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The rate and associated factors with antibody response in patients with COVID-19 infection

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Ethics Committee Approval
The study was approved by the Clinical Research Ethics Committee of Ümraniye Training and Research Hospital, University of Health Sciences in June 12, 2020 with the number B.10.1.TKH.4.34.H.GP.0.01/177.
All procedures in this study involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments.

Conflict of Interest
No conflict of interest was declared by the authors.

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Abstract

Background/Aim: It remains unknown in what form and to what extent antibodies to SARS-CoV-2 confer immunity and whether these antibodies from previous infections could ensure protection from reinfection. This study aimed to investigate the rate of antibody positivity among patients who recovered from COVID-19 infection and the factors influencing antibody production among these patients.
Methods: This prospective case control study included 111 males (mean age: 34 years, range: 18-60 years) who recovered from PCR-confirmed COVID-19. The patients underwent antibody testing on the 28th day of recovery. Sixty-seven patients (60.4%) had antibodies against COVID-19 as well as positive IgM and IgG, and 39.6% of patients were negative for Ab production.
Results: The mean ages of the antibody-positive and negative groups were 43 and 29 years, respectively, the age of the positive group was significantly higher than the age of the negative group (P<0.001). The rate of antibody production in symptomatic patients was approximately 4.5 times higher than that in asymptomatic patients. The factors that were associated with antibody production were advanced age (OR=1.1), cough (OR=6.1), fever (OR=4.5), shortness of breath (OR=12.4), myalgia (OR=4.7), increased levels of CRP (OR=32.1), sedimentation rate (OR=17.3), LDH (OR=6.9), D-dimer (OR=10.6), ferritin (OR=29.4), and the presence of lymphopenia (OR=4.2) and thrombocytopenia (OR=7.1).
Conclusion: The finding that a substantial number of patients recovering from COVID-19 did not develop antibody response suggests that these patients are still at risk for reinfection. In addition, patients who have experienced symptomatic disease course, advanced age and developed higher inflammatory response may be better candidates for plasma donation.

Keywords: Reinfection, SARS-CoV-2, Antibody, Covid-19

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Introduction

Severe Acute Respiratory Syndrome *Coronavirus*-2 (SARS-CoV-2) has been the third new coronovirus resulting in outbreaks following SARS-CoV-1 and Middle East respiratory syndrome coronavirus (MERS-CoV) in the past two decades. The infection is called *Coronavirus* Disease 2019 (COVID-19) [1].

The presence of positive anti-SARS-CoV-2 antibodies indicates that the individual experienced SARS-CoV-2. IgG antibodies which are specific for SARS-CoV-2 develop later than SARS-CoV-2 IgM antibodies. Concurrent IgM and IgG antibody positivity cannot rule out recently infected patients who may still be contagious [3]. Antibody response to SARS-CoV-2 presumably provides immunity that protects the individual against reinfection of the virus, but it still remains unknown in what form and to what extent antibodies to SARS-CoV-2 confer immunity and whether these antibodies from previous infections could ensure protection from reinfection [4]. People recovering from an infection are known to develop antibodies against the pathogen. The use of plasma from recovered patients has been utilized for years for treatment of infected patients or to protect healthy people against infections. This is also the case for plasma from COVID-19 survivors, which was shown to provide clinical improvement, to decrease viral load and increase blood oxygen concentrations within 24 hours [5]. Due to the role of convalescent plasma in the treatment of COVID-19 patients, efforts to identify individuals with immunity that protects against the disease have increased over time [2].

This study aimed to investigate the rate of antibody positivity and the factors affecting antibody production among COVID-19 survivors who presented to our hospital for plasma donation.

Materials and methods

Study design and patients

This study was planned as a retrospective cross-sectional study at our hospital, a tertiary education and research hospital working as a reference center during the COVID-19 pandemic. The study was approved by the Clinical Research Ethics Committee of Ümraniye Training and Research Hospital, University of Health Sciences in June 12, 2020 with the number B.10.1.TKH.4.34.H.GP.0.01/177.

A potential plasma donor must receive a prior diagnosis of COVID-19 confirmed by a positive RT-PCR test on the oro-nasopharyngeal swab specimen. To become a plasma donor after recovery, molecular test results of two consecutive oro/nasopharyngeal swab samples obtained at least 24 hours apart must be negative, and at least 14 must pass after recovery. In case of the absence of a negative test result, at least 28 days must pass from the clinical recovery. Plasma donors are preferably selected among men, but women who are not pregnant, and persons who have not received a blood transfusion can also be candidates [6]

This study included 111 male COVID-19 survivors aged 18-60 years whose clinical recovery was confirmed by RT-PCR testing from oro/nasopharyngeal swabs and who presented to our hospital between April 15 and June 1, 2020, for plasma donation at the 28th day of recovery. In the antibody-positive group, all patients had positive antibody tests both for IgM and IgG.

Exclusion criteria were female gender (due to their small number), being younger than18 or older than 60 years old, lack of a positive PCR test result, a history of previous blood transfusion, a longer or shorter period of recovery than 28 days.

Identification of SARS-CoV-2 IgM and IgG antibodies

The lateral flow immunochromatographic assay (ICA) strip (Colloidal Gold-The Weimi Diagnostic Kit, China) was used. Venous blood samples of the patients were sent to the laboratory immediately after being taken into EDTA tubes and serum samples were studied after centrifugation.

Definition of clinical recovery

The date of clinical recovery was defined as the date of discharge of hospitalized patients, the completion of a 5-day-treatment of patients who received treatment at home without any indication for hospitalization and who did not develop any symptoms that required re-presentation to the hospital.

Data collection

Among patients who presented to the outpatient department of infectious diseases to donate plasma, those who underwent SARS-CoV-2 antibody testing on the 28th day of clinical recovery were included in the study. The baseline laboratory findings were examined. Data were recorded on the laboratory findings, the symptoms at presentation, ages and comorbidities as well as the time when symptoms developed, and thorax computerized tomography (CT) was performed. The treatments specific to COVID-19 that the patients received either at the hospital or at home were also noted.

Signs of pneumonia on CT imaging, laboratory results including white blood cell (WBC), neutrophil, lymphocyte, platelet counts, levels of CRP, lactate dehydrogenase (LDH), D-dimer, and ferritin and sedimentation rate were recorded. Patients' records were reviewed in terms of symptoms at presentation including fever, shortness of breath, cough, myalgia, and impaired smell and taste. Treatment protocols specific to COVID-19 with hydroxychloroquine and azithromycin were noted.

Statistical analysis

Continuous variables were expressed as mean (SD), median, minimum and maximum, and categorical variables, as frequencies and percentages. Due to their small number (n=2), female patients were excluded from the study. The Mann–Whitney U or the Pearson Chi-square (or Fisher's exact) tests were used for statistical analysis, as appropriate. Logistic regression analysis was performed to determine the factors affecting antibody response. Analyses were performed using SPSS Version 21.0 (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY). *P*-values less than or equal to 5% were considered significant.

Results

The mean age of the 111 patients included in the analysis was 34 (13.11) years (median: 33 years, range:19-60 years). At the 28th day of recovery, 67 patients (60.4%) had antibodies against COVID-19. The patients received

hydroxychloroquine for an average of five days (min:5, max:10) and azithromycin for four days (min:3, max:9) (Table 1). The mean age of those who had antibody response was 43 years, compared with 29 years in the antibody-negative group (Table 2).

Symptoms at presentation

Of 111 patients, 77 (69.4%) had at least one symptom at presentation, while 34 (30.6%) were asymptomatic at the time of RT-PCR and during the treatment (Figure 1). Thirty-eight patients (34.2%) had high fever, 16 (14.4%) had shortness of breath, 50 (45%) had cough, and 46 (41.4%) had myalgia. Three patients (2.7%) had loss of taste and smell.

In the antibody-positive group, 6 patients (9%) were asymptomatic at the time of RT-PCR-confirmed diagnosis. The remaining 61 patients (91%) had at least one complaint, including fever in 31 (46.3%), shortness of breath in 15 (22.4%), cough in 41 (61.2%), and myalgia in 37 (55.2%). All three patients (4.5%) with complaints of inability to smell and taste developed antibody response. (Table 2) (Figure 1).

Of patients who did not produce antibody response, seven (15.9%) had high fever, one (2.3%) had shortness of breath, nine (20.5%) had cough, and nine (20.5%) had myalgia (Table 3).

Laboratory findings

Laboratory results of the study group are summarized in Table 1. At baseline, 14 patients (12.6%) had decreased and seven (6.3%) had increased WBC counts. Thirty-six patients (32.4%) had an increased neutrophil percentage. Sixty-one patients (55%) had decreased lymphocyte counts and 43 (38.7%) had a decreased lymphocyte percentage. Thrombocytopenia was detected in 26 patients (23.4%). Elevated levels of CRP, LDH, D-dimer, and ferritin and an increased sedimentation rate were found in 50 (45%), 36 (33.3%), 25 (25%), 28 (28.3%), and 34 patients (40.5%), respectively. No patient had an increased procalcitonin level (Table 1).

Figure 1: The rates of antibody positivity in symptomatic and asymptomatic groups

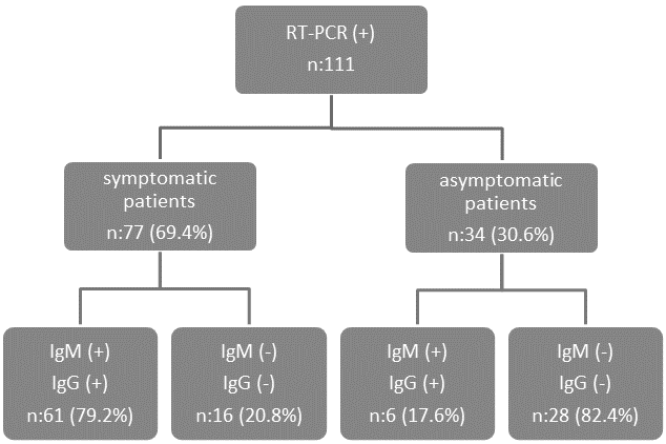

Table 1: Characteristics of the patients

Laboratory Findings		n	%
COVID-19 IgM & IgG	Positive	67	60.4
	Negative	44	39.6
	Total	111	100.0
Decreased WBC count	Present	14	12.6
	Absent	97	87.4
	Total	111	100.0
Increased WBC	Present	7	6.3
	Absent	104	93.7
	Total	111	100.0
Increased Neutrophil %	Present	36	32.4
	Absent	75	67.6
	Total	111	100.0
Decreased Lymphocyte Count	Present	61	55.0
	Absent	50	45.0
	Total	111	100.0
Decreased Lymphocyte %	Present	43	38.7
	Absent	68	61.3
	Total	111	100.0
Decreased platelet count	Present	26	23.4
	Absent	85	76.6
	Total	111	100.0
Increased CRP	Present	50	45.0
	Absent	61	55.0
	Total	111	100.0
Increased Sedimentation	Present	34	40.5
	Absent	50	59.5
	Total	84	100.0
Increased LDH	Present	36	33.3
	Absent	72	66.7
	Total	108	100.0
Increased D-dimer	Present	25	25.0
	Absent	75	75.0
	Total	100	100.0
Increased Ferritin	Present	28	28.3
	Absent	71	71.7
	Total	99	100.0
Increased Procalcitonin	Present	0	0.0
	Absent	110	100.0
	Total	110	100.0

Medical Background		n	%
Concomitant Disease	Present	13	11.7
	Absent	98	88.3
	Total	111	100.0
Hypertension	Present	7	6.3
	Absent	104	93.7
	Total	111	100.0
Diabetes Mellitus	Present	4	3.6
	Absent	107	96.4
	Total	111	100.0
Chronic heart disease	Present	4	3.6
	Absent	107	96.4
	Total	111	100.0
Psoriasis	Present	1	0.9
	Absent	110	99.1
	Total	111	100.0
HIV	Present	1	0.9
	Absent	110	99.1
	Total	111	100.0

Symptoms		n	%
Fever	Present	38	34.2
	Absent	73	65.8
	Total	111	100.0
Shortness of Breath	Present	16	14.4
	Absent	95	85.6
	Total	111	100.0
Cough	Present	50	45.0
	Absent	61	55.0
	Total	111	100.0
Myalgia	Present	46	41.4
	Absent	65	58.6
	Total	111	100.0
Loss of smell	Present	3	2.7
	Absent	108	97.3
	Total	111	100.0
Loss of taste	Present	3	2.7
	Absent	108	97.3
	Total	111	100.0.

Table 2: Treatments, regression of symptoms and involvement on CT of response-positive and negative patients

		COVID-19 IgM & IgG Positive	Negative	*P*-value
Symptom	Present	6 (9.0%)	28 (63.6%)	<0.001
	Absent	61 (91.0%)	16 (36.4%)	
Involvement on CT	Present	40 (59.7%)	19 (43.2%)	0.088
	Absent	27 (40.3%)	25 (56.8%)	
Age (Years)	Mean	43.0	29.0	<0.001
	Standard Deviation	12.387	9.103	
	Median	46.0	26.0	
	Minimum	20.0	19.0	
	Maximum	60.0	52.0	
Use of hydroxychloroquine (Days)	Mean	6.0	5.0	0.011
	Standard Deviation	1.812	1.257	
	Median	5.0	5.0	
	Minimum	2.0	2.0	
	Maximum	10.0	10.0	
Azithromycin use (Day)	Mean	4.0	3.0	0.275
	Standard Deviation	1.390	0.882	
	Median	3.0	3.0	
	Minimum	2.0	3.0	
	Maximum	9.0	5.0	

In the antibody-positive group, 12 patients (17.9%) had leukocytosis and four (6%) had leukopenia. Twenty-one patients (31.3%) had an increased neutrophil percentage, 46 (68.7%) had decreased lymphocyte counts and 30 (44.8%) had a decreased lymphocyte percentage. Twenty-three (34.3%) had thrombocytopenia. Elevated levels of CRP, LDH, D-dimer, and ferritin, and an increased sedimentation rate were detected in 47 (70.1%), 31 (47.7%), 23 (37.1%), 27 (44.3%), and 32 patients (57.1%), respectively, with none having an increased procalcitonin level (Table 3).

In the antibody-negative group, two patients (4.5%) had leukopenia and three (6.8%) had leukocytosis. Fifteen patients (34.1%) had an elevated neutrophil percentage. Decreased lymphocyte counts and decreased lymphocyte percentage were observed in 15 (34.1%) and 13 (29.5%) patients, respectively. Only three patients (6.8%) had thrombocytopenia. Increased levels of CRP, LDH, D-dimer, and ferritin and an increased sedimentation rate were found in three (6.8%), five (11.6%), two (5.3%), one (2.6%), and two (7.1%) patients, respectively. None had an increased procalcitonin level (Table 3).

Concomitant diseases

Overall, 13 patients (11.7%) had at least one accompanying disease, including hypertension in seven patients (6.3%), diabetes in four (3.6%), chronic heart disease in four (3.6%), psoriasis in one, and HIV in one (0.9%) (Table 1). In the antibody-positive group, 10 patients (14.9%) had at least one concomitant disease, including hypertension in five (7.5%), diabetes in four (6%), chronic heart disease in two (3%), and HIV in one patient (1.5%). The remaining three patients (6.8%) in the antibody-negative group had at least one concomitant disease, including hypertension in two (4.5%), chronic heart disease in two (4.5%) and psoriasis in one (2.3%) (Table 3).

CT findings

Chest CT showed pneumonia in 59 patients and no pulmonary involvement in 52 patients. The majority of patients with pulmonary involvement were in the antibody-positive group (n=40, 67.8%) (Table 2).

Logistic regression analysis

The factors associated with antibody production are summarized in Table 4. Only pneumonia on CT imaging did not have a significant effect on antibody production (P=0.09). All other factors were found to have significant effects on antibody positivity, including age (OR=1.1; %95 CI=1.0-1.2; P<0.001), decreased lymphocyte count (OR=4.2; 95% CI=1.9-9.5; P<0.001), thrombocytopenia (OR=7.1; 95% CI=2.0-25.6; P=0.003), elevated levels of CRP (OR=32.1; 95% CI=8.9-115.9; P<0.001), LDH (OR=6.9; 95% CI=2.4-19.8; P<0.001), D-dimer (OR=10.6; 95% CI=2.3-48.2; P=0.002), ferritin (OR=29.4; 95% CI=3.7-228.1; P=0.001), increased sedimentation rate (OR=17.3; 95% CI=3.7-80.2; P<0.001), high fever (OR=4.5; 95% CI=1.8-11.7; P=0.002), shortness of breath (OR=12.4; 95% CI=1.6-97.7; P=0.017), cough (OR=6.1; 95% CI=2.5-14.8; P<0.001) and myalgia (OR=4.7; 95% CI=2.0-11.5; P<0.001).

Table 3: Concomitant diseases and laboratory findings of response-positive and negative patients

		COVID-19 IgM & IgG Positive n (%)	Negative n (%)	*P*-value			COVID-19 IgM/IgG Positive n (%)	Negative n (%)	*P*-value
Concomitant Disease	Present	10 (14.9)	3 (6.8)	0.318	Decreased WBC	Present	12 (17.9)	2 (4.5)	0.075
	Absent	57 (85.1)	41 (93.2)			Absent	55 (82.1)	42 (95.5)	
Hypertension	Present	5 (7.5)	2 (4.5)	0.701	Increased WB	Present	4 (6.0)	3 (6.8)	1.000
	Absent	62 (92.5)	42 (95.5)			Absent	63 (94.0)	41 (93.2)	
Diabetes Mellitus	Present	4 (6.0)	0 (0.0)	0.151	Increased Neutrophil	Present	21 (31.3)	15 (34.1)	0.924
	Absent	63 (94.0)	44 (100.0)			Absent	46 (68.7)	29 (65.9)	
Chronic Heart Disease	Present	2 (3.0)	2 (4.5)	0.648	Decreased Lymphocyte count	Present	46 (68.7)	15 (34.1)	<0.001
	Absent	65 (97.0)	42 (95.5)			Absent	21 (31.3)	29 (65.9)	
Psoriasis	Present	0 (0.0)	1 (2.3)	0.396	Decreased Lymphocyte %	Present	30 (44.8)	13 (29.5)	0.107
	Absent	67 (100.0)	43 (97.7)			Absent	37 (55.2)	31 (70.5)	
HIV	Present	1 (1.5)	0 (0.0)	1.000	Decreased Thrombocyte count	Present	23 (34.3)	3 (6.8)	0.002
	Absent	66 (98.5)	44 (100.0)			Absent	44 (65.7)	41 (93.2)	
Fever	Present	31 (46.3)	7 (15.9)	0.001	Increased CRP	Present	47 (70.1)	3 (6.8)	<0.001
	Absent	36 (53.7)	37 (84.1)			Absent	20 (29.9)	41(93.2)	
Shortness of Breath	Present	15 (22.4)	1 (2.3)	0.007	Increased Sedimentation	Present	32 (57.1)	2 (7.1)	<0.001
	Absent	52 (77.6)	43 (97.7)			Absent	24 (42.9)	26 (92.9)	
Cough	Present	41 (61.2)	9 (20.5)	<0.001	Increased LDH	Present	31 (47.7)	5 (11.6)	<0.001
	Absent	26 (38.8)	35 (79.5)			Absent	34 (52.3)	38 (88.4)	
Myalgia	Present	37 (55.2)	9 (20.5)	<0.001	Increased D-dimer	Present	23 (37.1)	2 (5.3)	0.001
	Absent	30 (44.8)	35 (79.5)			Absent	39 (62.9)	36 (94.7)	
Loss of Smell	Present	3 (4.5)	0 (0.0)	0.276	Increased Ferritin	Present	27 (44.3)	1 (2.6)	<0.001
	Absent	64 (95.5)	44 (100.0)			Absent	34 (55.7)	37 (97.4)	
Loss of Taste	Present	3 (4.5)	0 (0.0)	0.276	Increased Procalcitonin	Present	0 (0.0)	0 (0.0)	NA
	Absent	64 (95.5)	44 (100.0)			Absent	66 (100.0)	44 (100.0)	

Table 4: Factors Affecting IgM/IgG Production in patients with COVID-19

Risk Factor	OR (95% Cl)	*P*-value
Age	1.1 (1.0-1.2)	<0.001
The Presence CT Involvement	1.9 (0.9-4.2)	0.090
Concomitant Disease	2.4 (0.6-9.3)	0.205
Hypertension	1.7 (0.3-9.1)	0.540
Diabetes Mellitus	NA	NA
Chronic Heart Disease	0.6 (0.1-4.8)	0.668
Psoriasis	NA	NA
Decreased WBC	4.6 (1.0-21.6)	0.054
Increased WBC	0.9 (0.2-4.1)	0.857
Increased NEU %	0.8 (0.4-2.0)	0.883
Decreased Lymphocyte count	4.2 (1.9-9.5)	<0.001
Decreased Lymphocyte %	1.9 (0.9-4.3)	0.109
Decreased Platelet count	7.1 (2.0-25.6)	0.003
Increased CRP	32.1 (8.9-115.9)	<0.001
Increased Sedimentation	17.3 (3.7-80.2)	<0.001
Increased LDH	6.9 (2.4-19.8)	<0.001
Increased D-Dimer	10.6 (2.3-48.2)	0.002
Increased Ferritin	29.4 (3.7-228.1)	0.001
Fever	4.5 (1.8-11.7)	0.002
Shortness of Breath	12.4 (1.6-97.7)	0.017
Cough	6.1 (2.5-14.8)	<0.001
Myalgia	4.7 (2.0-11.5)	<0.001
Loss of smell	NA*	NA*
Loss of taste	NA*	NA*

Variables specified as NA* were not evaluated because of impairing the significance of the model
[CI: Confidence Interval], [OR: Odds Ratio]. Dependent variable: IgM/IgG test result (positive or negative).

Discussion

Antibodies produced against SARS-CoV-2 can be detected at an average of 10 to 15 days after the onset of symptoms, and for IgG, it may take 20 days [7]. To detect seropositivity, we assessed only the results of antibody tests obtained on the 28th day of clinical recovery. Thus, time to detect antibodies was adequate and eliminated the effect of changes that may occur over time on antibody production.

COVID-19 specific antibodies can be detected by enzyme-linked immunosorbent assay (ELISA) and immunochromatographic assay (ICA). A study examined seven different ICA tests and compared them with ELISA. The sensitivity of ICA 14-25 days after the onset of the symptoms exceeded 92% for IgG as compared with 89.5% with ELISA. Specificity of ICA was between 91.3%-100% for IgM and 90.3%-99.0% for IgG, being between 97.1%-100% for both IgG and IgM. The sensitivity of ICA was as high as that of ELISA during the first 3 weeks from the onset of complaints [8]. In a study with the ICA antibody test, Imai et al. found that all COVID-19 patients with IgG positivity also had IgM positivity [9]. The utility and sensitivity of combined IgM-IgG analysis were higher than those of a single IgM or IgG test [10]. In our study, antibody tests were performed with the ICA and both IgM and IgG were positive in 67 patients.

Because the detection of antibodies is only possible after a considerably long time from the onset of infections, antibody tests are not a convenient method to detect acute infections. These tests may particularly be useful for isolation programs, examination of antibody responses related to protection against SARS-CoV-2, patient triage, identification of infection-related deaths, determining the exact rate of infection in an affected area, and identification of a potential plasma donor who has recovered from COVID-19 [11,12]. In the fight against the spread of COVID-19, considerable efforts have been made nationwide for the utilization of plasma treatment, screening for potential donors and encouraging plasma donation. Accordingly, we used antibody tests to analyze seroconversion of recovered patients who presented to our outpatient department to donate plasma.

This study included only men due to the small number (n=2) of female patients applying for plasma donation. Interestingly, there was a striking gap between the mean ages of antibody-positive and negative patients. Similar to our results, the incidence of antibody production was higher in individuals over 40 years of age than in the younger patients [7]. The low antibody response in young patients may be associated with the increased rate of asymptomatic disease among them.

Antibody positivity was linked to a poorer clinical course [7]. Long et al. found IgG positivity in 93.3% of asymptomatic patients and in 96.8% of symptomatic patients during the early recovery period. In the asymptomatic group, IgG became negative in the subsequent follow-up of 40% of seropositive patients. These findings suggest that asymptomatic individuals are likely to have a weaker immune response to SARS-CoV-2 infection [13]. In this study, the rate of antibody production in symptomatic patients was approximately 4.5 times higher than in asymptomatic patients. In addition, among the symptoms at presentation, dyspnea was the leading factor in antibody production with an OR of 12.4, followed by cough (OR 6.1), myalgia (OR 4.7), and fever (OR 4.5). Among the laboratory parameters, the leading factor was CRP (OR 32.1) followed by ferritin (OR 29.4) and sedimentation rate (OR 17.3).

Failure to develop anti-SARS-CoV-2 antibody response may result from several factors, including transient viral colonization, false-positive RT-PCR results, contamination of the specimens at the time of RT-PCR, failure of the host to produce an immune response to a specific genotype of the SARS-CoV-2 virus, decreased viral load of the SARS-CoV-2 RNA, and elimination of the virus with hydroxychloroquine treatment before inducing immune response [14]. Examining serial RT-PCR test results at the PCR laboratory, we found no evidence of contamination that could lead to false positivity. Although data were insufficient to assess the relationship between the underlying immunosuppression and antibody response, we found that four patients with diabetes and one patient with HIV had antibody response. Conversely, the antibody-negative group had neither drug use nor concomitant disease that could cause any immunosuppression. It has been reported that early use of hydroxychloroquine may also be associated with failure to produce antibody response by rapidly eliminating the virus before activating the immune system. The rate of antibody response was 60.4% among participants receiving hydroxychloroquine treatment.

Even though the patients might have produced antibody response following SARS-CoV-2 infection, false negative results may be obtained due to several causes, including low IgM and IgG antibody levels below the detection threshold, decreases in IgM antibody levels after 2 weeks and their disappearance over time, low IgM levels below the peak at the time of testing [10]. In our study, a negative test for IgM was never accompanied by a positive IgG test.

Limitations

Due to lack of RT-PCR kits at our hospital to detect the viral load of SARS-CoV-2, we could not assess the effect of viral load on patients' antibody response. In addition, as we only included male patients, the results cannot be generalized for females.

Conclusions

Since the antibody response rate is significantly higher in symptomatic patients, older patients and patients with higher inflammatory parameters, these patients appear to be more suitable candidates for plasma donation. Clinical observations from this study can be used for a controlled prospective study with a larger group of patients, including a more clinically diverse population and other laboratory parameters that may affect antibody response.

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