diluent (DILSPE), and ELISA was performed using an ANA Screening IgG kit (DIA.PRO, Italy) according to the manufacturer's standards. The cutoff value was calculated as negative control (OD450nm) + 0.250. Samples with cut of value (S/Co) <0.8, S/Co (0.8-1.1), S/Co >1.1 were considered negative "normal", equivocal "moderate" and positive "abnormal" respectively. Note that samples that tested positive and equivocal were repeated in triplicates with mean and standard deviation calculated.

ANA HEp-2 IFA Assay. All ICU patients' sera (n=126) and an equivalent number of randomly selected non-ICU sera (n=121) were subjected to Indirect Fluorescent Antibody (IFA). A technique was performed using the AccuDiag™ ANA HEp-2 IFA kit (Diagnostic Automation/Cortez Diagnostics, US) according to the manufacturer's standards. A positive reaction is indicated by the presence of any pattern of nuclear apple-green staining observed at a 1:40 dilution based on a 1+ to 4+ scale of staining intensity (+1 weak → +4 strong). Samples were regarded as positive if they tested positive with either ELISA or IFA test. These samples were then

Table 1. Demographic Data of COVID-19 Patients with Moderate-to-Abnormal ANA Level.

| Sample # | Gender | Age | Nationality | Comorbidities | Clinical Outcome | ANA detection/ Status |
|----------|--------|------------|-------------|--|------------------|------------------------|
| C020 | M | Early 60's | Bangladeshi | - | <i>Deceased</i> | IFA |
| C024 | M | Early 50's | Indian | Hypertension | Alive | <i>ELISA/ Abnormal</i> |
| C047 | M | Early 40's | Filipino | - | Alive | ELISA/ Moderate |
| C083 | M | Early 60's | Filipino | DM2, gouty arthritis | Alive | <i>ELISA/Abnormal</i> |
| F003 | M | Mid 70's | Indian | Hypertension | <i>Deceased</i> | ELISA/ Moderate |
| F004 | M | Mid 50's | Qatari | DM, Hypertension, Ischemic heart disease/First degree heart block, | Alive | ELISA/ Moderate |
| F026 | M | Late 40's | Filipino | Hypertension, ESRD, Dyslipidemia, hyperuricemia | <i>Deceased</i> | ELISA/ Moderate |
| F057 | M | Late 50's | Sri Lankan | DM, Hypertension, CAD, Dyslipidemia | <i>Deceased</i> | ELISA/ Moderate |

DM: Diabetes Mellitus, ESRD: End-Stage Renal Disease, CAD: Coronary Artery Disease.

subjected to PhIP-Seq analysis.

Phage Immunoprecipitation-Sequencing (PhIP-Seq) and Peptide Enrichment Analysis. PhIP-Seq and peptide enrichment analysis were performed as previously described¹⁷ using the T7 Human ORF 90mer library, a phage display library expressing 90-aa protein fragments tiling through the human proteome with a 45-aa overlap.¹⁸ The T7 Human ORF 90mer Library was obtained from S. Elledge (Brigham and Women's Hospital and Harvard University Medical School, Boston, MA, USA). In brief, we imputed $-\log_{10}(P)$ values as described previously¹⁷ by fitting a zero-inflated generalized Poisson model to the distribution of reading counts obtained from the tested samples following immunoprecipitation; then we regressed the parameters for each peptide sequence based on the read counts obtained from an input library sample (*i.e.*, prior to immunoprecipitation). These $-\log_{10}(P)$ values were considered peptide enrichment scores and reflected a quantitative measure for the presence of autoantibody specificity in a given sample. A peptide enrichment score of ≥ 2.3 was considered statistically significant. We also removed peptides from the downstream analysis enriched in mock-IP samples, which served as negative controls. We only considered peptides significantly enriched in at least two test samples. We then computed log odds ratios (LOD) for all retained peptides ($n = 328$) to identify autoantibody specificities that were differentially enriched between ICU patients and asymptomatic COVID-19 cases. Peptides with a $|\text{LOD}| \geq \ln(1.5)$ were considered differentially enriched ($n = 79$).

Gene Set Enrichment Analysis. Of the 79 differentially

enriched peptides, 62 were derived from coding sequences with a defined gene annotation (Entrez) and were considered for gene enrichment analysis. We used the Molecular Signatures Database (MSigDB) for this analysis as previously described.¹⁹ Out of the 62 queried genes, 42 were found to be significantly enriched (P -value $< 10^{-5}$ and FDR q -value < 0.05) in one of the 20 gene sets.

Detection of Shared Linear B Cell Epitopes. To test for shared linear B cell epitopes between the identified autoantigens and SARS-CoV-2 antigens, we built a pairwise distance matrix that captured the maximum size of linear sequence identity of amino acids between the 79 differentially enriched human 90 aa peptides and 17 reference sequence of SARS-CoV2 proteins in UniProtKB (<https://covid-19.uniprot.org>; used for analysis not to deposit the data) as previously described.²⁰ A linear sequence identity of 7 amino acids or more was considered a shared linear B cell epitope.

Results. ANA antibodies were screened in non-ICU ($n=273$) and ICU ($n=126$) COVID-19 patients using ANA IgG ELISA. All of non-ICU patients ($n=273$) tested negative; ($S/Co < 0.8$) with an average of 0.286 (± 0.073). On the other hand, 7/126 ICU patients ($\sim 5.6\%$) reported a S/Co value of > 0.8 , showing moderate to high ANA levels (**Figure 1a**). Four percent of the ICU patients (5/126) tested equivocal (S/Co : 0.8-1.1, moderate ANA level), whereas 1.58% (2/126) tested positive ($S/Co > 1.1$, abnormal ANA level) (**Figure 1b**). The positive samples, C024 and C083, had a S/Co value of 4.561 and 1.159, respectively (**Figure 1b**). To confirm the presence of ANA, IFA was performed using HEp-2

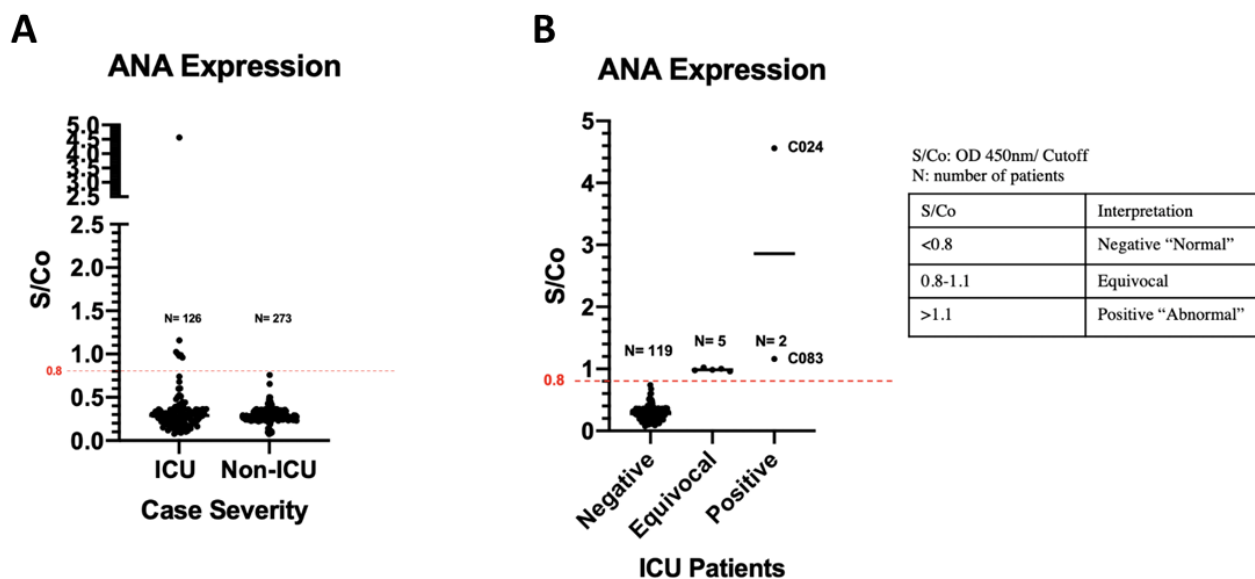


Figure 1. ANA ELISA levels of the COVID-19 Patients. (A) Sera samples of ICU (n=126) and non-ICU (n=273) COVID-19 patients; and (B) sera samples of ICU COVID-19 patients (n=126). Samples were tested at 1:101 dilution.

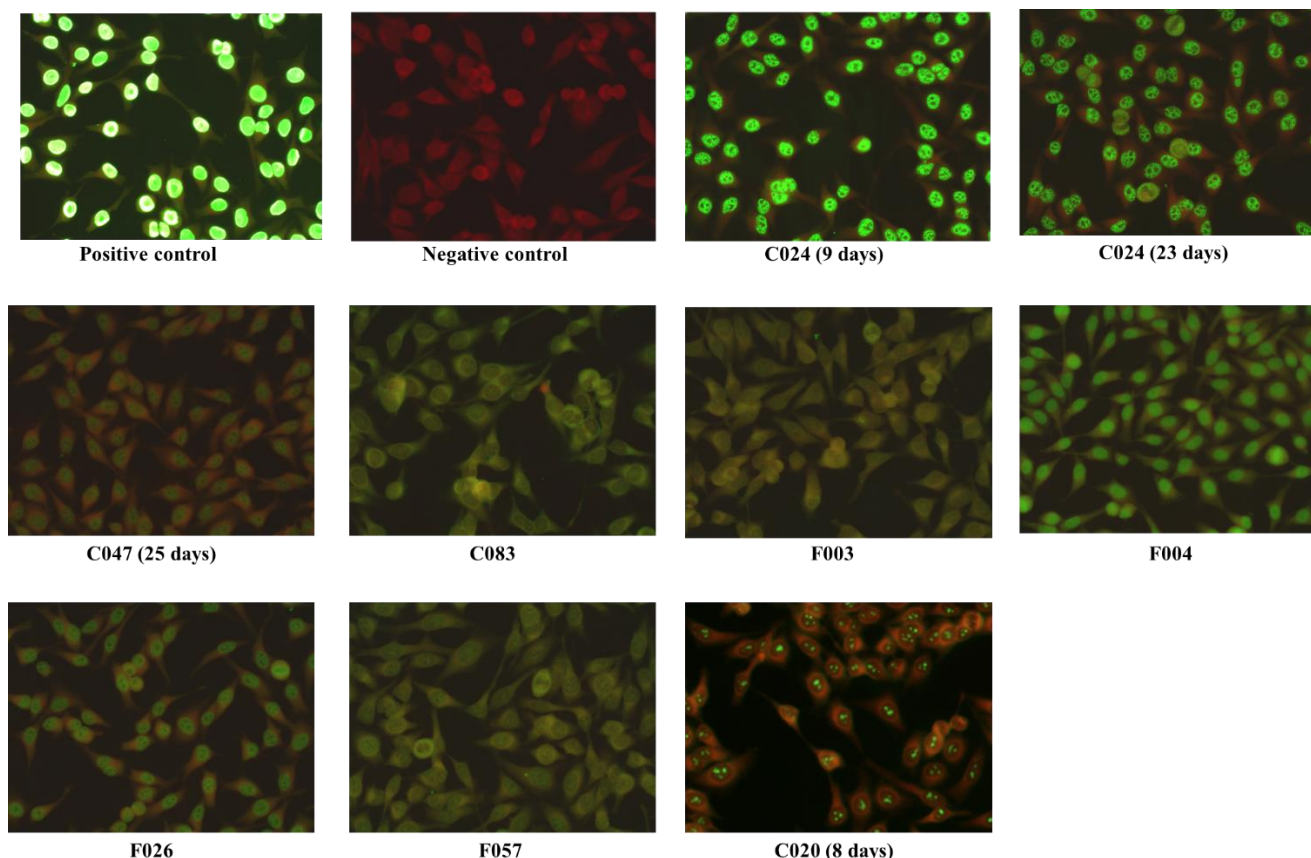


Figure 2. Immunostaining of Hep2 Cells with ANA from COVID-19 Sera Samples. Sera samples of ICU patients (n=126) and an equivalent number of randomly selected non-ICU patients sera (n=121) were subjected to Indirect Fluorescent Antibody (IFA). HEp2 cells were used as a substrate to detect ANA antibodies in human serum. Samples were tested at 1:40 dilution. Note that # of days corresponds to the time of sample collection, assuming ICU admission is day 1.

cells on all ICU and an equivalent number of non-ICU samples (Figure 2). An additional sample (C020) tested strongly positive for IFA. The majority of the samples (C024, F026, F004, and C047) showed a "speckled"

ANA pattern (**Figure 2**). In addition to nuclear ANA level, cytoplasmic ANA level was observed in samples F003, F004, C020, F057, and C083 (**Figure 2**). Samples F057 and C083 showed a "punctate nuclear envelope" ANA pattern (**Figure 2**). All patients who tested equivocal/positive for ANA are males within the age range of 41-75 years (Average= 55 years) (**Table 1**). In relation, 71.4% of the ANA-positive patients (5/7) are co-diagnosed with hypertension, and the mortality rate was 42.9% (3/7), specifically the samples F003, F026, and F057 that showed moderate ANA Level (**Table 1**). Diabetes was also common among ANA-positive patients, accounting for 42.8% of patients (3/7), including patient C083, which exhibited abnormal ANA levels. Finally, we performed a large-scale autoantibody screen of the ANA-positive (C024, C083) and five equivocal sera samples using phage-immunoprecipitation sequencing.^{9,12} Randomly selected ANA-negative samples obtained from ICU patients with COVID-19 (n = 7) and from asymptomatic COVID-19 cases (n = 15) were assayed for comparison. Principal component analysis of the peptide enrichment scores confirmed that most ANA-positive and equivocal

samples of ICU cases clustered separately from the asymptomatic COVID-19 cases, except for the day 9 sample of C024 and the sample collected from C83 on day 17 after ICU admission (**Figure 3A**). We identified 79 autoantibody specificities that were differentially enriched in ICU patients in comparison to the asymptomatic COVID-19 cases (**Supplementary Table 1**), allowing a clear separation of critical versus asymptomatic COVID-19 cases by hierarchical clustering (except for one asymptomatic case) (**Figure 3B**). Interestingly, our unbiased screen revealed autoantibody specificities against several autoantigens present in AAgAtlas 1.0, a human autoantigen database,²¹ including nuclear proteins such as the DEAD-Box Helicase 42 (DDX42) and Mtr4 Exosome RNA Helicase (MTREX), as well as proteins involved in immune defenses and cellular signaling, such as Immunoglobulin Superfamily DCC Subclass Member 1 (DCC) and Ras Suppressor Protein 1 (RSU1). To functionally characterize the self-antigens that were being targeted in critically ill COVID-19 patients, we performed a gene set enrichment analysis using the Molecular Signatures Database (MSigDB)¹¹ and

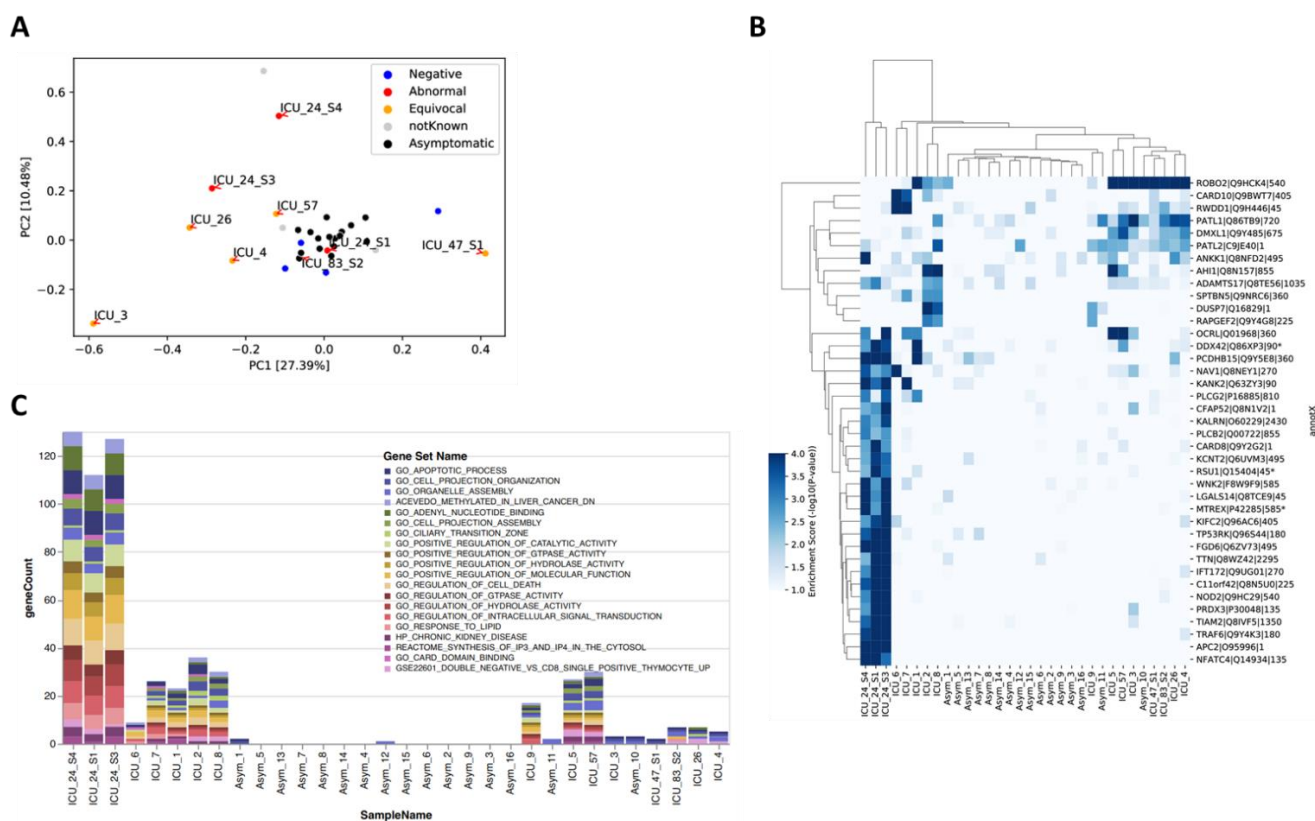


Figure 3. Autoantibody profile of selected cases assessed by PhIP-Seq. **(A)** Principal component analysis of the peptide enrichment scores reflecting autoantibody-autoantigen interactions in ICU patients and asymptomatic COVID-19 cases. The color core indicates the ANA status. **(B)** Heatmap plot showing the binding profile of the 79 differentially enriched (DE) peptides in ICU cases versus asymptomatic cases, with hierarchical clustering. Each row indicates a human peptide (90mer, start position is indicated relative to the UniProtKB entry), and each column represents a sample. The color gradient for each cell of the heatmap plot represents the peptide enrichment score ($-\log_{10}(P)$ value) for a given antigenic peptide and sample. A $-\log_{10}(P) \geq 2.3$ was considered significantly enriched; * Represents known autoantigens with an entry in the human autoantigen database (AAgAtlas 1.0). **(C)** Stacked bar plot showing the results of a gene set enrichment analysis of the peptides shown in **(B)**. The color code indicates the gene sets from the Molecular Signatures Database (MSigDB) for which at least one DE peptide was enriched (P -value < 10^{-5} and FDR q -value < 0.05). Samples are sorted as shown in **(B)** according to hierarchical clustering.

including all of the 79 putative autoantigens for which we had found autoantibodies to be differentially enriched among the tested ICU cases when compared to asymptomatic COVID-19 cases. This analysis confirmed that autoantibodies in ICU patients primarily targeted intracellular proteins involved in intracellular signal transduction, metabolism, apoptotic processes, and cell death. Autoimmune responses were primarily observed in samples with moderate and high ANA levels, particularly in the samples of patient C024 with the highest ANA measurements, which appeared to increase over time (**Figure 3C** and **Supplementary Table 2**).

Discussion. COVID-19 disease progression may pass through up to four different phases. The first phase is characterized by an initial viral infection phase that is usually mild or asymptomatic in approximately 80% of patients. The host-virus interactions then delineate the progression of the disease. Some patients progress to a second phase, characterized by a hyper-immune response (i.e., cytokine storm). A state of hypercoagulability occurs in the third phase.¹ In combination, they may lead to organ damage in the fourth phase, which is usually mediated by the host's innate immune system.^{1,5,14} In this present study, we assessed the generation of antinuclear autoimmune antibodies (ANA) in critically ill COVID-19 patients to better understand the disease prognosis and pave the way for the possible use of immunomodulatory drugs for the treatment of these patients. It is worth noting that several immunomodulatory drugs have been proven to be effective in relieving COVID-19 symptoms, such as tocilizumab.¹

Interestingly, ANAs were exclusively observed in ICU COVID-19 patients (8/126, 6.34%), which suggests a potential correlation between COVID-19 severity and ANA production. In other words, SARS-CoV-2 infection may have triggered the production of ANA autoantibodies leading to possible cases of autoimmunity in severely ill COVID-19 patients. However, the mechanism is yet to be studied. Only one patient (C24) had a high level of ANA as tested by ELISA. We tested this patient's samples at different time points, and all were highly positive (**Figure 2**). It was inapplicable to follow up with this patient to see the ANA titer levels after he was discharged from the hospital.

Immunological dysregulation, including the production of autoimmune antibodies, has been previously described in COVID patients.^{12,22,23} In one study, Pascolini et al. reported the presence of anti-platelet autoantibodies (APA) in three COVID-19 patients suffering from immune-mediated thrombocytopenia. Such antibodies were not detected in our samples when using the PhIP-Seq assay. In general, viral infections trigger autoimmunity through one of the following mechanisms, (1) molecular mimicry, (2)

bystander activation, and (3) epitope spreading.^{2,5,6} In molecular mimicry, viruses display antigens structurally similar to self-antigens activating a cross-reactive immune response against both self and non-self-antigens. During bystander activation, a non-specific hyper antiviral immune response characterized by a pro-inflammatory environment causes the release of self-antigens from damaged tissues, which are then presented by antigen-presenting cells (APC), triggering autoreactive T cells and autoimmunity. One example is HIV, which mimics the human T-cell receptor (TCR) to a great extent where autoantibodies are produced.²⁴ In support of this mechanism, our large-scale autoantibody screen of selected patients by PhIP-Seq revealed several known and novel autoantigens among ICU cases, particularly those with moderate and high ANA responses. An in-depth analysis of these autoantibody specificities confirmed that these autoimmune responses were primarily directed against intracellular proteins and, therefore, likely as a consequence of extensive tissue damage during disease progression. Of note, the patient with the highest ANA serum levels and most robust autoantibody responses as assessed by PhIP-Seq (a 53-year-old male with Indian nationality) had a clinical history of hypertension but was otherwise previously healthy.

Similarly, epitope spreading is characterized by the release of more self-antigens activating autoreactive T cells that eventually spread to other autoreactive T cells (i.e., the diversification of epitope specificity). A recent study identified cross-reactive epitopes between SARS-CoV-2 and human molecular chaperones.²⁵ Bioinformatics analysis showed that a family of heat shock proteins (Hsp70) shared antigenic epitopes with SARS-CoV-2, capable of inducing autoimmunity against endothelial cells through the process of molecular mimicry.²⁵ Thus, a similar mechanism may apply to ANA production, where cross-reactive epitopes between SARS-CoV-2 and nuclear antigens may exist. However, none of the autoantigens we identified in this study shared linear B cell epitopes with any of the SARS-CoV-2 protein reference sequences (**Supplementary Figure 1**).

In terms of comorbidities, hypertension was common among patients who showed ANA levels, specifically in deceased patients (F003, F026, and F057). Thus, this may suggest a potential link between hypertension and ANA level. However, a more extensive cohort study is needed to validate this hypothesis. Autoimmune diseases such as lupus and RA have increased risk for hypertension and cardiovascular disease.²⁶ Therefore, we speculate that hypertension may act as a risk factor promoting a pro-inflammatory environment, possibly leading to autoimmunity through bystander activation. Although these samples showed moderate ANA levels, it is inconclusive because extra time points of the

samples are needed to check ANA level change over time. The second most common comorbidity was diabetes, specifically patient C083, who experienced both type 2 diabetes and abnormal ANA level. Type 2 diabetes is suspected to be an autoimmune condition given the presence of circulating autoantibodies against β cells;²⁷ thus, this may contribute to abnormal ANA levels (i.e., risk factor).

Furthermore, ANA level was confirmed using IFA, where HEp-2 cells were immunostained with ANA expressed in sera samples. ANA level comes in different patterns depending on the antigens to which ANA binds. According to the results, most positive/equivocal samples showed speckled patterns suggesting potential antigens such as n-RNP, Sm, and SSB/La.²⁸ Interestingly, only one patient had a detectable ANA level with a speckled pattern. Further, one sample (C020) showed a nucleolar pattern. Previous studies have shown a correlation between ANA nucleolar pattern and systemic sclerosis.²⁹ According to the study, a nucleolar pattern of ANA was associated with pulmonary fibrosis (i.e., lung scarring) ($P < 0.01$), suggesting a critical organ involvement with a decreased chance of survival in systemic sclerosis patients.

Regarding COVID-19, a similar association was observed between the presence of the ANA reactivity with nucleolar pattern and severe COVID-19 disease.^{14,15} Further, in a small study by Chang et al.,³⁰ autoantibodies were detected in moderate and critical cases of COVID-19. The study involved 47 PCR-confirmed COVID-19 hospitalized patients. The total ANA positive rate was 21.3%, which is higher than our study but lower than other studies, as reported in their discussion. Interestingly, similar to our findings, ANA titers were mostly weak (Median 1:40), showing 50% nucleolar and 30% speckled staining. While 9.1% (1/11) of their patients with autoantibodies and 8.3% (3/36) of patients without autoantibodies died, almost 50% of ANA-positive patients in our study died. It is worth noting that ANA positivity in our study was confirmed with large-scale autoantibody screening by phage immunoprecipitation-sequencing (PhIP-Seq), which revealed autoantibody specificities that predominantly targeted proteins involved in intracellular signal transduction, metabolism, apoptotic processes, and cell death by PhIP-Seq.

Unlike other studies, we did not detect neutralizing anti-cytokine (IFN) antibodies in the PhIP-Seq assay, as previously reported.^{12,31} Their study¹² identified individuals with high titers of neutralizing autoantibodies against type I IFN- $\alpha 2$ and IFN- ω in about 10% of patients with severe COVID-19 pneumonia. We selected only ANA-positive samples for further screening with PhIP-Seq, which could be the reason for the negative outcome. Further, with our PhIP-Seq screen, we have a limited ability to detect autoantibodies that

target conformational epitopes (due to the smaller size of peptides, 90 aa in length, that are being used for phage display) which may have limited the sensitivity.

Screening randomly selected pre-pandemic samples ($n=2655$) from Qatar Blood Bank donors (unpublished results) revealed ten samples with abnormal ANA levels (~0.38%). Among these positive ANA samples, 5 (50%) were positive for documented viral infections (**Supplementary Table 3**). Four samples (A, B, C, and D) tested positive for B19 Virus IgG, two samples (A and E) for WNV (West Nile Virus) IgG, and one sample (A) for Dengue virus. B19 virus has been associated with several autoimmune diseases, such as rheumatoid arthritis, systemic lupus, antiphospholipid syndrome, systemic sclerosis, and vasculitides.³² It has also been shown to induce cross-reactive autoantibodies utilizing molecular mimicry between parvovirus VP1 protein and host proteins (e.g., human cytokeratin and transcription factor GATA 1).³² Likewise, WNV infection has been reported to promote autoimmune conditions, including myasthenia gravis (MG), through the process of molecular mimicry.³³ In addition, several studies have shown cross-reactivity between antibodies directed against dengue virus nonstructural protein 1 (NS1) and human platelets/endothelial cells damaging them.³⁴ As observed, molecular mimicry and autoimmunity are common among these viruses, suggesting a similar mechanism taking place during SARS-CoV-2 infection.

Conclusions. This study sheds light on a potential relationship between COVID-19 and autoimmunity, particularly ANA production. Nevertheless, some limitations are associated with this study. First, the sample size is relatively small, and a larger-scale study may be needed. Second, some of the sera samples were only taken at one-time points, which makes it harder to explore ANA change over time. Third, people are admitted to ICU mostly seven days after infection, so the time points of the ICU samples are calculated from their admission to the ICU rather than the beginning of the infection. Thus, the acute vs. convalescent phase inconsistency of the ICU and non-ICU samples may affect the accuracy of the results. Still, this study provides a closer insight into the immunological progression of the disease and its prognosis. Therefore, we propose including the screening for autoimmune antibodies as a routine test for COVID-19 patients.

Acknowledgment. The authors would like to thank all the nurses and staff who facilitated the sample collection.

Statement of Ethics. This study was approved by IRB committees of Hamad Medical Corporation (MRC-01-20-145), Sidra Medicine (IRB Protocol #: 1511001953), and Qatar University (QU-IRB 1289-EA/20). In addition, we have received written informed consent from the

participants.

Funding Sources. This study was supported by funds from QNRF, grant # NPRP11S-1212-170092.

Authors' contribution. HMY and GKN designed the study. ADF, TK, FA, MMA, HTZ, DWA, and FHA ran the experiments. FSC, ST, and AHH collected samples. AHE, LAR, AA, AAA, and NM helped in logistics and

supervision. All authors read and approved the manuscript.

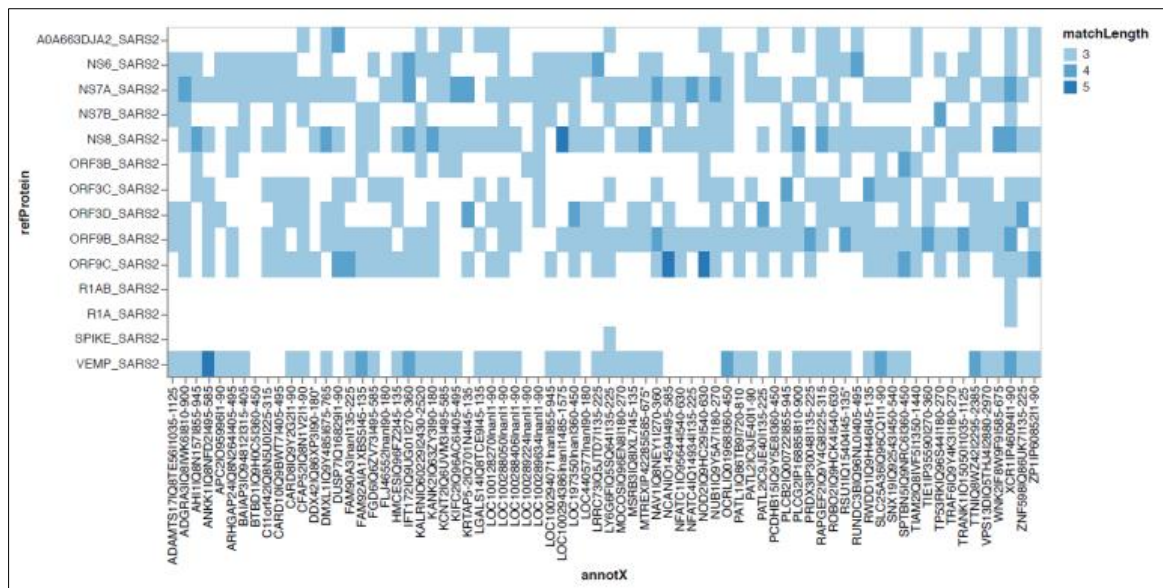
Data Availability Statement. All data are provided in this manuscript either in the main text or in the supplemental files. Inquiries about additional information can be requested directly from the corresponding author.

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Supplementary Files



Supplementary Figure 1

Supplementary Table 1

| # | Gender | Age | Nationality | Severity | Living Status (At/Abw, Di) | HBsAg % | Diabetes Mellitus | Hypertension | Cardiovascular disease | Cerebrovascular disease | GI/ID/Peptic ulcer disease (PUD) | Renal Disease/Transplant | Liver Disease/Transplant | Asthma | Osteoporosis | Previous infectious diseases (TB, HIV, HCV, Malaria etc) | Other Comorbidities | Day(s) of sample collection (relative to ICU admission) | ANA test results | Medications |
|---------|--------|-----|-------------|----------|----------------------------|---------|-------------------|--------------|------------------------|-------------------------|----------------------------------|--------------------------|--------------------------|--------|--------------|--|---------------------|---|------------------|---|
| ICU_1 | M | 70 | Non Qatari | Critical | D | NA | 1 | 0 | Ischaemic HD | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | negative | amoxicillin-clavulanic acid azithromycin Cefuroxime enoxacin hydroxychloroquin levocetirizine Acetylsalicylic acid Beta-Blocker calcipene Chlorhexidine Gluconate Esomeprazole Insulin-Aspart Ipratropium dexmedetomidine DIPHENHYDAMINE Insulin nifedipine gabapentin metformin necoridium valproic acid |
| ICU_2 | M | 40 | Non Qatari | Severe | A | 6.9 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | negative | Hydroxychloroquin Azithromycin Lopinavir / Ritonavir/Methylprednisolone 40mg BID Beta-Blocker enoxacin Esomeprazole Insulin-Aspart Insulin-Glargin Manganese Tartrate Multivitamin and Minerals Raciprill Polyethylene Glycol Senna extract Sodium Phosphate Nifedipine hydroxychloroquin Lopinavir / Ritonavir aspirin beta-Blocker Senna sulfate nifedipine paracetamol paracetamol povidone iodine Quetiapine S-Tagliminur/SODMans Atorvastatin Bupropion/Nicotine Insulin-Aspart/Insulin-Glargin Nystatin-Biphenacillin-tioconazole Glycerin Vitaminized Lactate Colistimethate Colistimethate/Mepolizumab/Infliximab/Hydrocortisone |
| ICU_7 | M | 54 | Non Qatari | Severe | A | 6.3 | 1 | 1 | CAD/CABG | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | negative | Hydroxychloroquin Lopinavir / Ritonavir aspirin beta-Blocker Senna sulfate nifedipine paracetamol paracetamol povidone iodine Quetiapine S-Tagliminur/SODMans Atorvastatin Bupropion/Nicotine Insulin-Aspart/Insulin-Glargin Nystatin-Biphenacillin-tioconazole Glycerin Vitaminized Lactate Colistimethate Colistimethate/Mepolizumab/Infliximab/Hydrocortisone |
| ICU_8 | M | 56 | Non Qatari | Critical | D | 7.3 | 1 | 1 | 0 | Stroke | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | negative | Hydroxychloroquin Lopinavir / Ritonavir aspirin beta-Blocker Senna sulfate nifedipine paracetamol paracetamol povidone iodine Quetiapine S-Tagliminur/SODMans Atorvastatin Bupropion/Nicotine Insulin-Aspart/Insulin-Glargin Nystatin-Biphenacillin-tioconazole Glycerin Vitaminized Lactate Colistimethate Colistimethate/Mepolizumab/Infliximab/Hydrocortisone |
| ICU_24 | | | | | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 9/23/20 | positive | Paracetamol |
| ICU_83 | | | | | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| ICU_47 | | | | | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| ICU_3 | | | | | ND | ND | ND | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | ND | equivocal |
| ICU_4 | | | | | ND | ND | ND | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | ND | equivocal |
| ICU_26 | | | | | ND | ND | ND | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | ND | equivocal |
| ICU_17 | | | | | ND | ND | ND | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | ND | equivocal |
| ICU_5 | | | | | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| ICU_4 | | | | | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| ICU_9 | | | | | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| Aym4 | | | | | Asymptomatic | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| Aym5 | | | | | Asymptomatic | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| Aym9 | | | | | Asymptomatic | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| Aym11 | | | | | Asymptomatic | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| Aym12 | | | | | Asymptomatic | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| Aym17 | | | | | Asymptomatic | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| Aym18 | | | | | Asymptomatic | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| Aym103 | | | | | Asymptomatic | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| Aym107 | | | | | Asymptomatic | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| Aym108 | | | | | Asymptomatic | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| Aym145 | | | | | Asymptomatic | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| Aym174 | | | | | Asymptomatic | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| Aym177 | | | | | Asymptomatic | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| Aym1791 | | | | | Asymptomatic | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| Aym18 | | | | | Asymptomatic | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |
| Aym183 | | | | | Asymptomatic | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | | ND | ND |

Supplementary Table 2

| GeneSymbol [Uniprot] [start-end] | prevalence ICU cases | prevalence asymptomatic cases | log odds ratio | M5igDB entry | aa sequence |
|-----------------------------------|----------------------|-------------------------------|----------------|--------------|--|
| ADAMTS17 [Q8T56] [1035-1125] | 25,16 | 0,31 | 4,68 | | TITSPILAAITYEYEDQWTVVYVREKLNCDQMNWYQCCQTCDFYAKMKRQPPNFG |
| AH11 [Q8N57] [855-945] | 25,16 | 0,31 | 4,68 | | TFLFAGEEGYVWVNFPEQEVAMYSOLPYKSPRSDSYFENVAFACAFGQCNPELLWYQVFNQVQAEAFERYRNGTFLPGIHQS |
| ANKK1 [Q8NF02] [495-585] | 18,94 | 0,31 | 4,32 | | TLPLUAYVYVGVVPLVLLVTSQGAELDAQQRNLRTPLHLVREGVQRAIHLKLSGAVPDALQDQGVNHTAARAGYELCKMLLVGAS |
| APC2 [Q95996] [1-90] | 18,94 | 0,31 | 4,32 | | MASSVAPEQLVQVEKAIENSHLRQLERDNGSHLSKLETTESGNKCVLHLQGLQEQEARVIVSSGQTEVELEQKALQMDTSLVNLK |
| ARHGAP24 [Q8N264] [405-495] | 18,94 | 0,31 | 4,32 | | SVHKDVSRSPLVWIKKFNAPNIGSGVITVNSFSSNAELGETLQITPNNGSLQARRSSVLSVGTSKMGTLVVIRNGLSNDSLPG |
| BAIAP3 [Q94812] [315-405] | 18,94 | 0,31 | 4,32 | | KIGNGRFYQVGVASRANGTAGPTEHDDTDFGLCLNPVREVPVAGVDRWVFIPESSASRVGGIHLVLUKITDQDRTAMGQKGGSRGLFS |
| BTB01 [Q9H0C3] [360-450] | 18,94 | 0,31 | 4,32 | | VYFGLVYSHGFTDHYQVNIQIEYKIKQTLGQDQGTGFCGQANTFRVVFKEPFLPVVCTACATLKGSDSHVTKLGGKVKVHTETPA |
| C11orf42 [Q8NSUD] [225-315] | 18,94 | 0,31 | 4,32 | | VYFPLNMPPLAPTSAPADTEAADVPPVPAVPTFPFQGEFEDKPRFYSYKGRNPPWQPQLSENVLSPRSPPGAGGGGPRDQGH |
| LDC1001 [38270] [nan] [1-90] | 18,94 | 0,31 | 4,32 | | MVTPAGLVGRQGRPREPRTAFPRSSRAGQVGVVSGAQVSSVWRERQPCSGSGRGLHILGTQGNVDTTGLGLVPTTFFQKELTGGAL |
| HMCE5 [Q96FZ2] [45-135] | 18,94 | 0,31 | 4,32 | | PQSSPVLRLHLPKEDADSSERLAPMRWGLVPSVWKESSPSKQLNTNCRSDVMEKSRVPLGKGRRCVLAQGVYVWQRCQGN |
| LRRIC73 [Q51T07] [135-225] | 56,21 | 0,31 | 6,02 | | LTPPGSAKGLLELTSANPQTTPGWSRLAIAVAHSSQVVRVNLDDPMPGQVHAGMLAVAVASSRTLVLEQLGKLPDGLTLDGMDV |
| CARD10 [Q96W77] [405-495] | 18,94 | 0,31 | 4,32 | | QLQYSLQKDKQYRKVGLAEERDELLETTLSLEGTALLEVQLDRAQGGTCLKACASSHSLSLSEFSPVLPDPGPEATGEA |
| LDC1002 [89406] [nan] [1-90] | 18,94 | 0,31 | 4,32 | | MPYVGSWGLFATGVLLKAAASELEKSSPSSEKSEKSLRNHLHLQCLAQNRGVSFSDMPKRAEKPVPKLHPISLPGSFKPLKS |
| D0K42 [Q8EX93] [90-180] | 31,37 | 0,31 | 4,99 | autoantigen | IFPAENSPTRQYFKHSKVDSDGQGLAEFMAEVEDQAARDKMLLEEKERKRVNIGRDEEEDDQEAFYRMAENPTAGVDEEEDEN |
| DNXL1 [Q9H485] [675-765] | 31,37 | 0,31 | 4,99 | | LWNEESLDRQNKSTVDAFQDPASVSELSLVWRVDPVGLVSGFSGVSELRNLHVSAPSNAWLPLTPSYCLGAYCNSQACVAS |
| DUSP7 [Q16829] [1-90] | 18,94 | 0,31 | 4,32 | | MNKGVLPPARAHMSTSGAAAGGTGTRADGEGAGSGSAGGAGTGAAGATGAGAMPCKSAGEVQLDELRAGDSGLLDCRPHHEFESHIET |
| FAM90A3 [nan] [135-225] | 31,37 | 6,52 | 1,88 | | NKCVFELVAVSGPWHVPTVSKRPRVPLADGSAEISDRGSLASLPLRKALESSSLSGQLGAAADIPQVAVRHQVREPLV |
| FAM92A [A13855] [45-135] | 50,00 | 12,73 | 1,92 | | KDQKDLVNEIYAAATEPHLEGLMNFADEFADKQVQVQEERLEAKVVEPKTYGTVMKRDKDAKATLARNRAEQQLTQERLETK |
| FGDE [Q6ZV73] [495-585] | 18,94 | 0,31 | 4,32 | | PIA00GRLPFGATGVLLKAAASELEKSSPSSEKSEKSLRNHLHLQCLAQNRGVSFSDMPKRAEKPVPKLHPISLPGSFKPLKS |
| FL46552 [nan] [90-180] | 37,58 | 0,31 | 4,32 | | DFANLEDFCHTSYRFKQPLURASHPSGLVAFDEPRSLRQ |
| ADGRA3 [Q8R6W6] [810-900] | 17,73 | 12,73 | 1,42 | | VYVGGQITRNASGCVQVGLHYSTLATVLLVWVGTARNYKQVTQAKRCCQEPDFPPRMLRYVGGGPFVIGGITAANKNY |
| IFT172 [Q9UG01] [270-360] | 18,94 | 0,31 | 4,32 | | RISVWEAEPKEETLITLAWWRDGRVLTGLGGVEQDCLCLRSYKWFELVYVGSYVNTLSSVGTVRVLSHIGVFEVEE |
| KALRN [D66228] [2430-2520] | 18,94 | 0,31 | 4,32 | | ILGHWVLEKINSEASECDDLPNTSMELAPNFIQVAPFLVLDVTLGGDFVLQKVCGRPFRTVWLDQKVTGDAADIPQVAVRHQVREPLV |
| KANK2 [Q8J2V3] [90-180] | 25,16 | 0,31 | 4,68 | | AGQSGRHSAYSVCGRFYQGALETGGFNPRVETLDAARRLEDDAATPTLGLSPLSAAAGSTASLVGGLPPFPSSGLSPVFPV |
| KCNT2 [Q6JVM3] [495-585] | 18,94 | 0,31 | 4,32 | | E2TFYAEKIGSITAFSAHKKFVGLVGRERDNKLNLLPGRVIMNSTDICVYNITEENAFKNQDQGRSASVSRVYHSGRL |
| KFC2 [Q96AC6] [405-495] | 18,94 | 0,31 | 4,32 | | LKGNVRLCRLRPGTSSSVLSVEPFGVGTVTCYGRHRRFLDWVPPDASQEVFRLEPAVLSLGRYSVCTFYGGTGTGKTYME |
| KRTAP5-2 [Q701M4] [45-135] | 25,16 | 0,31 | 4,68 | | S5SGCGSQRPVFRMWAEQFVPCVSWVPAACSTCGSGSGGSG |
| LGC514 [Q8TCE3] [45-135] | 18,94 | 0,31 | 4,32 | | GSCVITFLTFLVDQLVNFYVDMEDSDIAFQRLRFHGHANMNCVGVWRVYEKYLVYEDGPPFELCVHKEYEYVWVWG |
| LDC1002 [89406] [nan] [1-90] | 18,94 | 0,31 | 4,32 | | MVTPAGLVGRQGRPREPRTAFPRSSRAGQVGVVSGAQVSSVWRERQPCSGSGRGLHILGTQGNVDTTGLGLVPTTFFQKELTGGAL |
| LDC1002 [89634] [nan] [1-90] | 18,94 | 0,31 | 4,32 | | MPPLPSPQTPKPPGKGLPTGHTNQAETRGAEDKQRARPNASGAGQCVTPRRITHTQDHRDQGRKREKREGRGEGREBERERUKR |
| LDC1002 [94071] [nan] [855-945] | 18,94 | 0,31 | 4,32 | | IMHEVRYKCECGTKTWFPLNKRHBTGKPYKCECGTKTFCSSLKHSHSHTGDRTPAKNAKPLGGSLTLNLSHSHKHRT |
| LDC1002 [94086] [nan] [1485-1575] | 18,94 | 0,31 | 4,32 | | PERASRWSFLPRMWAEQFVPCVSWVPAACSTCGSGSGGSG |
| LDC1973 [50] [nan] [360-450] | 18,94 | 0,31 | 4,32 | | GYPVAYRQDSSQQLTVELRANPGLDELLETVNRRVCEQVLPDQDELREKLEERSLRRLCLQA |
| LDC4405 [77] [nan] [90-180] | 18,94 | 0,31 | 4,32 | | TYPVGLVGRQGRPREPRTAFPRSSRAGQVGVVSGAQVSSVWRERQPCSGSGRGLHILGTQGNVDTTGLGLVPTTFFQKELTGGAL |
| LYSG6F [Q5Q564] [135-225] | 18,94 | 0,31 | 4,32 | | ADGSPNCLVCSVPRMDSVTVWQKGGPVGRVGVFWSGSAALLVCPGGSESPRPRRIRKLVHMKVSVLSAASDASPLC |
| MOCOS [Q6EEN8] [180-270] | 18,94 | 0,31 | 4,32 | | EERSASANPDCDLPLHLYCFYQNSVGVVGRVPSLWSEVSGVFLVSTPGKAVLDAAYVSTGLPSLASHAQDVPVYGFYGGFT |
| MRSB3 [Q80X7] [45-135] | 18,94 | 0,31 | 4,32 | | SQQLPRTPLQLHVTQEGKTESAFEGYTHKDPKGVYCVVCGTLPKSETQDSGSGVPSYHVDVNGEATITDDPFTGMHRYVITS |
| NAV1 [Q8NYS1] [270-360] | 25,16 | 0,31 | 4,68 | | NLEETMSSLRGSGVYSHLEMTCYSDOANPDSVLSNRSPSWRHWGQSPRQAGDAPSGVGGSGDFPVLWPPMVPSSGSHRPAVL |
| NCAN [Q14594] [495-585] | 18,94 | 0,31 | 4,32 | | PEPGLDGGMAASADPTSEAAVNGEPLPAMAVTEMLGGQSRSPWADLTHEVDMGPAASGAGSGSPEPVLWPPMVPSSGSHRPAVL |
| NFATC1 [Q95444] [540-630] | 12,73 | 50,00 | -1,92 | | GKRNITLHGRALWGLMCCYVSAQQLLAQAQVSDSDFLVRANGVVPSTALEFHTVQFFAALYVDPVAGVYRLLRFH |
| NFATC4 [Q14594] [135-225] | 18,94 | 0,31 | 4,32 | | SRRPLPAPSGVQSQPARSVLGGPQGGGAGGGGGVLECPSTPTPFPALLENPDPAHDTGQFYSVYDPPPEGFGEVAGGQQG |
| NDC2 [Q9HCA2] [540-630] | 18,94 | 0,31 | 4,32 | | GFPPRLTLLGRALWGLMCCYVSAQQLLAQAQVSDSDFLVRANGVVPSTALEFHTVQFFAALYVDPVAGVYRLLRFH |
| NL1 [Q9Y5A7] [180-270] | 18,94 | 0,31 | 4,32 | | LKXKQDRKTRLEAKRAAEVYVCPREMTPLDANQTVGRSPRERKALMAMGVYKGRAPRLEKIPCLLDADKDYFCECC |
| OCLR [Q91668] [360-450] | 37,58 | 6,52 | 2,16 | | RFVFNHTTICVNGLAAHVEFERRNQYKDKARMSFVPMQTLQJMLMKNHVVWLDGRLNRKREKGVADPLDADKDYFCECC |
| PATL1 [Q8E7B9] [720-810] | 37,58 | 6,52 | 2,16 | | ATRELLRQPAALAKSIFNPLVSLVRYVDRQKLLEKLLQVQGR |
| PATL2 [Q9E40] [1-90] | 37,58 | 12,73 | 1,42 | | RKCLRGTGKTCGLASEELVSAQQLXEENEGE EEEEEDEEDLPDLDPQEEENDGDPVGLVAVNHTQRALSSPQKAPGMLG |
| PATL2 [Q9E40] [135-225] | 31,37 | 6,52 | 1,88 | | LPCSLVTPVYVRFSLQHPHRLQQLQQHSGTSPAKXPVQSQDFYANLMTREKXDVWVWVQVGLQSAKFLDQVYEQYKQ |
| PCDH8 [Q9Y5E8] [360-450] | 31,37 | 6,52 | 1,88 | | PETEVALFRIRDRDSENGKMICQDQVQFLKSPVNFYRVTGALDRTRAEYNTITDGLTFRLETRERREARRVVEELDQGAELPFGVGGVAC |
| PLC8 [Q0072] [855-945] | 18,94 | 0,31 | 4,32 | | NGALAPYVPSVPAARAGEEAMAEPTASLEELRLQVVLQVRRHRELEERRGARVEELDQGAELPFGVGGVAC |
| PLGG2 [P36885] [810-900] | 18,94 | 0,31 | 4,32 | | YVTRGQVYVWYVEDSADFEELKQJEDNPLGSLRGLDNLTVYRWAAPQGNQKQSFVFLPEGRGAETADRVLELDFW |
| PRDK3 [P30048] [135-225] | 18,94 | 0,31 | 4,32 | | SHFLSLAVNTRPKNGLGHHMALLSCLTKSQSDYVGLLEGGSLALGRLDPNQGVIHLSVNDLQVDFSEVLELWIKVAFYVETH |
| RAP67 [Q9V4G8] [225-315] | 18,94 | 0,31 | 4,32 | | IADQDYRILNQQVKMVDVEEGEIVMWEHRELDRTGRGHWKGTSERLTMDHVEHSVVDPTTFFVDETLYRRTLSQSPVMDK |
| ROBO2 [Q9HCK4] [540-630] | 56,21 | 0,31 | 6,02 | | PSFKPQVTVNENSVLQVPGTPTLPASAYEAFSGVSNSGVTVANNKTTLTVVGRPLNTVYMVAHVEPGLDQVSDPSPQVR |
| RSU1 [Q15404] [45-135] | 18,94 | 0,31 | 4,32 | autoantigen | VLSHNLTMVPNPPALLENLVLNFTNQLIEELPTQSSQLKHLKLNKRNLTLPFGGSLPVLNENSGPGENFFLT |
| RUNC3 [Q8N0D] [405-495] | 18,94 | 0,31 | 4,32 | | DPQVSGDGGKQDTLNVWSEKEDTSSLGCGSLTVSAVSESLTSLKNDVLSAFTTETMSTGLPS |
| RWDD1 [Q9H46] [45-135] | 18,94 | 0,31 | 4,32 | | IEVQTLKVTSEYKDEAPLYEYFSGENLEDNDVSDIHLALQAEENLGMVFTLTVAVQENLNEVQKTRREEKQKEKAEK |
| MTREX1 [P4285] [585-675] | 18,94 | 0,31 | 4,32 | autoantigen | ESKSPQDYHRAIPVYKDYVWEEYQYNKVPREESVYVYVYRQVLAUKGKIEEYHREYCLPLGQLRWVKNWEGDDGFWGVV |
| SLOC2 [SLOC2] [1-90] | 18,94 | 0,31 | 4,32 | | M3G0RDLVHLAGGGCGGTGVALTCPLEVYVTRQLQSSVTVLVEVQLNTMAGASVWVYVSPFHCILVKLKEGRSLRGLGAVGV |
| SNX19 [Q92543] [450-540] | 18,94 | 0,31 | 4,32 | | TADKEQGVYAVTALLEGKPTKSPRSCLKLDLNDVSLDPTLPPVLSSPPGLSSATSPFLASPLSPDGVYVQKRLTGITIT |
| SPTAN5 [Q9NR6C] [360-450] | 18,94 | 0,31 | 4,32 | | LSQVWRALVEAARSGALQQLRLLQLRLETLARRFQHAALRESFLIDAEQVLDQARAPPASLITVEAAVQELGAEGLVQEGRFQA |
| TIAM2 [Q8NV5] [1350-1440] | 18,94 | 0,31 | 4,32 | | VYVWRALVEAARSGALQQLRLLQLRLETLARRFQHAALRESFLIDAEQVLDQARAPPASLITVEAAVQELGAEGLVQEGRFQA |
| TI1 [P35590] [270-360] | 18,94 | 0,31 | 4,32 | | QCPQSGGCHLFLCQPPYGCSSGSGWRSQCACAPGHGADCLRQCLQNGGTCDFRSGPFLVYVWVWVWVWVWVWVWVWVWVWVWV |
| TPS38K [Q95544] [180-270] | 18,94 | 0,31 | 4,32 | | LDLDFLSALPEDGVDLYLEKALSTHPNTVTEAFKSTYSSKARPVLUKDELVRLGRSVMG |
| TRAF6 [Q9H4K] [180-270] | 18,94 | 0,31 | 4,32 | | DCPRQVSDCNCASMAFEDKIHQDNCPLAVICEYCNLIREQMPNHFDLDCPTAPIPTFTFGGHEKMRHRLRHLDQNTQSHM |
| TRANK1 [O15050] [1035-1125] | 18,94 | 0,31 | 4,32 | | TGKTTCLYRVLNKPHYVWEKAGQAGSLAQLVWLRLEVEPGKESPGGEEEEEDEEEDSIEVTEVSDGQVEACAGGAVEP |
| TTN1 [Q8W42] [2295-2385] | 18,94 | 0,31 | 4,32 | | MGGVYHNDVLESNGKHTISRRGRQLTVKDVTKDQGEYSFDVGGKTCCKLMKPRPAILQLSDQKCEQDQVQWVLESVE |
| CARD8 [Q9Y2G2] [1-90] | 18,94 | 0,31 | 4,32 | | RASGTRLSPTNLTFFFHPEDKFLYVSDAALLTKADDEEORHFVRGVRQVSPMELNFGVYSVSGANLVWVMPVEWSSL |
| VPS10 [Q8TH4] [2880-2970] | 25,16 | 0,31 | 4,68 | | PRRRQVPPVAVRNHTGCTLWATLTTPTRAALSHSQSPVPEGNGTFLDQTHNSVWREVLVGESEPTFAEAGKLRHRTIDLRH |
| CFAP52 [Q8N1V2] [1-90] | 18,94 | 0,31 | 4,32 | | MDNKRPEADVALELDVIGFDILWYDNRELLARELSHKGEALFSPNDFLVSGLDQDGVVWVWVWVWVWVWVWVWVWVWVWV |
| WNK2 [F8W9F9] [585-675] | 18,94 | 0,31 | 4,32 | | MPSEPEADQHLPTLPTSLASDSTVDSGQGSVYSDSQSQVSLGGLADAAPSAPQCVSPVSEGPLVQSLPGLGAYQCP |
| XCR1 [P46094] [1-90] | 18,94 | 0,31 | 4,32 | | PPSSEFESTTFFYDLQSQPCENQAVVATLATTLYLVLSVGSALVWLVWVWVWVWVWVWVWVWVWVWVWVWVWVWVWVWV |
| ZNF598 [Q8ELK7] [135-225] | 18,94 | 0,31 | 4,32 | | QHMWRQVHLCBLQLHQLFTYERWYSRDLARHMQGQDPTSHRQHLCKCDERYLNDLDELHLKRRDHYFCFLCDSDGAGQDY |
| ZP1 [P60852] [1-90] | 62,42 | 0,31 | 6,28 | | MAGGSATWGYVALLVATLGLGRWLQDQPLGLRHSYDCRGKMGQLLVPFPPQGLRFRVDFEENFGDVMNCXCHHVVTSRQJE |

Supplementary Table 3. Screening of positive ANA prepandemic samples (i.e., prior Covid-19) against different viruses.

| Sample | Gender | ANA IgG | Dengue | Chikungunia | HEV IgM | HEV IgG | B19V IgM | B19V IgG | WNV IgM | WNV IgG |
|--------|--------|----------|----------|-------------|----------|----------|----------|----------|----------|----------|
| A | M | positive | positive | Negative | ND | ND | Negative | Positive | Negative | Positive |
| B | M | positive | Negative | Negative | Negative | Negative | Negative | Positive | Negative | Negative |
| C | M | positive | ND | ND | Negative | Negative | Negative | Positive | ND | ND |
| D | M | positive | ND | ND | ND | ND | Negative | Positive | ND | ND |
| E | M | positive | ND | ND | ND | ND | ND | ND | Negative | Positive |

ND: Not determined.