

COVID-19 elicits an impaired antibody response against SARS-CoV-2 in patients with haematological malignancies

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Summary

COVID-19 is associated with high mortality in patients with haematological malignancies (HM) and rate of seroconversion is unknown. The ITA-HEMA-COV project (NCT04352556) investigated patterns of seroconversion for SARS-CoV-2 IgG in patients with HMs. A total of 237 patients, SARS-CoV-2 PCR-positive with at least one SARS-CoV-2 IgG test performed during their care, entered the analysis. Among these, 62 (26.2%) had myeloid, 121 (51.1%) lymphoid and 54 (22.8%) plasma cell neoplasms. Overall, 69% of patients (164 of 237) had detectable IgG SARS-CoV-2 serum antibodies. Serologically negative patients (31%, 73 of 237) were evenly distributed across patients with myeloid, lymphoid and plasma cell neoplasms. In the multivariable logistic regression, chemoimmunotherapy [odds ratio (OR), 3.42; 95% confidence interval (CI), 1.04–11.21; $P = 0.04$] was associated with a lower rate of seroconversion. This effect did not decline after 180 days from treatment withdrawal (OR, 0.35; 95% CI: 0.11–1.13; $P = 0.08$). This study demonstrates a low rate of seroconversion in HM patients and indicates that treatment-mediated immune dysfunction is the main driver. As a consequence, we expect a low rate of seroconversion after vaccination and thus we suggest testing the efficacy of seroconversion in HM patients.

Keywords: Covid-19, SARS-CoV-2, leukemia, lymphoma, myeloma.

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Introduction

COVID-19, the disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has been declared pandemic in March 2020. According to the largest series, its mortality for patients with haematological malignancies (HM) was 37%.^{1,2} A meta-analysis including 3 210 HMs reported an overall 34% risk of death.² Among 650 patients with multiple myeloma (MM),³ 198 with chronic lymphocytic leukaemia (CLL),⁴ 177 with non-Hodgkin lymphomas (NHL),⁵ and 318 who received haematopoietic stem cell transplantation (HSCT)⁶ case fatality was 33%, 33%, 34%, and 33%, respectively.

Several studies have shown that 95–100% of immunocompetent patients with COVID-19 have seroconverted about three weeks after symptom onset,^{7,8} while this information in patients with HM is scant. A low rate (67%) of anti-SARS-CoV-2 IgG development has been described in 21 patients with CLL (67%);⁹ a slightly better rate (88%) was found in eight patient with acute myeloid leukaemia.¹⁰

This study was registered in the ClinicalTrials.gov Identifier, NCT04352556. We investigated patterns of seroconversion for SARS-CoV-2 IgG in a broad range of patients with HMs. The is a retrospective study and the cohort came from the Italian Hematology Alliance on COVID-19 (ITA-HEMA-COV) project, that already provided information on mortality in HM with COVID-19.¹ Addressing the rate of humoral immune response to SARS-CoV-2 in HM patients who have been exposed to SARS-CoV-2 is a critical step to properly inform and develop vaccination strategies and monitoring in this vulnerable patient population. In fact, there is preliminary evidence showing a low rate of seroconversion after vaccines against SARS-CoV-2.¹¹

Methods

To investigate the presence of SARS-CoV-2 antibodies, we analyzed serology reports within the ITA-HEMA-COV database, starting 23 February 2020, until 17 February 2021 (first and last observed HM patient with COVID-19). The study was approved by the institutional review board of each centre. A total of 2 463 patients (735 myeloid, 1 214 lymphoid, 514 plasma cell neoplasms) were identified with a real-time polymerase chain reaction (RT-PCR) positive for SARS-CoV-2. We excluded 577 cases who died without performing

serology and 1 649 coming from centres without test availability. Eventually, 237 patients with HM, SARS-CoV-2 PCR-positive and at least one SARS-CoV-2 IgG test performed during their standard care, were included. For SARS-CoV-2 serological testing we used commercial, widely available high-throughput immunoassays available at the centres such as the Abbott (SARS-CoV-2 nucleocapsid IgG, Chicago, IL, USA), the DiaSorin (SARS-CoV-2 Spike-1 and Spike-2 IgG, Saluggia, Italy), the Roche [SARS-CoV-2 nucleocapsid and Spike protein RBD (receptor-binding-domain) IgG, Basel, Switzerland] or the Siemens (Atellica, SARS-CoV-2 Spike protein RBD IgG, Munich, Germany) tests. Sensitivity and specificity of these tests was at least 98% in a head-to-head comparison study,¹² with some divergent results in seroprevalence studies on cancer patients.¹³

Continuous variables are expressed as median, minimum, and maximum values. Categorical variables are presented as frequencies and percentages. Characteristics of the study population were described for patients with a positive result to the SARS-CoV-2 IgG test and for negative ones.

Univariate logistic regression models were applied to study the association between the absence of seroconversion and the following variables: age, sex, comorbidities, HM type, COVID-19 disease severity, hospitalization, last therapy applied and time to COVID-19, active therapy (time from last therapy to COVID-19 within three months) and time from COVID-19 to first serology evaluation. A multivariable logistic regression model, adjusted for the time from COVID-19 to first serology evaluation, was implemented using parameters of interest. In addition, we did this latter analysis on the subgroup on active therapy. The odds ratio (OR) together with the 95% confidence interval (CI) and Wald chi-square *P*-value were calculated. All statistical analyses were done with SAS version 9.4 and R statistical software version 3.2.0 (Cary, NC, USA).

Results and discussion

A total of 237 patients were evaluated: 62 (26.2%) had myeloid neoplasms, 121 (51.1%) lymphoid neoplasms, and 54 (22.8%) had plasma cell neoplasms. As the distribution of HMs was superimposable to that of the whole series of 2 463 cases (*P* = 0.40), findings obtained here can be representative of a real-life situation. Median age was 61 years (range, 19–91), male/female ratio was 1.14, with most patients having symptomatic

Table I. Characteristics of 237 patients with haematological malignancies, exposed to SARS-CoV-2 infection according to IgG serology response.

	Positive serology <i>n</i> = 164	Negative serology <i>n</i> = 73	All patients <i>n</i> = 237
Age, years			
Median [min–max]	61 [19–91]	61 [22–88]	61 [19–91]
Sex, <i>n</i> (%)			
Female	75 (45.73)	36 (49.32)	111 (46.84)
Charlson comorbidity Index			
Median [min–max]	3 [0–14]	4 [0–13]	3 [0–14]
Coexisting condition, <i>n</i> (%)			
Heart disease	16 (9.76)	9 (12.33)	25 (10.55)
Pulmonary disease	15 (9.15)	6 (8.22)	21 (8.86)
Vascular disease	19 (11.59)	4 (5.48)	23 (9.70)
Connective tissue disease	5 (3.05)	3 (4.11)	8 (3.38)
Liver disease	3 (1.83)	3 (4.11)	6 (2.53)
Kidney disease	5 (3.05)	3 (4.11)	8 (3.38)
Diabetes	5 (6.85)	13 (7.93)	18 (7.59)
Non-haematological cancer	13 (7.93)	7 (9.59)	20 (8.44)
Type of haematological malignancies, <i>n</i> (%)			
Myeloid neoplasms	14 (8.54)	4 (5.48)	18 (7.59)
Myeloproliferative neoplasm	9 (5.49)	0 (0.00)	9 (3.80)
Myelodysplastic syndrome	21 (12.80)	10 (13.70)	31 (13.08)
Acute myeloid leukaemia	3 (1.83)	1 (1.37)	4 (1.69)
Acute lymphoblastic leukaemia	4 (2.44)	2 (2.74)	6 (2.53)
Lymphomas	71 (43.29)	44 (60.27)	115 (48.52)
Hodgkin lymphomas	14 (8.5%)	1 (1.4)	15 (6.3)
Aggressive non-Hodgkin lymphomas	21 (12.80)	24 (32.88)	45 (18.99)
Indolent non-Hodgkin lymphomas	14 (8.54)	15 (20.55)	29 (12.24)
Chronic lymphoproliferative disorders	21 (12.80)	4 (5.48)	25 (10.55)
Plasma cell neoplasms	42 (25.61)	12 (16.44)	54 (22.78)
Plasma cell myeloma	33 (20.12)	11 (15.07)	44 (18.57)
Symptomatic, <i>n</i> (%)			
Yes	52 (71.23)	134 (81.71)	186 (78.48)
COVID-19 disease severity, <i>n</i> (%)			
Mild	78 (47.56)	32 (43.84)	110 (46.41)
Severe	51 (31.10)	19 (26.03)	70 (29.54)
Critical	5 (3.05)	1 (1.37)	6 (2.53)
Asymptomatic	30 (18.29)	21 (28.77)	51 (21.52)
Last therapy type, <i>n</i> (%)			
Chemotherapy	47 (28.66)	15 (20.55)	62 (26.16)
Immunotherapy	7 (4.27)	8 (10.96)	15 (6.33)
Chemoimmunotherapy	28 (17.07)	26 (35.62)	54 (22.78)
Targeted therapy	33 (20.12)	13 (17.81)	46 (19.41)
Autologous stem cell transplant	10 (6.10)	1 (1.37)	11 (4.64)
Allogeneic stem cell transplant	6 (3.66)	3 (4.11)	9 (3.80)
Active therapy, <i>n</i> (%)	85 (51.83)	48 (65.75)	133 (56.12)
Hospitalized patients, <i>n</i> (%)	44 (60.27)	90 (54.88)	134 (56.54)
Time from COVID-19 to first serology, days			
Median [min–max]	34 [2–275]	46 [7–383]	38 [2–383]
Time from last therapy to COVID-19, days			
Median [min–max]	49 [1–3 566]	27 [1–2 628]	42 [1–3 566]

COVID-19 (78.5%). A detailed description of patients and HMs is available in Table I.

Most patients (83.1%, 197 of 237) received HM-directed therapies before COVID-19. In detail, it was chemotherapy in 62 (26.2%), chemoimmunotherapy in 54 (22.8%), immunotherapy only in 15 (6.3%), targeted therapies in 46

(19.4%), autologous and allogeneic HSCT in 11 (4.6%) and 9 (3.8%) respectively. Among these, 133 (56%) were on active therapy at the time of COVID-19.

Overall, 69% of patients (164 of 237) tested positive for IgG SARS-CoV-2 antibodies and 31% (73 of 237) negative. This indicates that one-third of patients with HM are at high

risk of failing seroconversion which, contrarily, approaches 100% in the general population.⁷ The median time from COVID-19 to first SARS-CoV-2 IgG serology evaluation was 38 days (range, 2–383), longer than that reported in the immunocompetent population.⁷ In fact, viral shedding is persistent in immunocompromised patients¹⁴ and, as a consequence, seroconversion comes later. Testing frequencies in IgG-positive and IgG-negative cases is reported in Fig 1A: finding patients without seroconversion tested later (OR, 1.01; 95% CI, 1.00–1.01; $P = 0.02$) corroborates these results. Figure S1 reports the timing of seroconversion in seven patients who resulted negative in an early SARS-CoV-2 IgG evaluation and subsequently became positive. This suggests

that measuring serological response too soon after SARS-CoV-2 infection in HM might lead to an incorrect evaluation of immune response. This probably explains the very low rate of seroconversion reported in 20 HMs (16.6%), tested after 12 days from COVID-19.¹⁵

Figure 1B shows the rate of seroconversion per HM type and specific treatments (more details in Figure S2). We found that serological non-responders were spread evenly across patients with lymphomas, MM and myeloid neoplasms. However, the univariate logistic regression (Table SI) showed that patients with absent seroconversion more likely had lymphoid neoplasms (OR, 2.15; 95% CI, 1.03–4.50; $P = 0.04$), received chemoimmunotherapy (OR, 6.68, 95%

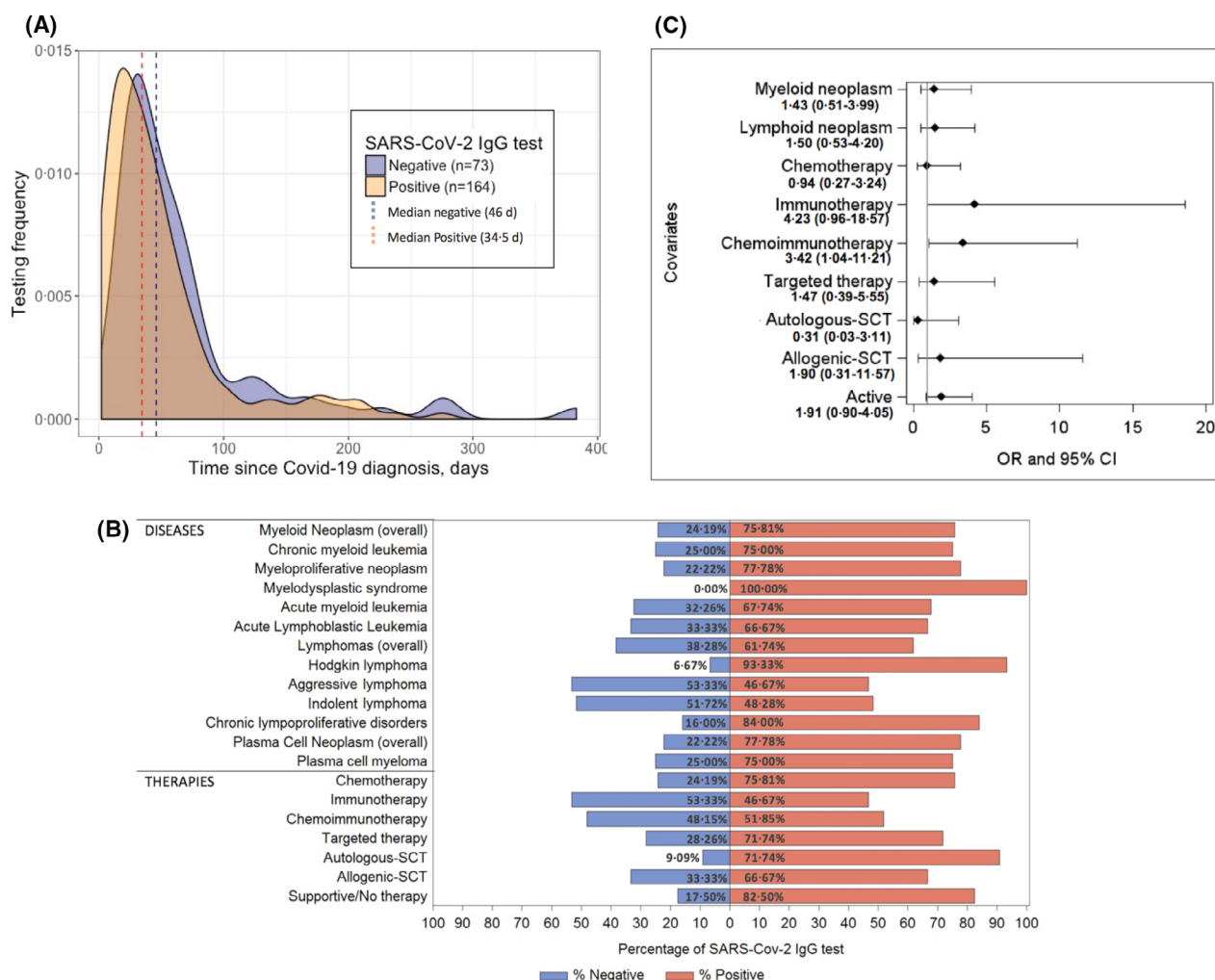


Fig 1. (A) Timing and antibody testing after a positive real-time polymerase chain reaction (RT-PCR) test. The testing frequency of patients evaluated showed that those resulting IgG-negative have been tested later (46 days), than positive (34 days) and some patients were IgG-positive long time after COVID-19 diagnosis. (B) Rate of seroconversion according to haematological malignancy and treatment. Serological non-responders were spread evenly across patients with myeloid, lymphoid and plasma cell neoplasms. Percentages of serological non-responders and responders are reported. (C) Results of multivariable analysis for identification of factors affecting negative seroconversion for SARS-CoV-2 in patients with haematological malignancies. Multivariable logistic regression revealed that chemoimmunotherapy ($P = 0.04$) and immunotherapy ($P = 0.06$) were associated with a significant and borderline lower rate of seroconversion, respectively. OR values with 95% CI are reported. Plasma cell neoplasms and no therapy represent the reference for the analysis. SCT, stem cell transplantation; OR, odds ratio; CI, confidence interval. [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

CI, 2.22–20.08; $P = 0.0007$), immunotherapy (OR, 4.71; 95% CI, 1.07–20.79; $P = 0.04$), or were on active therapy at the time of COVID-19 (OR, 1.84; 95% CI, 1.03–3.27, $P = 0.04$). To note, 27 out of 57 (47.4%) patients receiving immunotherapy/chemoimmunotherapy within one year from COVID-19 resulted positive.

In the multivariable logistic regression on the whole cohort, chemoimmunotherapy (OR, 3.42; 95% CI, 1.04–11.21; $P = 0.04$) was associated with a significantly lower rate of seroconversion, while immunotherapy (OR, 4.23; 95% CI, 0.96–18.57; $P = 0.06$) was of borderline significance (Fig 1C).

When analyzing patients on active therapy, chemoimmunotherapy (OR, 8.02; 95% CI, 2.25–28.56; $P = 0.001$), immunotherapy (OR, 5.89; 95% CI, 1.19–29.26; $P = 0.03$) and targeted therapy (OR, 3.61; 95% CI, 1.07–12.18; $P = 0.04$) were independent predictors of lower seroconversion (Figure S3). Both analyses maintained their value even adjusting for the time from COVID-19 to serology. In addition, the effect of chemoimmunotherapy and immunotherapy did not decline after 180 days from treatment withdrawal (OR, 0.35; 95% CI, 0.11–1.13; $P = 0.08$).

Conclusions

In conclusion, this study shows that COVID-19 can elicit antibodies to SARS-CoV-2 in 69% of patients with HM. The mechanism for this reduced seroconversion is not fully known, but our study indicates that treatment-mediated immune dysfunction can play an important role. Limitations of the study come from the real-world data collection, i.e. various SARS-CoV-2 IgG tests used with different epitopes and different thresholds for seroconversion, and various time points for blood sampling. Then, it should be noted that the cellular response to the SARS-CoV-2 may also have a protective role in HM patients who have recovered from COVID-19 but failed humoral response. We expect a lower rate of seroconversion after vaccination and thus HM patients should be tested for seroconversion and should maintain all the protective measures. Our data further highlight the importance of vaccination for caregivers and the need for effective infection treatment. HM can potentially become a reservoir for viral genetic variants.

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Author contributions

FP designed and performed the research, analyzed data, and wrote the paper; PC designed the research, analyzed data, and wrote the paper; MS and PAG designed the research; LB did statistical analysis; AR, FM, MGD, RB, EA, IR, RC, RL, FF, AV, AB, ML, MM, AP and LA provided and analyzed data.

Conflict of interest

The authors have no conflicts of interest to disclose.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Data S1. Supplemental data.

Table S1. Results of univariate logistic regression for identification of factors affecting negative seroconversion for SARS-CoV-2 in haematological malignancies.

Fig S1. Description of seroconversion time period in seven patients with haematological malignancies.

Fig S2. Rate of seroconversion in haematological malignancies according to detailed treatments.

Fig S3. Results of multivariable analysis for identification of factors affecting negative seroconversion for SARS-CoV-2 in patients with haematological malignancies on active therapy.

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