

Supplemental Material:

Supplemental Table 1: Laboratory Values at time of testing, admission, and maximum during COVID-19 course

Characteristic	Overall		Allo		Auto		CAR T	
	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)
WBC	51	4.7 (2.8, 6.6)	24	5.3 (3.9, 8.7)	24	3.9 (3.4, 6.4)	3	2.8 (1.6, 4.2)
ANC	50	3.2 (1.7, 5.0)	24	3.4 (1.9, 6.2)	24	2.8 (1.5, 4.4)	2	3.6 (2.9, 4.3)
ALC	50	0.9 (0.5, 1.5)	24	0.9 (0.6, 2.0)	24	0.9 (0.5, 1.3)	2	0.3 (0.3, 0.4)
Abs monocyte	50	0.4 (0.3, 0.8)	24	0.6 (0.3, 0.9)	24	0.4 (0.3, 0.6)	2	0.2 (0.2, 0.3)
HGB	51	11.6 (9.4, 13.2)	24	10.9 (8.4, 12.8)	24	11.6 (10.4, 13.3)	3	12.1 (11.3, 13.2)
PLT	51	157 (67, 190.5)	24	146 (51.5, 198.5)	24	161 (126.5, 185.5)	3	139 (93, 163.5)
CR	50	0.9 (0.8, 1.5)	24	1.2 (0.8, 1.6)	23	0.9 (0.8, 1.4)	3	0.8 (0.7, 0.8)
AST	41	29 (19, 42)	20	23.5 (18.8, 38.2)	18	31 (20.2, 46.8)	3	46 (37.5, 46.5)
ALT	44	26.5 (16, 48)	22	21.5 (15.2, 42)	19	34 (17.5, 60.5)	3	31 (24, 33.5)
Alk phos	44	80.5 (61.8, 105)	22	95 (62.5, 115.5)	19	78 (65, 98.5)	3	61 (54, 78.5)
LDH	18	261.5 (193, 352)	12	260.5 (183.8, 386.2)	4	279 (233, 303.2)	2	466.5 (364.2, 568.8)
Ferritin	10	472 (282.5, 724.5)	3	540 (344, 1095)	5	407 (320, 537)	2	486.5 (336.8, 636.2)
CRP	8	12.9 (10.5, 16.3)	3	12.2 (8.8, 73.1)	4	14.1 (10.6, 16.3)	1	13.3
ESR	1	>100	1	>100	0	NA	0	NA
D-Dimer	9	1 (0.6, 1.4)	2	2.3 (1.4, 3.1)	5	1 (0.8, 1.1)	2	1.6 (1.1, 2.2)
CPK	5	148 (144, 187)	1	763	3	148 (91.5, 167.5)	1	144

Characteristic	Overall		Allo		Auto		CAR T	
	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)
IL-6	9	40 (35.7, 133.5)	2	84.7 (60.2, 109.1)	5	35.7 (27.1, 40)	2	172.7 (106.7, 38.7)
Procal	19	0.1 (0.1, 0.7)	8	0.5 (0.2, 1)	9	0 (0, 0.1)	2	0.8 (0.4, 1.2)
Trop	10	0 (0, 0)	4	0 (0, 0.2)	6	0 (0, 0)	0	NA
WBC Adm	32	5.3 (3, 7)	13	5.4 (2.4, 8.3)	16	5.3 (3.7, 6.8)	3	3.4 (3.2, 4.5)
ANC Adm	32	3.7 (1.8, 5.3)	13	3.8 (1.7, 6.3)	16	3.9 (1.9, 5.3)	3	3 (2.9, 4)
ALC Adm	32	0.8 (0.3, 1.1)	13	0.8 (0.3, 1.3)	16	0.9 (0.5, 1.1)	3	0.1 (0.1, 0.3)
Abs monocyte Adm	32	0.3 (0.2, 0.7)	13	0.6 (0.3, 0.7)	16	0.3 (0.3, 0.6)	3	0.2 (0.2, 0.2)
HGB Adm	32	10.7 (9.1, 12.5)	13	9.1 (7.3, 11.9)	16	11.1 (10, 13)	3	12.1 (10.8, 12.1)
PLT Adm	32	130 (63.8, 194)	13	124 (57, 197)	16	137 (60.2, 196)	3	101 (100, 144.5)
CR Adm	32	1.2 (0.8, 1.7)	13	1.5 (1, 3.5)	16	1 (0.8, 1.6)	3	0.6 (0.6, 0.7)
AST Adm	26	30 (19.2, 45.8)	12	28.5 (16, 43.2)	11	30 (22, 32)	3	47 (38, 60.5)
ALT Adm	27	26 (16, 39.5)	12	21.5 (14, 60.5)	12	26.5 (17.8, 35.2)	3	21 (19, 35.5)
Alk Phos Adm	27	81 (56.5, 104)	12	88.5 (59, 118)	12	77.5 (63, 90)	3	47 (45.5, 76.5)
LDH Adm	12	303.5 (250, 374.8)	8	278 (203.8, 370.2)	3	304 (303.5, 339)	1	671
Ferritin Adm	12	538.5 (307.5, 1117.8)	5	1225 (1082, 1650)	6	363.5 (282.5, 504.5)	1	187
CRP Adm	12	12.4 (5.2, 16.3)	6	6.5 (3.4, 11.1)	5	15.8 (12.5, 17.7)	1	13.3
ESR Adm	2	>100	1	>100	1	>100	0	NA

Characteristic	Overall		Allo		Auto		CAR T	
	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)
D-Dimer Adm	10	1.1 (0.7, 1.8)	3	0.6 (0.6, 2.3)	6	1.1 (0.9, 1.4)	1	2.8
CPK Adm	5	148 (144, 187)	1	763	3	148 (91.5, 167.5)	1	144
IL-6 Adm	13	63.3 (35.7, 133.5)	5	63.3 (35.8, 67.9)	7	40 (31.4, 132.7)	1	304.7
Procal Adm	15	0.3 (0.1, 1.1)	5	0.6 (0.4, 0.8)	8	0.1 (0, 0.7)	2	0.9 (0.6, 1.2)
Trop Adm	10	0 (0, 0)	4	0.0 (0, 0.2)	5	0 (0, 0)	1	0
LDH max	34	372.5 (286.5, 34.2)	16	372.5 (271, 618.5)	15	345 (297, 451.5)	3	671 (476.5, 673)
Ferritin max	30	1395.5 (277.2, 4305)	14	2535 (1329.2, 5845.8)	13	584 (270, 3669)	3	187 (167, 2097)
CRP max	31	16.9 (10.1, 26.4)	17	21.1 (11.9, 25.7)	11	14.3 (7.1, 27)	3	13.3 (6.9, 13.9)
ESR max	3	>100	2	99 (98, 100)	1	>100	0	NA
D-Dimer max	26	2.7 (1.0, 4.1)	13	2.7 (1.9, 6.2)	11	3 (0.9, 3.9)	2	1.6 (1, 2.2)
CPK max	14	76.5 (36.8, 141.2)	5	49 (42, 125)	7	84 (27, 140.5)	2	106.5 (87.8, 125.2)
IL-6 max	30	93.5 (34.3, 231)	15	108.5 (58.5, 226.9)	13	49.5 (27.8, 233.7)	2	57.9 (36, 79.8)
Procal max	38	0.3 (0.1, 1.6)	17	0.4 (0.2, 1.7)	17	0.1 (0, 1.6)	4	0.4 (0.2, 0.7)
Trop max	22	0 (0, 0.1)	11	0 (0, 0)	10	0 (0, 0.2)	1	0 (0, 0)
CR max	50	1.2 (0.8, 1.7)	23	1.5 (0.9, 2.1)	23	0.9 (0.8, 1.4)	4	0.7 (0.6, 0.8)
AST max	44	43 (26.2, 60.5)	19	39 (21.5, 59.5)	21	47 (32, 60)	4	41.5 (34.2, 81.8)
ALT max	44	40.5 (19, 79.5)	19	35 (18.5, 70.5)	21	57 (24, 86)	4	32.5 (20, 66)

Characteristic	Overall		Allo		Auto		CAR T	
	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)
PT max	38	14.9 (13.9, 15.5)	16	15.2 (14, 17.9)	18	14.6 (13.9, 15.4)	4	14.6 (14, 15.1)
INR max	36	1.2 (1.1, 1.3)	15	1.2 (1.1, 1.4)	17	1.2 (1.1, 1.2)	4	1.2 (1.2, 3.6)
PTT max	34	38 (31.7, 40.8)	14	36.1 (31.8, 41.5)	16	38 (31.5, 40.4)	4	39 (36.3, 39.8)
Fibrinogen min	22	497 (354.5, 588.5)	9	515 (231, 597)	11	566 (450.5, 587)	2	241 (190.5, 291.5)

Abbreviations: IQR, interquartile range; Allo, Allogeneic hematopoietic stem cell transplantation; Auto, Autologous hematopoietic stem cell transplantation; CAR T, CD19 directed chimeric antigen receptor T cell therapy; WBC, white blood cell count, K/mcL; ANC, absolute neutrophil count, K/mcL; ALC, absolute lymphocyte count, K/mcL; Abs monocyte, absolute monocyte count, K/mcL; HGB, hemoglobin, g/dL; PLT, platelet count, K/mcL; CR, creatinine, mg/dL; AST, aspartate aminotransferase, U/L; ALT, alanine aminotransferase, U/L; Alk Phos, alkaline phosphatase, U/L; LDH, lactate dehydrogenase, U/L; Ferritin, ng/mL; CRP, c-reactive protein, mg/dL; ESR, erythrocyte sedimentation rate, mm/hr; D-dimer, mcg/mL FEU; CPK, creatinine phosphokinase, U/L; IL-6, interleukin-6, pg/mL; Procal, procalcitonin, ng/mL; Trop, troponin, ng/mL; Adm, on admission for COVID-19; Max, maximum value during COVID-19 course; Min, minimum value during COVID-19 course

Supplemental Table 2: Time to Event Outcomes

Characteristic	Overall		Allo		Auto		CAR T	
	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)
Length of initial COVID-19 Admission (days)	22	8 (5.0, 17.8)	7	6 (4.0, 14.5)	14	8.5 (5.2, 13.8)	1	21 (21, 21)
Time from COVID-19 diagnosis to symptom resolution (days, among patients with symptom resolution)	45	14 (10, 20)	21	15 (10, 23)	22	14 (9.2, 15.8)	2	17.5 (10.2, 24.8)
Time from symptom onset to COVID-19 NPS (days)	71	2 (0, 4.5)	33	2 (0, 4)	33	2 (0, 7)	5	1 (0, 9)
Time from COVID-19 NPS to admission, if applicable (days)	34	0 (0, 1.8)	13	0 (0, 2)	17	0 (0, 0)	4	3 (0, 7.8)
Time from COVID-19 NPS to hydroxychloroquine treatment (days)	25	1 (1, 2)	14	1 (1, 2)	9	1 (0, 2)	2	3.5 (1.8, 5.2)
Time from COVID-19 NPS to azithromycin treatment (days)	19	1 (0, 2)	9	1 (0, 7)	8	0 (0, 0.8)	2	1 (1, 1)
Time from COVID-19 NPS to remdesivir treatment (days)	3	14 (9.5, 15)	2	15 (14.5, 15.5)	1	5 (5, 5)	0	NA (NA, NA)
Time from COVID-19 NPS to methylprednisolone treatment (days)	14	5.5 (3.2, 10.5)	5	6 (5, 9)	8	4.5 (2.8, 10)	1	12 (12, 12)
Time from COVID-19 NPS to prednisone treatment (days)	6	15 (3.5, 19)	1	1 (1, 1)	4	15 (8.5, 21.2)	1	19 (19, 19)

Characteristic	Overall		Allo		Auto		CAR T	
	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)
Time from COVID-19 NPS to tocilizumab treatment (days)	8	8 (4.8, 12.8)	5	8 (5, 12)	2	8.5 (5.2, 11.8)	1	8 (8, 8)
Time from COVID-19 NPS to siltuximab treatment (days)	1	7 (7, 7)	1	7 (7, 7)	0	NA (NA, NA)	0	NA (NA, NA)
Time from COVID-19 NPS to anakinra treatment	1	9 (9, 9)	1	9 (9, 9)	0	NA (NA, NA)	0	NA (NA, NA)
Time from COVID-19 NPS to convalescent Plasma treatment	12	9.5 (4.8, 14.2)	5	11 (10, 14)	6	7 (4.2, 9)	1	15 (15, 15)
Time from COVID-19 NPS to IVIG treatment	5	6 (2, 13)	2	7.5 (4.8, 10.2)	3	6 (4, 10.5)	0	NA (NA, NA)
Time from COVID-19 to NAC treatment (days)	2	29 (28.5, 29.5)	2	29 (28.5, 29.5)	0	NA (NA, NA)	0	NA (NA, NA)
Time from intubation until extubation, death, or end of follow-up (days)	9	12 (8, 22)	6	15.5 (8.2, 22.8)	3	12 (7.5, 16.5)	0	NA (NA, NA)

Abbreviations: IQR, interquartile range; NPS, Nasopharyngeal swab; IVIG, intravenous immunoglobulin; NAC, N-acetylcysteine;

Supplemental Table 3: Univariable analysis for disease severity.

Characteristic	Overall N = 74	Mild N = 37 ^a	Moderate N = 20 ^a	Severe N = 17 ^a	p- value ^c
Age at COVID-19	61 (52, 67)	60 (51, 67)	63 (52, 64)	66 (56, 69)	0.2
Hematologic Malignancy					0.3
Aggressive NHL, Hodgkin Lymphoma, Indolent Lymphoma	24 (32%)	11 (30%)	8 (40%)	5 (29%)	
AML, ALL, MDS, MPN, Myelofibrosis, CML, CLL	25 (34%)	11 (30%)	5 (25%)	9 (53%)	
Multiple Myeloma, POEMS, Primary AL Amyloidosis	25 (34%)	15 (41%)	7 (35%)	3 (18%)	
Smoking status					0.7
Current or former	25 (34%)	11 (30%)	7 (35%)	7 (41%)	
Never	49 (66%)	26 (70%)	13 (65%)	10 (59%)	
On Imid at COVID-19 Diagnosis	18 (24%)	12 (32%)	5 (25%)	1 (5.9%)	0.11
Comorbidities at COVID-19 Diagnosis					0.002
0	34 (46%)	24 (65%)	7 (35%)	3 (18%)	
1	23 (31%)	9 (24%)	9 (45%)	5 (29%)	
2+	17 (23%)	4 (11%)	4 (20%)	9 (53%)	
Infiltrates on Imaging at COVID-19 Diagnosis	24 (63%)	6 (50%)	7 (54%)	11 (85%)	0.15
Unknown	36	25	7	4	
Time (days) post cellular therapy					0.8
<= day 100	5 (6.8%)	2 (5.4%)	2 (10%)	1 (5.9%)	
101-180	5 (6.8%)	1 (2.7%)	3 (15%)	1 (5.9%)	
181-365	10 (14%)	4 (11%)	3 (15%)	3 (18%)	
366-1095	26 (35%)	15 (41%)	5 (25%)	6 (35%)	
1096+	28 (38%)	15 (41%)	7 (35%)	6 (35%)	
Race					0.6
Non-white	24 (36%)	10 (30%)	8 (44%)	6 (38%)	
White	43 (64%)	23 (70%)	10 (56%)	10 (62%)	
Unknown	7	4	2	1	
Gender					0.8
F	27 (36%)	12 (32%)	8 (40%)	7 (41%)	
M	47 (64%)	25 (68%)	12 (60%)	10 (59%)	

Characteristic	Overall N = 74	Mild N = 37 ¹	Moderate N = 20 ¹	Severe N = 17 ¹	p- value ²
BMI	27.4 (24.1,30.6)	27.7 (25.6,31.0)	27.6 (24.7, 29.8)	23.8 (21.9,27.4)	0.083
Unknown	3	1	1	1	
Hematologic malignancy active at time of COVID dx					0.020
N	55 (74%)	30 (81%)	17 (85%)	8 (47%)	
Y	19 (26%)	7 (19%)	3 (15%)	9 (53%)	
ANC	3.3 (1.7, 5)	2.7 (2, 3.9)	2.2 (1.7, 4.1)	5 (2.6, 5.97)	0.2
Unknown	25	20	3	2	
ALC	0.9 (0.5, 1.5)	1 (0.8, 1.5)	0.9 (0.3, 1.5)	0.6 (0.5, 1.04)	0.2
Unknown	25	20	3	2	
Neutrophil to lymphocyte ratio at time of COVID-19	3.5 (1.3, 6.8)	3.1 (1.1, 4.4)	4.1 (1.7, 7.8)	4.5 (1.9, 9.7)	0.2
Unknown	25	20	3	2	
Characteristic	Overall, N = 25	Mild, N = 3	Moderate, N = 10	Severe, N = 12	p- value ²
Absolute CD3+	354 (119, 636)	956 (912, 1007)	141 (58, 541)	382 (234, 452)	0.043
Absolute CD4+	140 (51, 194)	387 (207, 416)	94 (29, 196)	146 (109, 154)	0.4
Absolute CD8+	221 (35, 327)	645 (546, 702)	44 (24, 214)	242 (86, 284)	0.040
Absolute CD19+	11 (0, 50)	0 (0, 414)	0 (0, 9)	32 (10, 60)	0.2
CD4:CD8 ratio	0.88 (0.54, 1.65)	0.60 (0.32, 0.80)	1.47 (0.78, 2.33)	0.64 (0.44, 1.21)	0.12
Absolute NK	100 (52, 151)	219 (128, 269)	66 (38, 117)	106 (65, 134)	0.4

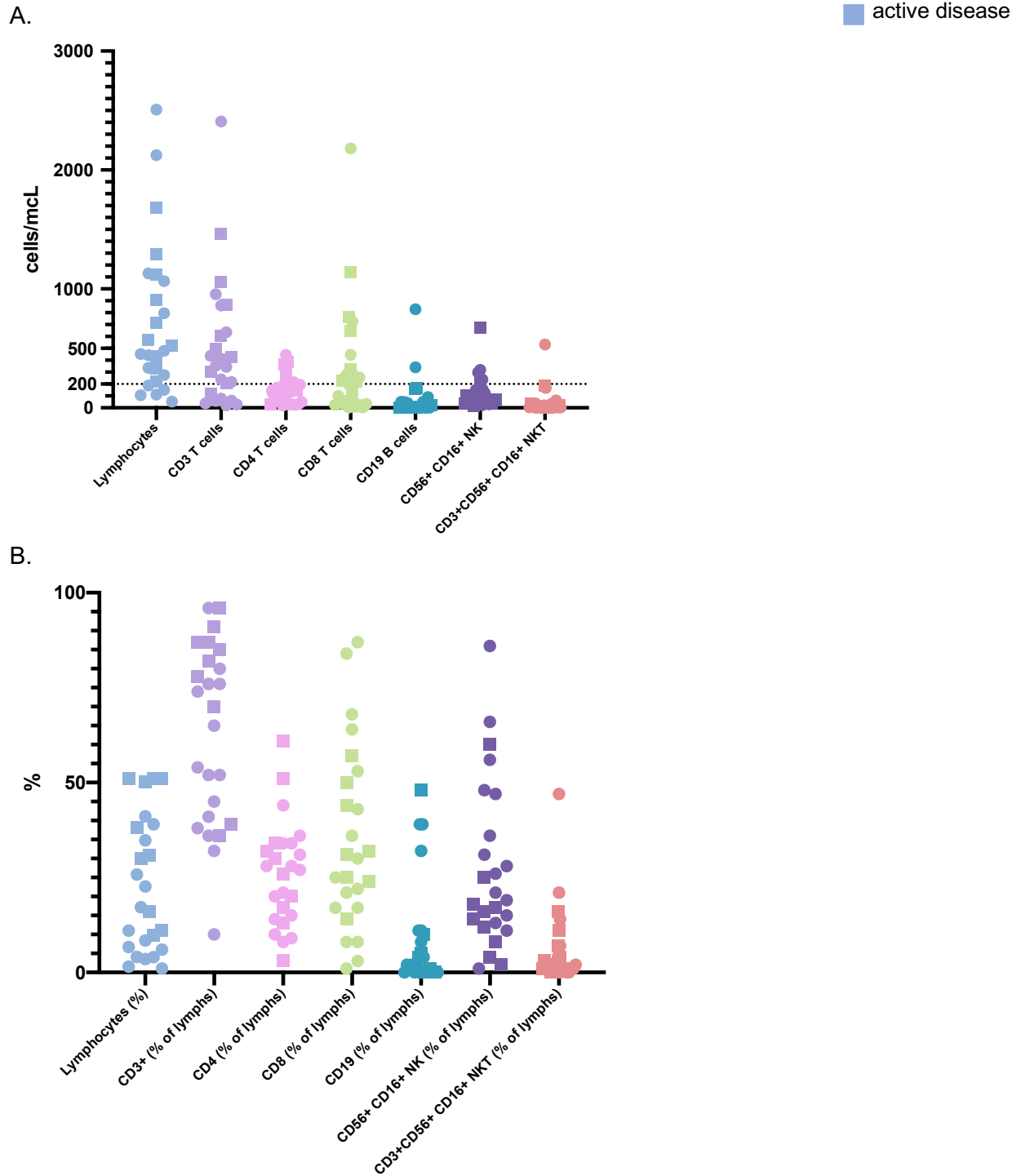
¹Statistics presented: median (IQR); n (%)

²Statistical tests performed: Kruskal-Wallis test; chi-square test of independence; Fisher's exact test

Abbreviations: IQR, Interquartile range; HR, Hazard Ratio; CI, Confidence Interval; NHL, non-Hodgkin Lymphoma; AML, acute myeloid leukemia; ALL, acute lymphoblastic leukemia; MDS, myelodysplastic syndrome; MPN, myeloproliferative neoplasm; CML, chronic myeloid leukemia; CLL, chronic lymphocytic leukemia; F, female; M, male; BMI, body mass index; ANC, absolute neutrophil count; ALC, absolute lymphocyte count; NK, Natural Killer cell.

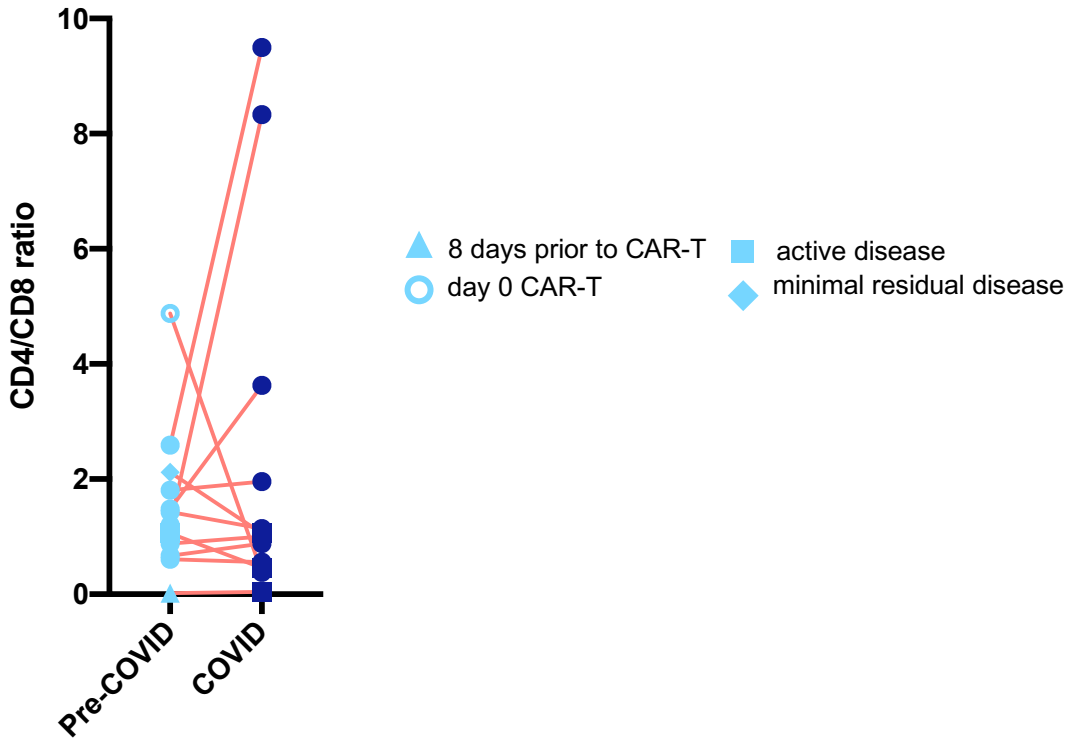
Supplemental Figures:

Supplemental Figure 1: A. Immune subsets in 25 COVID-19 BMT patients: 12 allogeneic transplant patients, 10 autologous transplant patients, and 3 CAR-T patients. A. Absolute lymphocyte subsets. B. Lymphocyte subsets by percentage.

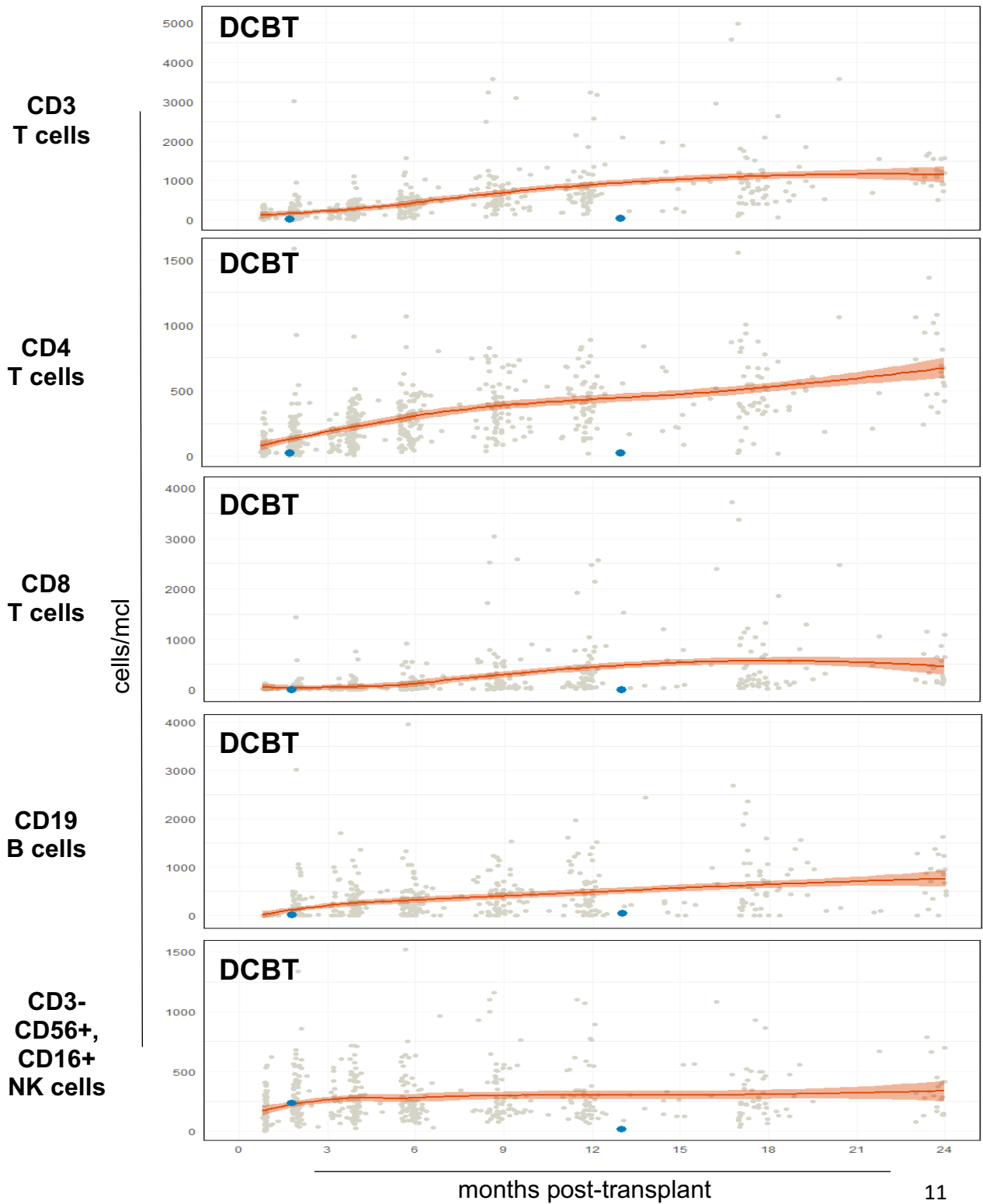


Supplemental Figure 2: Tracking immune subsets in COVID-19 BMT patients. A. CD4 to CD8 ratio pre-COVID (mean = 1.6, SD 1.3) and during COVID (mean = 2.4, SD 3.2) (n = 12).

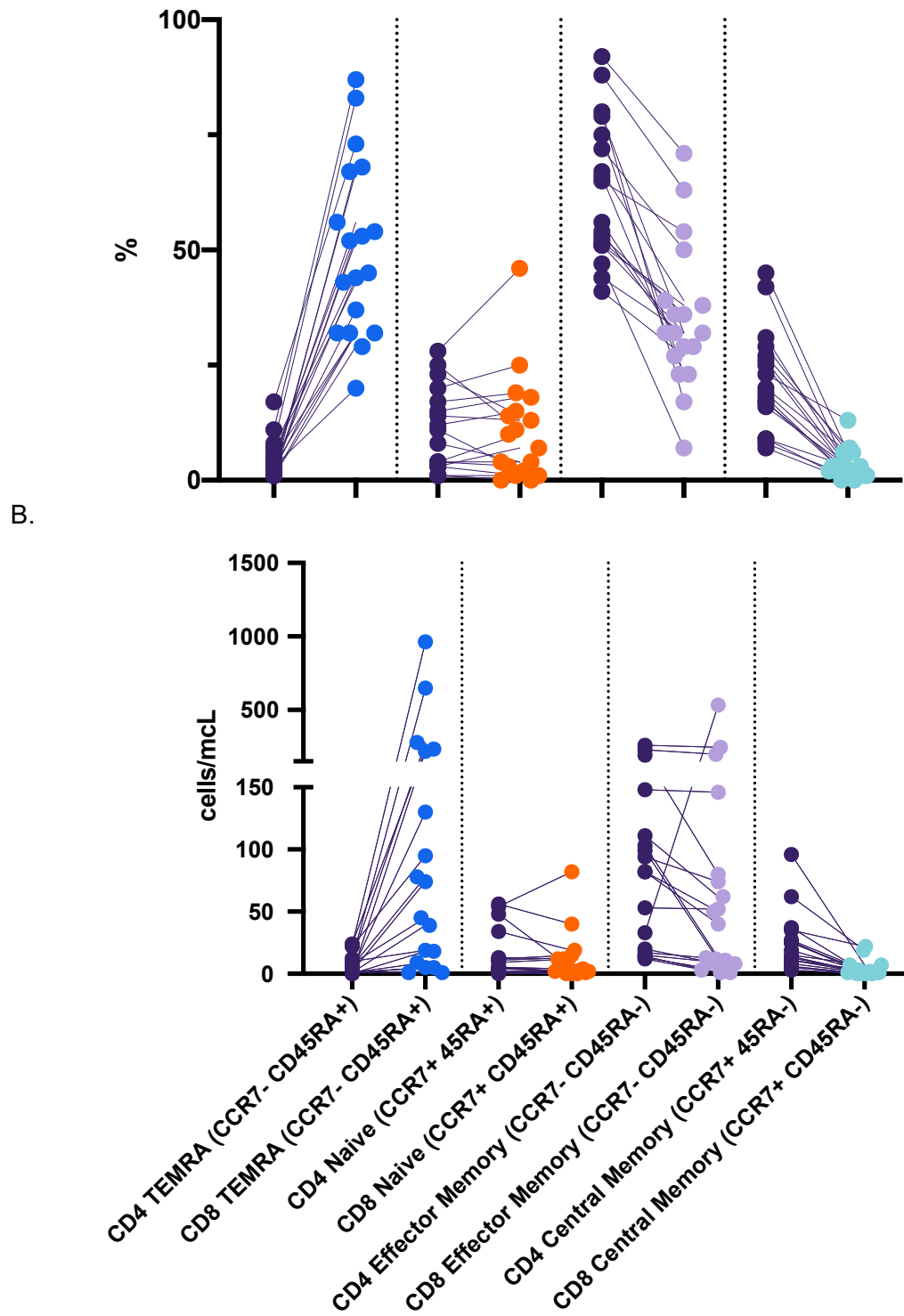
A.



Supplemental Figure 3: Absolute lymphocyte subsets in two double-unit umbilical cord blood transplant recipient (DCBT) SARS-CoV-2+ BMT subjects (blue) compared to immune reconstitution data from historical controls (gray points, DCBT recipients at MSKCC collected prior to the COVID pandemic); orange line indicates Loess curve of historical controls.



Supplemental Figure 4: T cell subsets in SARS-CoV-2+ BMT subjects (n = 18). A. Frequency and B. Absolute T cell counts comparing CD4s and CD8s for each subject.

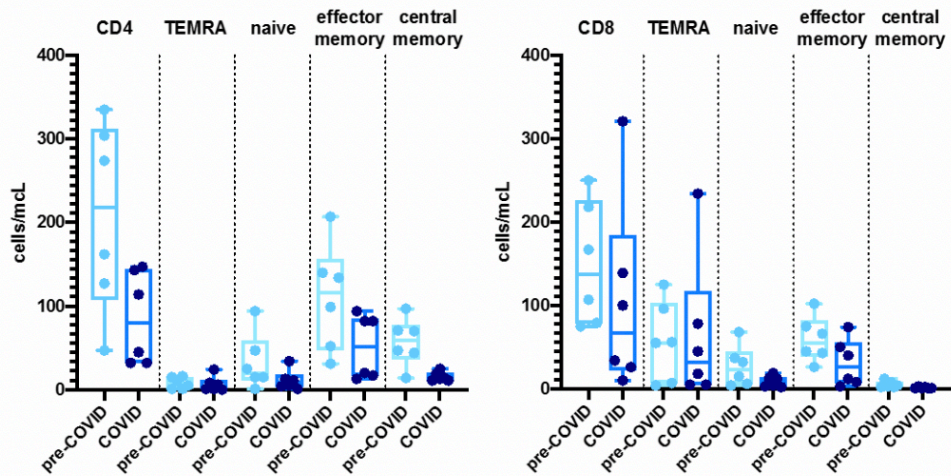


Supplemental Figure 5: Tracking T cell subsets in SARS-CoV-2+ BMT subjects A. Summary table of patients included in T cell subset tracking analysis. B. T cell subsets in COVID-19 BMT patients. B. Absolute CD4 and CD8 T cells subsets pre-COVID and during COVID (n = 6). C. T cell subsets (%) in CD4 and CD8 T cells (n = 6). Patient highlighted in individual colors for CD8 TEMRAs to delineate distinct time points post-transplantation.

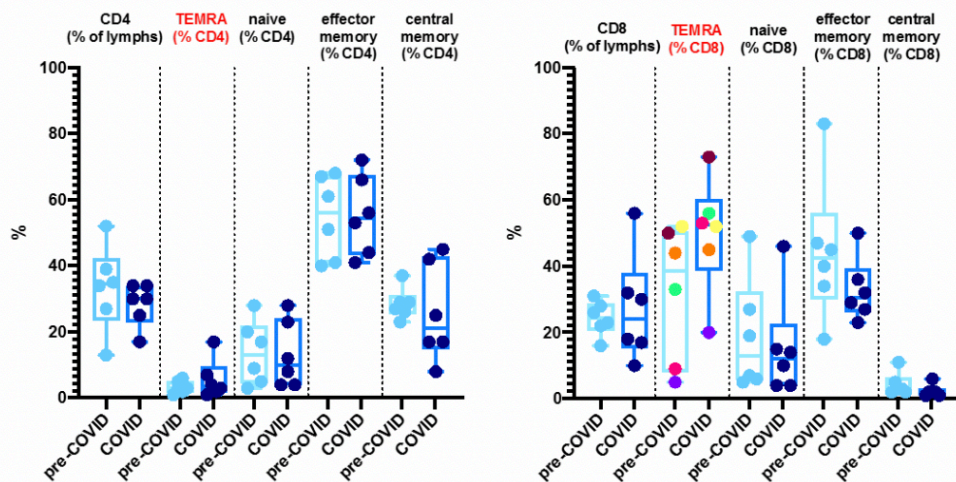
A.

Graft	Days post-transplant pre-COVID immune subsets	Days post-transplant COVID immune subsets
Allo-HCT (PBSC)	102	356
Allo-HCT (PBSC)	107	198
Allo-HCT (PBSC)	240	387
Allo-HCT (PBSC)	199	264
DCBT	354	403
CD19 CAR-T	451	506

B.

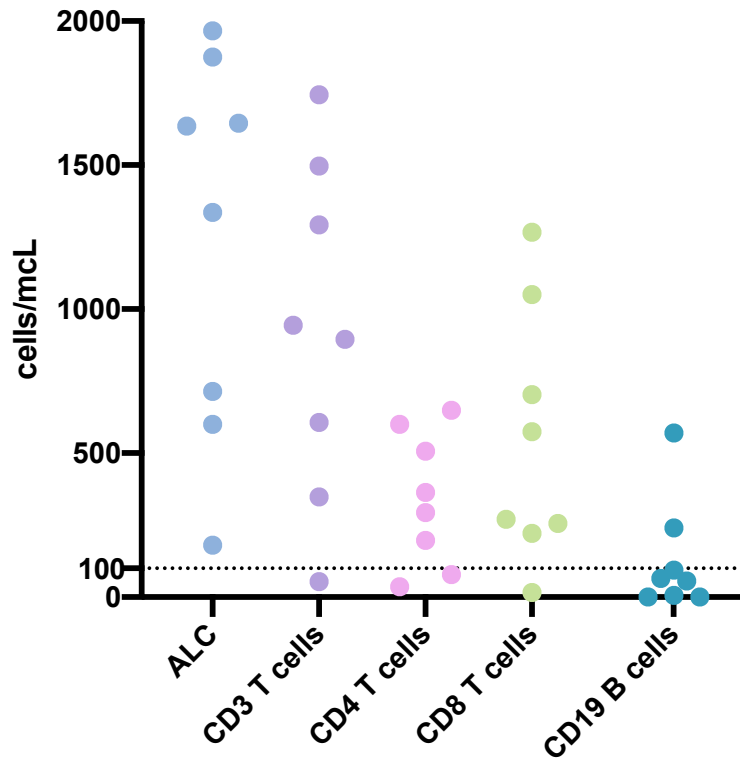


C.

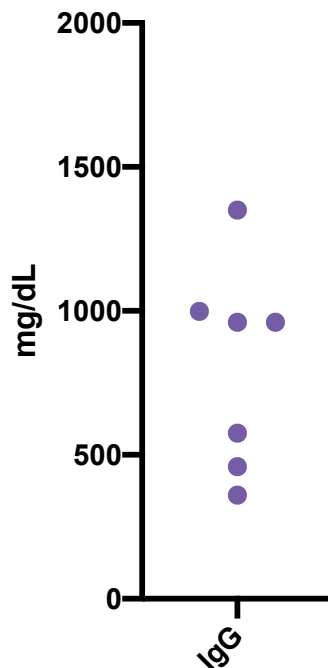


Supplemental Figure 6: Lymphocyte counts in patients with a SARS-CoV-2 antibody. A. Lymphocyte counts for 8/11 patients with lymphocytes subsets and a positive SARS-CoV-2 antibody (2 patients without absolute counts available, 1 recipient of convalescent plasma and thus antibody status is difficult to interpret). Nearest immune profiling performed in a range of 31 days before to 7 days after antibody testing. B. IgG available for 7/8 patients within 3 months of antibody testing.

A.

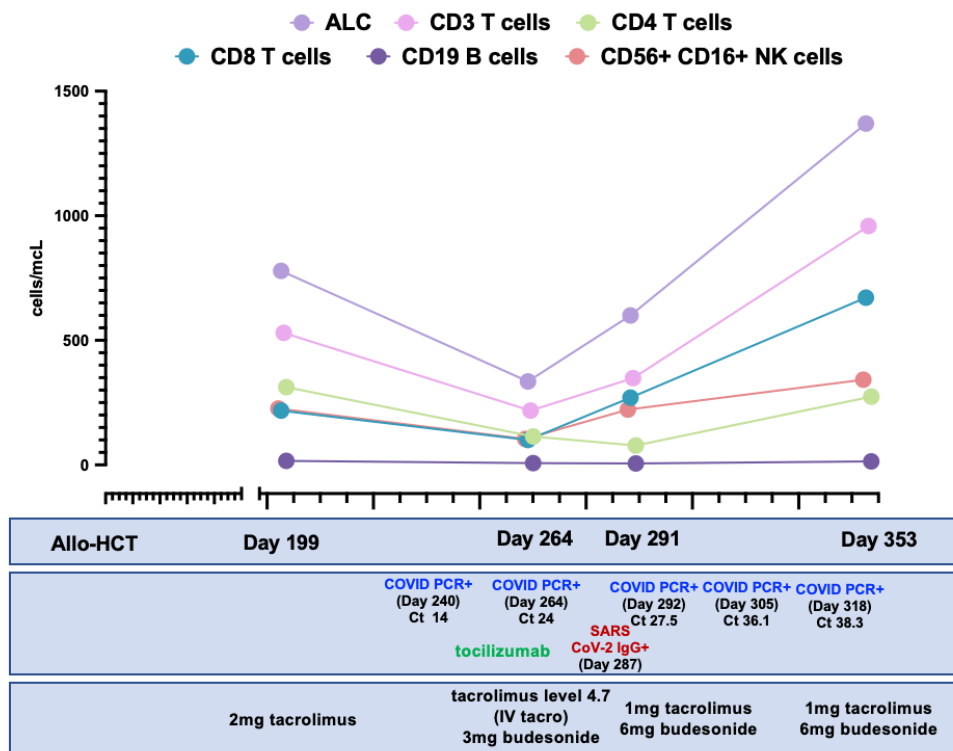


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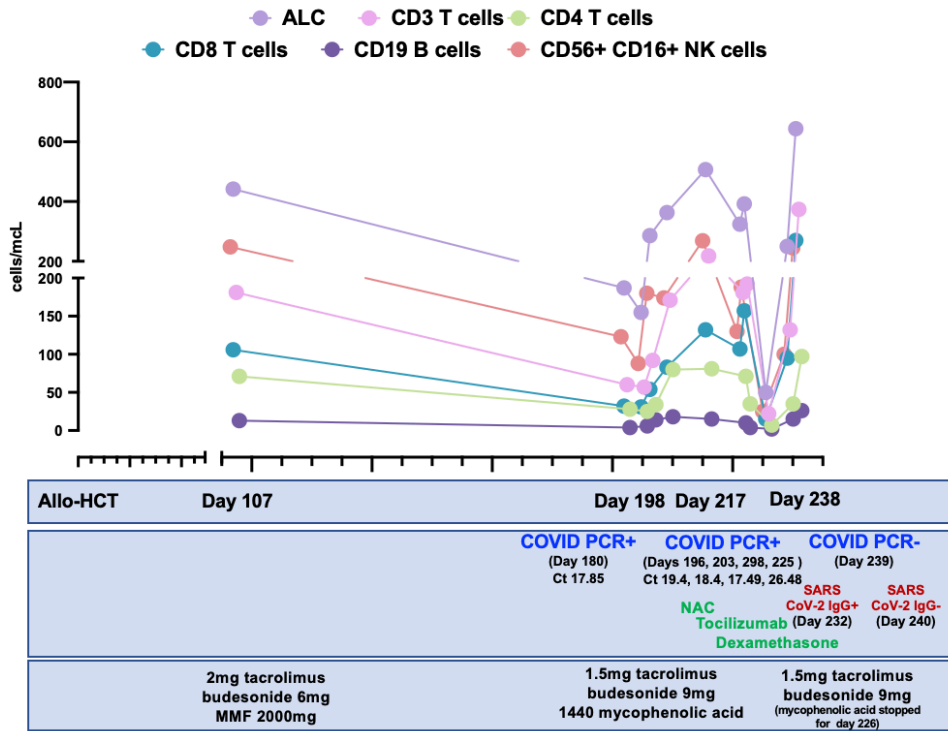


Supplemental Figure 7: Tracking lymphocyte subsets over time before, during, and in recovery from a COVID-19. Available COVID PCR data with cycle threshold (Ct) and antibody status included. A. Unmodified mismatched unrelated PBSC Allo for AML in remission. Mitogen proliferation day 199: normal and robust; mitogen proliferation day 291: non-responsive; mitogen proliferation day 353: normal and robust. B. Haploidentical related PBSC Allo for atypical CML. Mitogen proliferation day 107 non-responsive; mitogen proliferation day 264: responsive. Subject received convalescent plasma day 204. C. DCBT for ALL in remission. Subject received convalescent plasma day 406. D. Unmodified matched PBSC Allo for ALL with relapsed ALL and MDS post-transplant. Mitogen proliferation day 236: normal and robust; mitogen proliferation day 387: normal and robust. Subject received convalescent plasma day 398. E. CAR-T for DLBCL in remission. Subject received convalescent plasma day 514. F. CD34+ selected T cell depleted Allo for AML in remission. Received rituximab for EBV viremia on 3206, 3210, 3213 and 3220. Mitogen proliferation day 3068: normal and robust; mitogen proliferation day 3311: normal and robust. G. DCBT for AML (MRD positive by flow cytometry). Subject received convalescent plasma day 64. Mitogen proliferation day 28: normal and robust; mitogen proliferation day 57: normal and robust mitogen proliferation day 119: normal and robust. Subjects in (C) and (D) died during the study period.

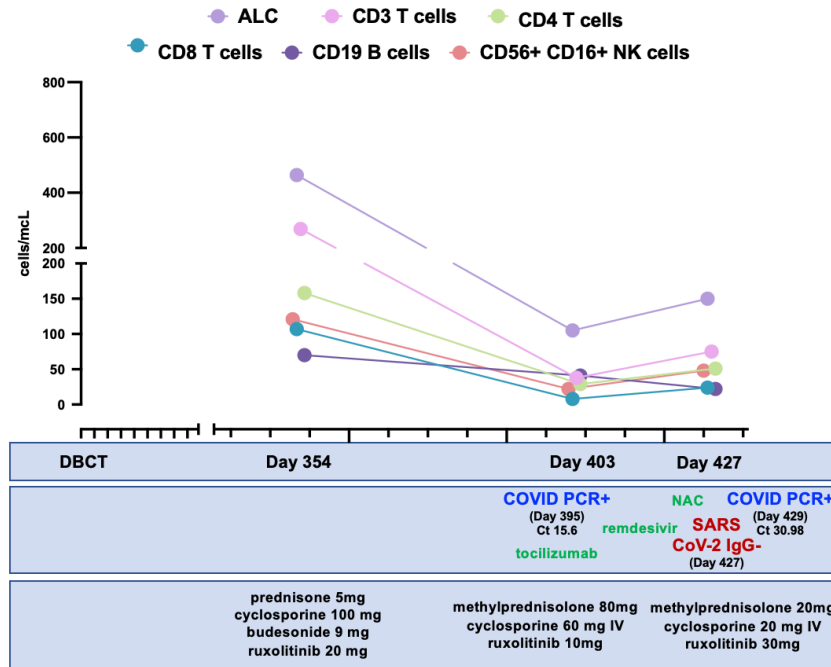
A.



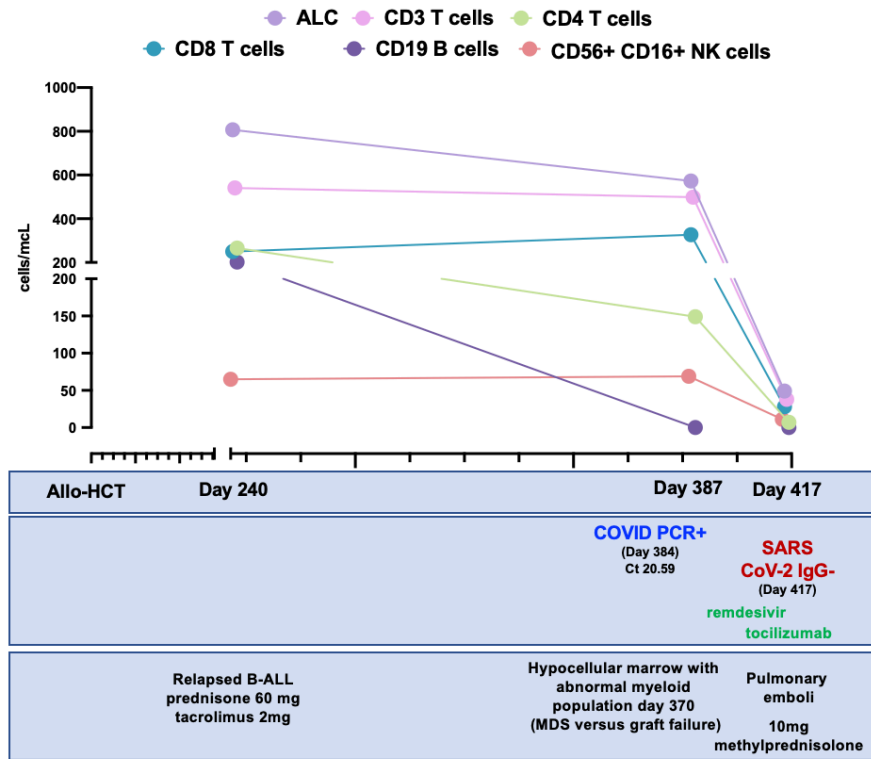
B.



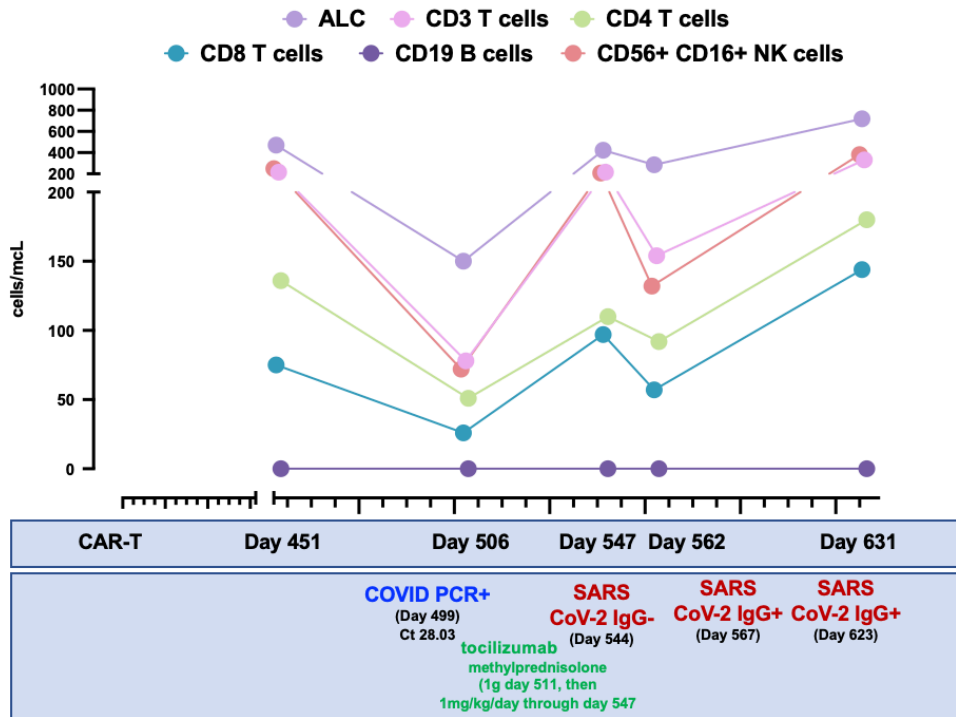
C.



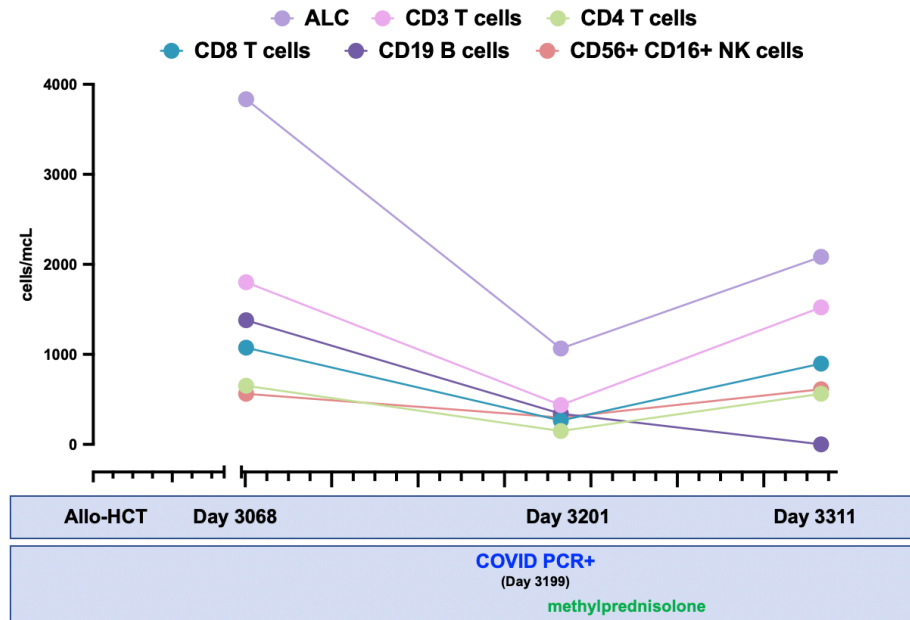
D.



E.



F.



G.

