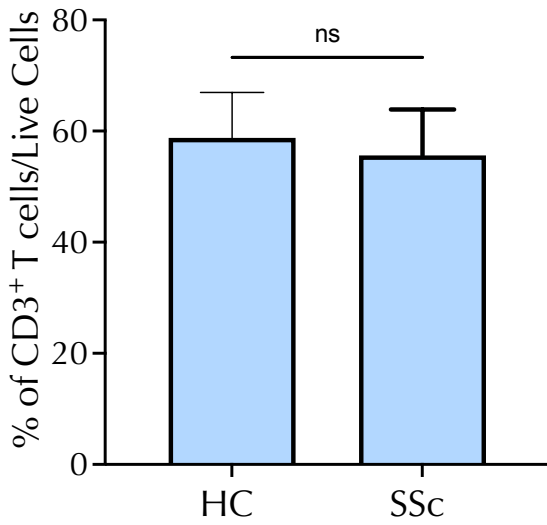


Target	Clone	Metal
CD20	2H7	113In
CD3	UCHT1	115In
CCR6	G034E3	141Pr
CD57	HCD57	142Nd
CD123	6H6	143Nd
GraB	GB11	144Nd
CRTH2	BM16	145Nd
CD8a	RPA T8	146Nd
CD45RO	UCHL1	147Sm
CD28	CD28.2	148Nd
Grak	GM26E7	149Sm
CD11c	Bu15	150Nd
ICOS	C398.4A	151Eu
CD14	M5E2	152Sm
CCR2	K036C2	153Eu
TIGIT	MBSA43	154Sm
CD4	RPA T4	155Gd
CD73	AD2	156Gd
CD16	3G8	157Gd
CD27	L128	158Gd
CCR7	G043H7	159Tb
CXCR6	K041E5	160Gd
T-bet	4B10	161Dy
FoxP3	PCH101	162Dy
CXCR3	G025H7	163Dy
CXCR5	J252D4	164Dy
CD127	TX31	165Ho
GATA3	TWAJ	166Er
CD38	HTA125	167Er
CCR9	L053E8	168Er
TCRgd	B1	169Tm
CX3CR1	2A9-1	170Er
CCR5	NP6G4	171Yb
Ki67	B56	172Yb
CD25	M-A251	173Yb
CCR10	6588-5	174Yb
PD-1	EH12.2H7	175Lu
CD56	R19760	176Yb
HLA-DR	BVD2-23B6	209Bi

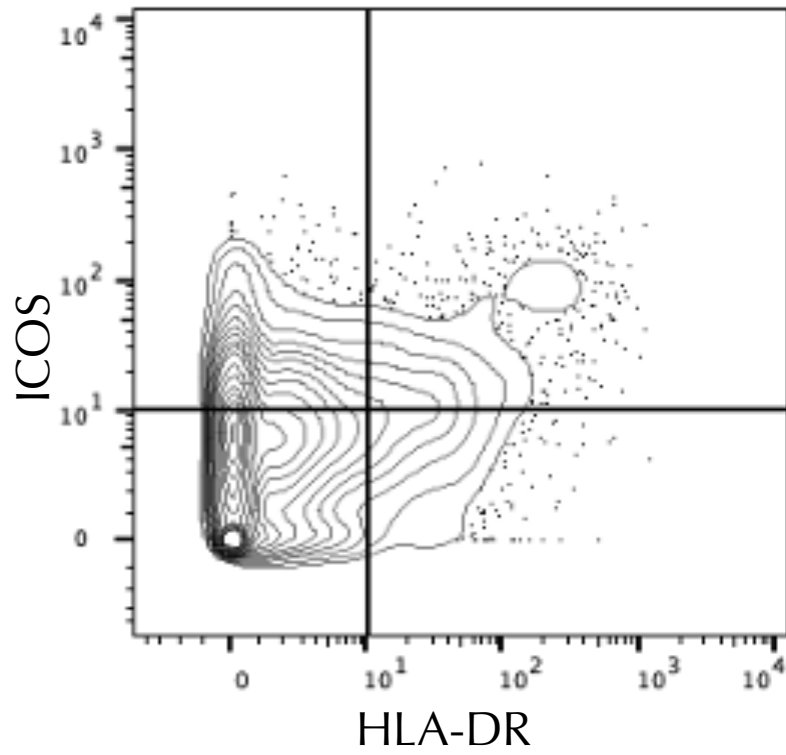
Supplementary Table 1: Markers used for mass cytometry analyses.

Signature	Genes
Cytotoxicity	GZMA, GZMB, GZMH, PRF1, NKG7, GNLY, CD40LG, KLRG1, KLRB1, ITGAL
Tfh	CXCR5, CXCL13, TOX2, ICA1, PDCD1, FAM43A, SCGB3A1, ASCL2, CHI3L2, CDK5R1, CEBPA, GNG4, CXXC5, GFOD1, TIGIT, POU2AF1, ATP9A, KIAA1671, SGPP2, BCL6, EGR2, LGMN, CD79A, KIAA1324, NFATC1, MYL6B, BCAT1, CTLA4, KCNK5, CTTN, LAG3, ICOS, THADA, LHFPL2, MAF, ID3, TRIB1, BTLA, SLC9A9, CAV1, SH2D1A, SH3TC1, MAGEH1, ST8SIA1, IKZF3, IGFBP4, NMB, TBC1D4, TRIM8, CCDC50, MYH10, PTPN11, FAM46C, ITM2A, FABP5, SPSB1, ODC1, MERTK, FBLN7, SERTAD2, TOX, CORO1B, SCD, SHISA2, RAB27A, FAM167A, STX11, LRRC1, PTTG1, CD200, KIAA0101, LIMS1, SLC7A5, PON2, FKBP5, NAB1, PFKFB3, DUSP6, AIM2, GADD45G, COL6A3, FAM179A, PHGDH, NUDT7, RNF19A, DUSP2, PAQR4, PPP1CC, SLC25A46, CARHSP1, HES6, H1FO, SRGN, CDCA7, SIRPG, MT1E, CD38, ASB2, KIFC1, RDH10, LRMP, DDIT4, P2RY11, NUCB2, TMEM2, ACTA2, SERPINE2, CASP9, INPP1, SGCE, MTUS1, GRAMD3, AFF3, NCALD, ANKRD55, AGMAT, TRIM32, CPA5, MAPK6, NDFIP2, UBE2E3, SEPN1, LIMS2, NETO2, GLCCI1, FAAH2, RPL39L, SSH2, PHACTR2, ERMP1, TNFRSF18, ANKS1B, SOCS1, FEN1, PYHIN1, PTPN13, QPRT, ACTN1, MYO5A, POMT1, LAT, SYT11, BCAS4, INSIG1, WSB2, RAB11FIP1, NR3C1, TRAF3IP2, GINS2, RFC5, FAM110A, RILPL2, IL2RB, ASAP1, GK, TSPAN5, ALDH5A1, TIAM1, CBLB, CLINT1, SMPDL3A, SIPA1L2, JARID2, ORMDL3, TSHR, BAZ2B, ATP6V1D, ZFPM1, TM2D3, RAB37, GPR19, F2R, SRPK2, BIK, FBXO33, MAPKAPK3, PTPN2, LBH, PTPN7, UBE2G1, FHL2, TJP2, IFNAR2, VOPP1, IRF4, CDK6, HIF1A, P2RX5, CXCR4, TMEM99, FYN, DCUN1D3, BATF, CDT1, GF11, ARHGAP10, PRKCZ, IL6R, LTA, KPNA2, PPP2R5C, PPP1R16B, VWA5A, FAM160B1, TMEM64, MBOAT1, FAM134B, TP53INP1, RYR1, AKAP13, PCNA, HIST1H2BD, HES4, NAP1L4, PLCH2, GAPDH, HECW2, TRIB2, SAT1, SLC29A1, ZFP91, RACGAP1, MCM2, SFXN1, IL21

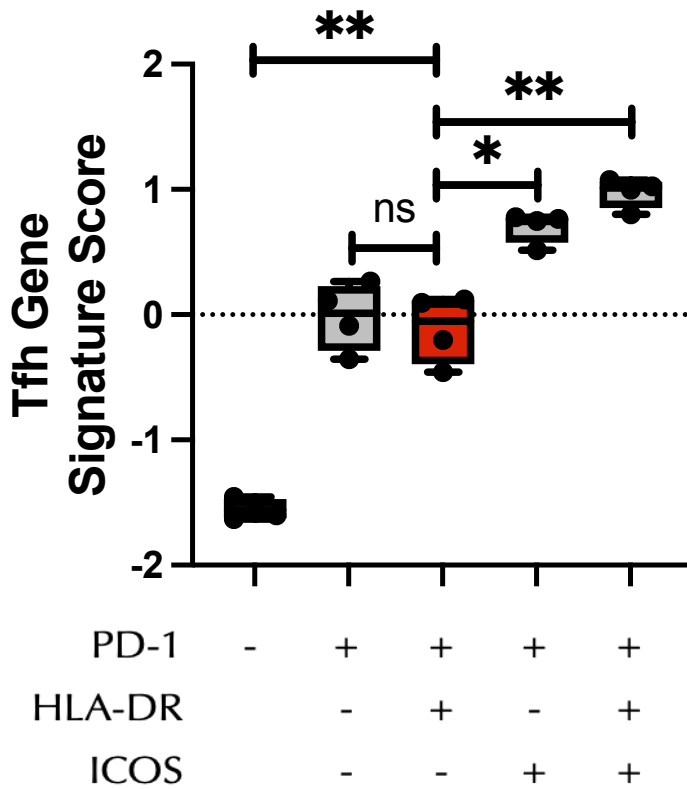
Supplementary Table 2: Genes used for Cytotoxicity and Tfh Gene Enrichment Scores. Genes comprising the cytotoxicity and Tfh gene signatures were derived from Hashimoto *et al.* 2019 and Locci *et al.* 2013, respectively.



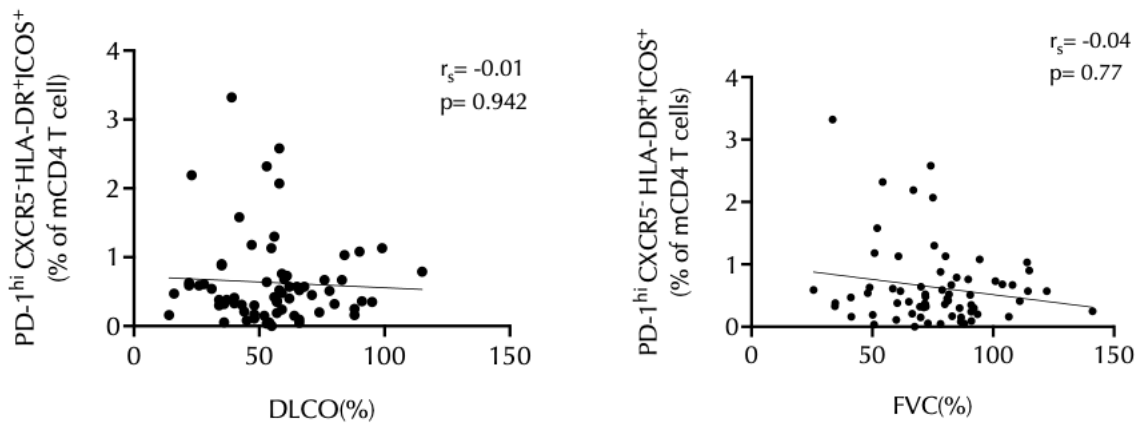
Supplementary Figure 1: Percentage of total T cells are similar in healthy controls and SSc patients. Quantification of CD3+ T cells in patients with SSc (n = 82) compared with healthy controls (n = 18) using mass cytometry data. ns, non-significant.



Supplementary Figure 2. ICOS expression is a continuum in PD-1hi CXCR5- HLA-DR+ CD4 T cells. Biaxial plot of ICOS expression in PD-1hi CXCR5- CD4 T cells.



Supplementary Figure 3: PD-1^{hi}CXCR5⁻HLA-DR⁺ICOS⁻ CD4 T cells show a lower Tfh score associated with a T helper phenotype compared with other PD-1^{hi}CXCR5⁻ CD4 T cell populations. The Tfh gene signature score is depicted for the CD4 T cell subsets derived from bulk RNA sequencing data of CXCR5⁻ CD4 T cell subsets in RA patients as depicted in Figure 3B. Subsets are defined by expression of PD-1, HLA-DR, and ICOS as noted. Paired t-test comparisons are shown. *p<0.05; **p<0.01; ns, non-significant.



Supplementary Figure 4. PD-1^{hi} CXCR5⁻ HLA-DR⁺ ICOS⁺ CD4 T cell frequencies are not significantly correlated with DLCO or FVC. Frequencies of PD-1^{hi} CXCR5⁻ HLA-DR⁺ ICOS⁺ CD4 T cell subset correlated with DLCO(%) shows $r = .01$, $p = 0.942$ and correlation with FVC(%) shows $r = -0.04$, $p = 0.77$.