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**Supplementary Table 1. Characteristics of 20 MRD-positive and 12 MRD-negative patients for scRNA sequencing.**

| Characteristics | MRD positive (n=20) | MRD negative (n=12) | *P* |
|---|---|---|---|
| **Age (years)** | | | 0.632 |
| mean±SD | 33.2±3.1 | 31.3±4.5 | |
| **Gender，n (%)** | | | 0.724 |
| Male | 13 (65.0) | 7 (58.3) | |
| Female | 7 (35.0) | 5 (41.7) | |
| **Time from transplantation to sample collection (months)** | | | 0.340 |
| mean±SD | 6.3±0.9 | 9.0±1.3 | |
| **Duration of follow-up, (days)** | | | 0.258 |
| mean±SD | 376.6±43.5 | 501.6±39.6 | |
| **Disease risk index at diagnosis，n (%)** | | | 0.620 |
| Low risk | 4 (20.0) | 6 (50.0) | |
| Intermediate risk | 15 (75.0) | 4 (33.3) | |
| High risk | 1 (5.0) | 2 (16.7) | |
| **Numbers of chemotherapies to achieve CR, n (%)** | | | 0.319 |
| 1 | 12 (60.0) | 9 (75.0) | |
| >1 | 8 (40.0) | 3 (25.0) | |
| **Numbers of chemotherapies before transplantation** | | | 0.646 |
| mean±SD | 5.1±0.6 | 4.3±0.5 | |
| **Disease status at transplantation，n (%)** | | | 0.370 |
| CR1 | 15 (75.0) | 11 (91.7) | |
| >CR1 | 5 (25.0) | 1 (8.3) | |
| **Types of grafts，n (%)** | | | 0.068 |
| PB | 14 (70.0) | 4 (33.3) | |
| BM+PB | 6 (30.0) | 8 (66.7) | |
| **Donor type，n (%)** | | | 1.000 |
| HLA-identical sibling donor | 4 (20.0) | 2 (16.7) | |
| HLA-haploidentical related donor | 16 (80.0) | 10 (83.3) | |
| **Donor–recipient relationship，n (%)** | | | 1.000 |
| Mother–child | 1 (5.0) | 0 (0.0) | |
| Others | 19 (95.0) | 12 (100.0) | |
| **Donor–recipient sex matched，n (%)** | | | 1.000 |
| Female–male | 16 (80.0) | 10 (83.3) | |
| Others | 4 (20.0) | 2 (16.7) | |
| **Blood group matched，n (%)** | | | 0.069 |
| Matched | 9 (45.0) | 11 (91.7) | |
| Major mismatched | 8 (40.0) | 1 (8.3) | |
| Minor mismatched | 2 (10.0) | 0 (0.0) | |
| Major-minor mismatched | 1 (10.0) | 0 (0.0) | |

Abbreviations: scRNA, single cell; MRD, minimal residual disease; SD, standard deviation; CR, complete remission; PB, peripheral blood; BM, bone marrow BM, bone marrow; HLA, human leukocyte antigen.

**Supplementary Table 2. Characteristics of the bulk RNA sequencing cohort.**

| Characteristics | N=78 |
|---|---|
| **Age (years)** | |
| mean±SD | 38.9±1.8 |
| **Gender，n (%)** | |
| Male | 39 (50.0) |
| Female | 39 (50.0) |
| **Duration of follow-up (days)** | |
| mean±SD | 232.0±5.0 |
| **Disease risk index at diagnosis，n (%)** | |
| Low risk | 9 (11.5) |
| Intermediate risk | 41 (52.6) |
| High risk | 28 (35.9) |
| **Number of chemotherapies to achieve CR，n (%)** | |
| 1 | 57 (73.1) |
| >1 | 21 (26.9) |
| **Numbers of chemotherapies before transplantation** | |
| mean±SD | 4.0±0.2 |
| **Disease status at transplantation，n (%)** | |
| CR1 | 64 (82.1) |
| >CR1 | 14 (17.9) |
| **Types of grafts，n (%)** | |
| PB | 76 (97.4) |
| BM+PB | 2 (2.6) |
| **Donor type，n (%)** | |
| HLA-identical sibling donor | 13 (16.7) |
| HLA-haploidentical related donor | 65 (83.3) |
| **Donor–recipient relationship，n (%)** | |
| Mother–child | 1 (1.3) |
| Others | 77 (98.7) |
| **Donor–recipient sex matched，n (%)** | |
| Female–male | 15 (19.2) |
| Others | 63 (80.8) |
| **Blood group matched，n (%)** | |
| Matched | 42 (53.8) |
| Major mismatched | 18 (23.1) |
| Minor mismatched | 12 (15.4) |
| Major-minor mismatched | 6 (7.7) |
| **Conditioning regimen，n (%)** | |
| Chemotherapy-based | 76 (97.4) |
| TBI-based | |
| **MRD positivity before transplantation，n (%)** | 2 (2.6) |
| Positive | 43 (55.1) |
| Negative | 31 (39.7) |
| Unknown | 4 (5.1) |
| **MRD dynamics after transplantation，n (%)** | |
| Continued negative | 21 (26.9) |
| Continued postive | 15 (19.2) |
| Negative turned into positive | 20 (25.5) |
| Positive turned into negtive | 12 (15.4) |

Abbreviations: MRD, measurable residual disease; SD, standard deviation; CR, complete remission; PB, peripheral blood; BM, bone marrow BM, bone marrow; HLA, human leukocyte antigen;  TBI, total body irradiation.

**Supplementary Table 3. Quality controls of scRNA sequencing.**
Quality-control indexes used for scRNA sequencing. For details, see the Patients and methods sections titled ScRNA seq Data Analysis.

| Name of sample | INDEX | RAW_READS | Total reads | RAW_BASES | READ_LENGTH | RawQ30 |
|---|---|---|---|---|---|---|
| AML25 | X36-1 | 12167583 | 316759383 | 2165829774 | 28;150 | 95.39;92.80 |
| AML25 | X36-2 | 9931079 | | 1767732062 | 28;150 | 95.22;92.42 |
| AML25 | X36-3 | 13768446 | | 2450783388 | 28;150 | 95.07;92.16 |
| AML25 | X36-4 | 11135184 | | 1982062752 | 28;150 | 94.42;90.87 |
| AML25 | X36-1 | 63844395 | | 11364302310 | 28;150 | 95.40;93.04 |
| AML25 | X36-2 | 52424371 | | 9331538038 | 28;150 | 95.31;92.85 |
| AML25 | X36-3 | 72531889 | | 12910676242 | 28;150 | 95.17;92.58 |
| AML25 | X36-4 | 57331961 | | 10205089058 | 28;150 | 95.21;92.00 |
| AML25 | X36-1 | 6108252 | | 1087268856 | 28;150 | 93.65;92.62 |
| AML25 | X36-2 | 5001070 | | 890190460 | 28;150 | 93.30;92.22 |
| AML25 | X36-3 | 6973609 | | 1241302402 | 28;150 | 93.24;92.10 |
| AML25 | X36-4 | 5541544 | | 986394832 | 28;150 | 93.36;91.52 |
| AML05 | X02-1 | 8649292 | 387218127 | 1539573976 | 28;150 | 93.43;92.60 |
| AML05 | X02-2 | 6753997 | | 1202211466 | 28;150 | 93.20;92.71 |
| AML05 | X02-3 | 9305880 | | 1656446640 | 28;150 | 93.40;92.60 |
| AML05 | X02-4 | 9635785 | | 1715169730 | 28;150 | 93.33;92.89 |
| AML05 | X02-1 | 86932116 | | 15473916648 | 28;150 | 96.44;93.96 |
| AML05 | X02-2 | 70312954 | | 12515705812 | 28;150 | 96.29;94.10 |
| AML05 | X02-3 | 95205459 | | 16946571702 | 28;150 | 96.37;93.99 |
| AML05 | X02-4 | 100422644 | | 17875230632 | 28;150 | 96.38;94.25 |
| AML06 | X66-1 | 11425915 | 333816615 | 2033812870 | 28;150 | 94.33;92.82 |
| AML06 | X66-2 | 10869609 | | 1934790402 | 28;150 | 94.46;92.34 |
| AML06 | X66-3 | 9352006 | | 1664657068 | 28;150 | 94.37;91.70 |
| AML06 | X66-4 | 10514449 | | 1871571922 | 28;150 | 94.38;92.58 |
| AML06 | X66-1 | 67215382 | | 11964337996 | 28;150 | 93.85;91.47 |
| AML06 | X66-2 | 63373471 | | 11280477838 | 28;150 | 94.00;90.98 |
| AML06 | X66-3 | 55095793 | | 9807051154 | 28;150 | 93.98;90.37 |
| AML06 | X66-4 | 61661720 | | 10975786160 | 28;150 | 93.94;91.28 |
| AML06 | X66-1 | 12088217 | | 2151702626 | 28;150 | 95.34;93.70 |
| AML06 | X66-2 | 11321534 | | 2015233052 | 28;150 | 95.43;93.25 |
| AML06 | X66-3 | 9891415 | | 1760671870 | 28;150 | 95.41;92.76 |
| AML06 | X66-4 | 11007104 | | 1959264512 | 28;150 | 95.39;93.47 |
| AML07 | X15-1 | 4450359 | 433901580 | 792163902 | 28;150 | 94.54;93.36 |
| AML07 | X15-2 | 25044352 | | 4457894656 | 28;150 | 94.47;93.10 |
| AML07 | X15-3 | 19548433 | | 3479621074 | 28;150 | 94.47;93.34 |
| AML07 | X15-4 | 24975552 | | 4445648256 | 28;150 | 94.41;93.39 |
| AML07 | X15-1 | 21365745 | | 3803102610 | 28;150 | 95.45;94.00 |
| AML07 | X15-2 | 122909220 | | 21877841160 | 28;150 | 95.31;93.77 |
| AML07 | X15-3 | 95423454 | | 16985374812 | 28;150 | 95.35;93.91 |
| AML07 | X15-4 | 120184465 | | 21392834770 | 28;150 | 95.32;93.99 |
| AML08 | X16-1 | 18649305 | 385952746 | 3319576290 | 28;150 | 94.57;93.09 |
| AML08 | X16-2 | 21907138 | | 3899470564 | 28;150 | 93.84;93.59 |
| AML08 | X16-3 | 15904709 | | 2831038202 | 28;150 | 94.45;93.62 |
| AML08 | X16-4 | 24525262 | | 4365496636 | 28;150 | 94.42;93.25 |
| AML08 | X16-1 | 70215619 | | 12498380182 | 28;150 | 94.94;91.97 |
| AML08 | X16-2 | 82566268 | | 14696795704 | 28;150 | 94.24;92.50 |
| AML08 | X16-3 | 60066921 | | 10691911938 | 28;150 | 94.84;92.58 |
| AML08 | X16-4 | 92117524 | | 16396919272 | 28;150 | 94.83;92.18 |
| AML14 | X34-1 | 11827449 | 424501791 | 2105285922 | 28;150 | 93.23;91.69 |
| AML14 | X34-2 | 11505575 | | 2047992350 | 28;150 | 93.08;92.69 |
| AML14 | X34-3 | 11345629 | | 2019521962 | 28;150 | 93.08;91.69 |
| AML14 | X34-4 | 10453867 | | 1860788326 | 28;150 | 93.10;91.69 |
| AML14 | X34-1 | 99578137 | | 17724908386 | 28;150 | 94.99;93.20 |
| AML14 | X34-2 | 96058953 | | 17098493634 | 28;150 | 94.86;94.00 |
| AML14 | X34-3 | 95302647 | | 16963871166 | 28;150 | 94.89;93.22 |
| AML14 | X34-4 | 88429534 | | 15740457052 | 28;150 | 94.88;93.22 |
| AML09 | X36-1 | 11416375 | 42866011 | 2032114750 | 28;150 | 93.57;84.14 |
| AML09 | X36-2 | 9886192 | | 1759742176 | 28;150 | 93.34;83.88 |
| AML09 | X36-3 | 11655764 | | 2074725992 | 28;150 | 93.27;83.45 |
| AML09 | X36-4 | 9907680 | | 1763567040 | 28;150 | 93.21;82.42 |
| AML11 | X37-1 | 12631285 | 50273321 | 2248368730 | 28;150 | 93.49;83.01 |
| AML11 | X37-2 | 12720762 | | 2264295636 | 28;150 | 93.63;84.34 |
| AML11 | X37-3 | 12875625 | | 2291861250 | 28;150 | 93.55;84.98 |
| AML11 | X37-4 | 12045649 | | 2144125522 | 28;150 | 93.43;84.32 |
| AML10 | X71-1 | 13207506 | 49068431 | 2350936068 | 28;150 | 95.78;93.03 |
| AML10 | X71-2 | 10942731 | | 1947806118 | 28;150 | 95.65;92.99 |
| AML10 | X71-3 | 13695453 | | 2437790634 | 28;150 | 95.67;92.55 |
| AML10 | X71-4 | 11222741 | | 1997647898 | 28;150 | 95.81;92.50 |
| AML12 | X72-1 | 13963484 | 53654471 | 2485500152 | 28;150 | 95.73;93.00 |
| AML12 | X72-2 | 12138502 | | 2160653356 | 28;150 | 95.73;93.02 |
| AML12 | X72-3 | 15511072 | | 2760970816 | 28;150 | 95.66;92.78 |
| AML12 | X72-4 | 12041413 | | 2143371514 | 28;150 | 95.79;93.16 |
| AML13 | X73-1 | 10755583 | 44597181 | 1914493774 | 28;150 | 95.71;93.04 |
| AML13 | X73-2 | 9771879 | | 1739394462 | 28;150 | 95.74;93.57 |
| AML13 | X73-3 | 12668182 | | 2254936396 | 28;150 | 95.68;93.14 |
| AML13 | X73-4 | 11401537 | | 2029473586 | 28;150 | 95.75;92.79 |
| AML09 | X36-1 | 118586942 | 444150916 | 21108475676 | 28;150 | 95.04;91.97 |
| AML09 | X36-2 | 102484694 | | 18242275532 | 28;150 | 94.91;91.60 |
| AML09 | X36-3 | 120102029 | | 21378161162 | 28;150 | 94.80;91.39 |
| AML09 | X36-4 | 102977251 | | 18329950678 | 28;150 | 94.86;90.62 |
| AML11 | X37-1 | 117123163 | 465491007 | 20847923014 | 28;150 | 94.95;90.69 |
| AML11 | X37-2 | 118122634 | | 21025828852 | 28;150 | 95.03;91.90 |
| AML11 | X37-3 | 119353854 | | 21244986012 | 28;150 | 94.94;92.35 |
| AML11 | X37-4 | 110891356 | | 19738661368 | 28;150 | 94.87;91.73 |
| AML13 | X73-1 | 22568372 | 93399178 | 4017170216 | 28;150 | 94.05;92.07 |
| AML13 | X73-2 | 20261106 | | 3606476868 | 28;150 | 94.04;92.83 |
| AML13 | X73-3 | 26607110 | | 4736065580 | 28;150 | 93.99;92.34 |
| AML13 | X73-4 | 23962590 | | 4265341020 | 28;150 | 94.02;91.71 |
| AML18 | X08-1 | 9582000 | 494098755 | 1705596000 | 28;150 | 96.07;93.16 |
| AML18 | X08-2 | 9080070 | | 1616252460 | 28;150 | 96.20;91.97 |
| AML18 | X08-3 | 11002348 | | 1958417944 | 28;150 | 96.15;93.04 |
| AML18 | X08-4 | 9594433 | | 1707809074 | 28;150 | 95.92;92.22 |
| AML18 | X08-1 | 112461942 | | 20018225676 | 28;150 | 94.53;92.65 |
| AML18 | X08-2 | 107347478 | | 19107851084 | 28;150 | 94.69;91.54 |
| AML18 | X08-3 | 130044352 | | 23147894656 | 28;150 | 94.61;92.67 |
| AML18 | X08-4 | 104986132 | | 18687531496 | 28;150 | 94.45;91.85 |
| AML19 | X15-1 | 2207742 | 311593776 | 392978076 | 28;150 | 94.80;91.22 |
| AML19 | X15-2 | 12154725 | | 2163541050 | 28;150 | 94.90;91.02 |
| AML19 | X15-3 | 9868728 | | 1756633584 | 28;150 | 94.68;91.02 |
| AML19 | X15-4 | 12019435 | | 2139459430 | 28;150 | 94.81;91.35 |
| AML19 | X15-1 | 14471639 | | 2575951742 | 28;150 | 95.16;91.28 |
| AML19 | X15-2 | 86649413 | | 15423595514 | 28;150 | 95.21;91.15 |
| AML19 | X15-3 | 70257822 | | 12505892316 | 28;150 | 95.01;91.23 |
| AML19 | X15-4 | 86425049 | | 15383658722 | 28;150 | 95.09;91.51 |
| AML19 | X15-1 | 980397 | | 174510666 | 28;150 | 94.36;92.19 |
| AML19 | X15-2 | 5893055 | | 1048963790 | 28;150 | 94.21;91.85 |
| AML19 | X15-3 | 4792334 | | 853035452 | 28;150 | 94.20;92.01 |
| AML19 | X15-4 | 5873437 | | 1045471786 | 28;150 | 94.17;92.08 |
| AML16 | X16-1 | 6234563 | 446720509 | 1109752214 | 28;150 | 94.82;90.00 |
| AML16 | X16-2 | 6170244 | | 1098303432 | 28;150 | 93.82;91.54 |
| AML16 | X16-3 | 4324396 | | 769742488 | 28;150 | 94.86;91.75 |
| AML16 | X16-4 | 6945632 | | 1236322496 | 28;150 | 94.82;91.07 |
| AML16 | X16-1 | 4385578 | | 780632884 | 28;150 | 95.10;90.40 |
| AML16 | X16-2 | 4914661 | | 874809658 | 28;150 | 94.28;90.99 |
| AML16 | X16-3 | 3433578 | | 611176884 | 28;150 | 95.15;91.36 |
| AML16 | X16-4 | 5514853 | | 981643834 | 28;150 | 95.05;90.74 |
| AML16 | X16-1 | 96848413 | | 17239017514 | 28;150 | 95.12;90.86 |
| AML16 | X16-2 | 109475236 | | 19486592008 | 28;150 | 94.44;91.84 |
| AML16 | X16-3 | 75973531 | | 13523288518 | 28;150 | 95.17;91.82 |
| AML16 | X16-4 | 122499824 | | 21804968672 | 28;150 | 95.11;91.20 |
| AML15 | X17-1 | 6532595 | 464448402 | 1162801910 | 28;150 | 94.95;91.93 |
| AML15 | X17-2 | 7484248 | | 1332196144 | 28;150 | 94.83;90.82 |
| AML15 | X17-3 | 8755040 | | 1558397120 | 28;150 | 94.92;91.44 |
| AML15 | X17-4 | 2663792 | | 474154976 | 28;150 | 94.81;91.41 |
| AML15 | X17-1 | 4033641 | | 717988098 | 28;150 | 94.92;91.25 |
| AML15 | X17-2 | 4603730 | | 819463940 | 28;150 | 95.11;90.57 |
| AML15 | X17-3 | 5396462 | | 960570236 | 28;150 | 95.19;91.14 |
| AML15 | X17-4 | 1623788 | | 289034264 | 28;150 | 95.11;91.10 |
| AML15 | X17-1 | 108556748 | | 19322923144 | 28;150 | 95.19;91.93 |
| AML15 | X17-2 | 124153714 | | 22099361092 | 28;150 | 95.12;90.94 |
| AML15 | X17-3 | 146866974 | | 26142321372 | 28;150 | 95.22;91.63 |
| AML15 | X17-4 | 43778670 | | 7792603260 | 28;150 | 95.13;91.55 |
| AML17 | X18-1 | 12432477 | 331360929 | 2212980906 | 28;150 | 94.91;91.70 |
| AML17 | X18-2 | 15829020 | | 2817565560 | 28;150 | 94.80;91.82 |
| AML17 | X18-3 | 12818450 | | 2281684100 | 28;150 | 94.86;91.60 |
| AML17 | X18-4 | 13467803 | | 2397268934 | 28;150 | 94.93;91.15 |
| AML17 | X18-1 | 57994023 | | 10322936094 | 28;150 | 93.74;91.36 |
| AML17 | X18-2 | 75135525 | | 13374123450 | 28;150 | 93.56;91.34 |
| AML17 | X18-3 | 59941841 | | 10669647698 | 28;150 | 93.70;91.22 |
| AML17 | X18-4 | 62484576 | | 11122254528 | 28;150 | 93.70;90.35 |
| AML17 | X18-1 | 4786524 | | 852001272 | 28;150 | 93.90;92.45 |
| AML17 | X18-2 | 6317372 | | 1124492216 | 28;150 | 93.64;92.43 |
| AML17 | X18-3 | 4945192 | | 880244176 | 28;150 | 93.83;92.33 |
| AML17 | X18-4 | 5208126 | | 927046428 | 28;150 | 93.81;91.83 |
| H03 | X52-1 | 20085104 | 500149174 | 3575148512 | 28;150 | 94.50;91.81 |
| H03 | X52-2 | 15866810 | | 2824292180 | 28;150 | 94.50;91.44 |
| H03 | X52-3 | 13864522 | | 2467884916 | 28;150 | 94.33;91.63 |
| H03 | X52-4 | 8082702 | | 1438720956 | 28;150 | 94.42;92.45 |
| H03 | X52-1 | 151628717 | | 26989911626 | 28;150 | 95.78;91.32 |
| H03 | X52-2 | 123316456 | | 21950329168 | 28;150 | 95.78;90.89 |
| H03 | X52-3 | 106030704 | | 18873465312 | 28;150 | 95.77;91.26 |
| H03 | X52-4 | 61274159 | | 10906800302 | 28;150 | 95.75;92.02 |
| H01 | X53-1 | 8701902 | 331603441 | 1548938556 | 28;150 | 94.95;91.23 |
| H01 | X53-2 | 10427627 | | 1856117606 | 28;150 | 94.92;90.93 |
| H01 | X53-3 | 9084533 | | 1617046874 | 28;150 | 94.92;92.31 |
| H01 | X53-4 | 7322299 | | 1303369222 | 28;150 | 94.93;92.12 |
| H01 | X53-1 | 37128321 | | 6608841138 | 28;150 | 96.60;91.73 |
| H01 | X53-2 | 42975320 | | 7649606960 | 28;150 | 96.59;91.63 |
| H01 | X53-3 | 36645776 | | 6522948128 | 28;150 | 96.53;92.11 |
| H01 | X53-4 | 31109486 | | 5537488508 | 28;150 | 96.56;92.07 |
| H01 | X53-1 | 36252794 | | 6452997332 | 28;150 | 94.06;92.14 |
| H01 | X53-2 | 43559401 | | 7753573378 | 28;150 | 93.98;91.90 |
| H01 | X53-3 | 37881367 | | 6742883326 | 28;150 | 94.04;92.98 |
| H01 | X53-4 | 30514615 | | 5431601470 | 28;150 | 94.08;92.81 |
| H02 | X66-1 | 14497476 | 473182609 | 2580550728 | 28;150 | 94.45;92.40 |
| H02 | X66-2 | 13496977 | | 2402461906 | 28;150 | 94.51;91.71 |
| H02 | X66-3 | 11415015 | | 2031872670 | 28;150 | 94.42;90.93 |
| H02 | X66-4 | 13304656 | | 2368228768 | 28;150 | 94.46;92.02 |
| H02 | X66-1 | 81147777 | | 14444304306 | 28;150 | 95.72;91.89 |
| H02 | X66-2 | 74861485 | | 13325344330 | 28;150 | 95.80;91.14 |
| H02 | X66-3 | 64551648 | | 11490193344 | 28;150 | 95.76;90.37 |
| H02 | X66-4 | 75195222 | | 13384749516 | 28;150 | 95.77;91.51 |
| H02 | X66-1 | 34267317 | | 6099582426 | 28;150 | 94.87;91.25 |
| H02 | X66-2 | 31906922 | | 5679432116 | 28;150 | 94.93;90.79 |
| H02 | X66-3 | 27034468 | | 4812135304 | 28;150 | 94.91;90.29 |
| H02 | X66-4 | 31503646 | | 5607648988 | 28;150 | 94.94;91.07 |
| AML24 | X41-1 | 15989461 | 434653748 | 2846124058 | 28;150 | 96.67;88.70 |
| AML24 | X41-2 | 13217115 | | 2352646470 | 28;150 | 96.58;88.70 |
| AML24 | X41-3 | 12016953 | | 2139017634 | 28;150 | 96.56;88.55 |
| AML24 | X41-4 | 12136559 | | 2160307502 | 28;150 | 96.76;88.83 |
| AML24 | X41-1 | 114050629 | | 20301011962 | 28;150 | 95.09;89.45 |
| AML24 | X41-2 | 93733498 | | 16684562644 | 28;150 | 95.07;89.44 |
| AML24 | X41-3 | 85128077 | | 15152797706 | 28;150 | 95.08;89.30 |
| AML24 | X41-4 | 88381456 | | 15731899168 | 28;150 | 95.23;89.46 |
| AML20 | X92-1 | 11983169 | 394565536 | 2133004082 | 28;150 | 96.29;89.23 |
| AML20 | X92-2 | 13658986 | | 2431299508 | 28;150 | 95.98;89.03 |
| AML20 | X92-3 | 10815156 | | 1925097768 | 28;150 | 96.14;89.15 |
| AML20 | X92-4 | 18255129 | | 3249412962 | 28;150 | 96.16;88.91 |
| AML20 | X92-1 | 62879865 | | 11192615970 | 28;150 | 95.37;89.54 |
| AML20 | X92-2 | 68190333 | | 12137879274 | 28;150 | 95.14;89.55 |
| AML20 | X92-3 | 54271588 | | 9660342664 | 28;150 | 95.21;89.47 |
| AML20 | X92-4 | 93982930 | | 16728961540 | 28;150 | 95.20;89.36 |
| AML20 | X92-1 | 13328677 | | 2372504506 | 28;150 | 95.37;89.81 |
| AML20 | X92-2 | 14973466 | | 2665276948 | 28;150 | 95.27;89.88 |
| AML20 | X92-3 | 11975841 | | 2131699698 | 28;150 | 95.32;89.81 |
| AML20 | X92-4 | 20250396 | | 3604570488 | 28;150 | 95.31;89.66 |
| AML21 | X03-1 | 15140598 | 481203330 | 2695026444 | 28;150 | 94.78;89.51 |
| AML21 | X03-2 | 13910569 | | 2476081282 | 28;150 | 94.95;89.68 |
| AML21 | X03-3 | 16299750 | | 2901355500 | 28;150 | 94.71;89.10 |
| AML21 | X03-4 | 16334491 | | 2907539398 | 28;150 | 94.68;89.86 |
| AML21 | X03-1 | 104156795 | | 18539909510 | 28;150 | 95.02;90.17 |
| AML21 | X03-2 | 98084854 | | 17459104012 | 28;150 | 95.15;90.30 |
| AML21 | X03-3 | 107667243 | | 19164769254 | 28;150 | 94.95;89.84 |
| AML21 | X03-4 | 109609030 | | 19510407340 | 28;150 | 94.94;90.48 |
| AML26 | X45-1 | 17209072 | 75902242 | 3063214816 | 28;150 | 92.62;90.12 |
| AML26 | X45-2 | 22325588 | | 3973954664 | 28;150 | 92.48;89.65 |
| AML26 | X45-3 | 19171072 | | 3412450816 | 28;150 | 92.37;89.72 |
| AML26 | X45-4 | 17196510 | | 3060978780 | 28;150 | 92.33;89.27 |
| AML26 | X74-1 | 12986786 | 367770924 | 2311647908 | 28;150 | 95.24;88.83 |
| AML26 | X74-2 | 13680522 | | 2435132916 | 28;150 | 95.43;88.78 |
| AML26 | X74-3 | 20789013 | | 3700444314 | 28;150 | 95.19;88.28 |
| AML26 | X74-4 | 18751796 | | 3337819688 | 28;150 | 95.22;89.33 |
| AML26 | X74-1 | 47474863 | | 8450525614 | 28;150 | 95.41;91.27 |
| AML26 | X74-2 | 50987069 | | 9075698282 | 28;150 | 95.52;91.28 |
| AML26 | X74-3 | 77181112 | | 13738237936 | 28;150 | 95.29;90.71 |
| AML26 | X74-4 | 69824673 | | 12428791794 | 28;150 | 95.38;91.81 |
| AML26 | X74-1 | 10898974 | | 1940017372 | 28;150 | 94.59;89.66 |
| AML26 | X74-2 | 11591592 | | 2063303376 | 28;150 | 94.73;89.63 |
| AML26 | X74-3 | 17554347 | | 3124673766 | 28;150 | 94.49;89.05 |
| AML26 | X74-4 | 16050177 | | 2856931506 | 28;150 | 94.59;90.19 |
| AML22 | X75-1 | 12956848 | 389501284 | 2306318944 | 28;150 | 95.25;89.52 |
| AML22 | X75-2 | 16387232 | | 2916927296 | 28;150 | 95.15;89.00 |
| AML22 | X75-3 | 10679695 | | 1900985710 | 28;150 | 95.24;89.23 |
| AML22 | X75-4 | 13688626 | | 2436575428 | 28;150 | 95.25;88.38 |
| AML22 | X75-1 | 80388539 | | 14309159942 | 28;150 | 95.47;91.97 |
| AML22 | X75-2 | 102290656 | | 18207736768 | 28;150 | 95.33;91.61 |
| AML22 | X75-3 | 67142617 | | 11951385826 | 28;150 | 95.36;91.70 |
| AML22 | X75-4 | 85967071 | | 15302138638 | 28;150 | 95.44;90.96 |
| AML23 | X76-1 | 13058466 | 343101395 | 2324406948 | 28;150 | 95.67;91.41 |
| AML23 | X76-2 | 8880619 | | 1580750182 | 28;150 | 95.44;90.82 |
| AML23 | X76-3 | 11518439 | | 2050282142 | 28;150 | 95.58;90.11 |
| AML23 | X76-4 | 14193490 | | 2526441220 | 28;150 | 95.63;91.17 |
| AML23 | X76-1 | 81205913 | | 14454652514 | 28;150 | 91.66;90.77 |
| AML23 | X76-2 | 54021747 | | 9615870966 | 28;150 | 91.54;90.24 |
| AML23 | X76-3 | 71386181 | | 12706740218 | 28;150 | 91.56;89.39 |
| AML23 | X76-4 | 88836540 | | 15812904120 | 28;150 | 91.63;90.52 |
| AML27 | X94-1 | 8565271 | 386615203 | 1524618238 | 28;150 | 95.72;90.64 |
| AML27 | X94-2 | 14211639 | | 2529671742 | 28;150 | 95.93;90.64 |
| AML27 | X94-3 | 13482537 | | 2399891586 | 28;150 | 95.70;90.91 |
| AML27 | X94-4 | 14282640 | | 2542309920 | 28;150 | 95.64;90.41 |
| AML27 | X94-1 | 56759019 | | 10103105382 | 28;150 | 94.52;91.64 |
| AML27 | X94-2 | 93890977 | | 16712593906 | 28;150 | 94.73;91.68 |
| AML27 | X94-3 | 89724065 | | 15970883570 | 28;150 | 94.52;91.81 |
| AML27 | X94-4 | 95699055 | | 17034431790 | 28;150 | 94.44;91.47 |
| AML26 | X95-1 | 10782944 | 415572599 | 1919364032 | 28;150 | 95.80;89.85 |
| AML26 | X95-2 | 7892293 | | 1404828154 | 28;150 | 96.03;89.93 |
| AML26 | X95-3 | 7568252 | | 1347148856 | 28;150 | 95.69;89.53 |
| AML26 | X95-4 | 15758004 | | 2804924712 | 28;150 | 95.76;89.82 |
| AML26 | X95-1 | 96273245 | | 17136637610 | 28;150 | 94.70;90.88 |
| AML26 | X95-2 | 67143373 | | 11951520394 | 28;150 | 94.86;90.83 |
| AML26 | X95-3 | 67306492 | | 11980555576 | 28;150 | 94.65;90.62 |
| AML26 | X95-4 | 142847996 | | 25426943288 | 28;150 | 94.62;90.88 |
| AML32 | X05-1 | 11180495 | 466662350 | 1990128110 | 28;150 | 97.55;84.65 |
| AML32 | X05-2 | 84038 | | 14958764 | 28;150 | 97.33;85.18 |
| AML32 | X05-3 | 11119988 | | 1979357864 | 28;150 | 97.75;85.45 |
| AML32 | X05-4 | 14989538 | | 2668137764 | 28;150 | 97.70;85.87 |
| AML32 | X05-1 | 129498183 | | 23050676574 | 28;150 | 97.49;83.05 |
| AML32 | X05-2 | 951301 | | 169331578 | 28;150 | 97.34;83.66 |
| AML32 | X05-3 | 128551638 | | 22882191564 | 28;150 | 97.70;84.19 |
| AML32 | X05-4 | 170287169 | | 30311116082 | 28;150 | 97.64;84.63 |
| AML29 | X57-1 | 14695953 | 402315752 | 2615879634 | 28;150 | 97.24;84.05 |
| AML29 | X57-2 | 13977940 | | 2488073320 | 28;150 | 97.28;83.85 |
| AML29 | X57-3 | 11878126 | | 2114306428 | 28;150 | 97.28;83.99 |
| AML29 | X57-4 | 19402093 | | 3453572554 | 28;150 | 97.27;83.57 |
| AML29 | X57-1 | 84271943 | | 15009405854 | 28;150 | 96.34;84.19 |
| AML29 | X57-2 | 79657698 | | 14179070244 | 28;150 | 96.35;83.93 |
| AML29 | X57-3 | 68367581 | | 12169429418 | 28;150 | 96.37;84.03 |
| AML29 | X57-4 | 110064418 | | 19591466404 | 28;150 | 96.37;83.64 |
| AML30 | X24-1 | 11600301 | 351522160 | 2064853578 | 28;150 | 96.59;90.28 |
| AML30 | X24-2 | 10951300 | | 1949331400 | 28;150 | 96.68;90.54 |
| AML30 | X24-3 | 9646825 | | 1717134850 | 28;150 | 96.60;90.52 |
| AML30 | X24-4 | 13938710 | | 2481090380 | 28;150 | 96.53;90.33 |
| AML30 | X24-1 | 71601489 | | 12745065042 | 28;150 | 96.42;87.38 |
| AML30 | X24-2 | 66850549 | | 11899397722 | 28;150 | 96.36;87.34 |
| AML30 | X24-3 | 59008918 | | 10503587404 | 28;150 | 96.69;88.22 |
| AML30 | X24-4 | 85779021 | | 15268665738 | 28;150 | 96.39;87.52 |
| AML30 | X24-1 | 5545435 | | 987087430 | 28;150 | 98.00;91.50 |
| AML30 | X24-2 | 5134982 | | 914026796 | 28;150 | 98.06;91.71 |
| AML30 | X24-3 | 4795579 | | 853613062 | 28;150 | 98.00;91.69 |
| AML30 | X24-4 | 6669051 | | 1187091078 | 28;150 | 97.95;91.54 |
| AML31 | X74-1 | 102582933 | 378914048 | 18259762074 | 28;150 | 95.58;88.66 |
| AML31 | X74-2 | 91059107 | | 16208521046 | 28;150 | 95.77;88.64 |
| AML31 | X74-3 | 57990031 | | 10322225518 | 28;150 | 95.60;88.38 |
| AML31 | X74-4 | 127281977 | | 22656191906 | 28;150 | 95.63;88.97 |
| AML33 | X88-1 | 20289327 | 351086459 | 3611500206 | 28;150 | 95.57;87.35 |
| AML33 | X88-2 | 15548215 | | 2767582270 | 28;150 | 95.68;87.11 |
| AML33 | X88-3 | 18551747 | | 3302210966 | 28;150 | 95.49;85.14 |
| AML33 | X88-4 | 16601213 | | 2955015914 | 28;150 | 95.60;87.11 |
| AML33 | X88-1 | 73896895 | | 13153647310 | 28;150 | 96.18;88.56 |
| AML33 | X88-2 | 56531172 | | 10062548616 | 28;150 | 96.33;88.37 |
| AML33 | X88-3 | 67497400 | | 12014537200 | 28;150 | 96.24;85.95 |
| AML33 | X88-4 | 60353556 | | 10742932968 | 28;150 | 96.28;88.31 |
| AML33 | X88-1 | 6230123 | | 1108961894 | 28;150 | 94.69;86.26 |
| AML33 | X88-2 | 4805776 | | 855428128 | 28;150 | 94.85;86.01 |
| AML33 | X88-3 | 5690670 | | 1012939260 | 28;150 | 94.60;83.32 |
| AML33 | X88-4 | 5090365 | | 906084970 | 28;150 | 94.77;86.02 |
| AML01 | X52-1 | 97584446 | 287233248 | 17370031388 | 28;150 | 94.61;91.97 |
| AML01 | X52-2 | 62186510 | | 11069198780 | 28;150 | 94.56;91.57 |
| AML01 | X52-3 | 58187585 | | 10357390130 | 28;150 | 94.58;91.93 |
| AML01 | X52-4 | 69274707 | | 12330897846 | 28;150 | 94.56;92.60 |
| AML02 | X60-1 | 10867007 | 359739984 | 1934327246 | 28;150 | 94.71;91.83 |
| AML02 | X60-2 | 9385203 | | 1670566134 | 28;150 | 94.85;91.86 |
| AML02 | X60-3 | 8650734 | | 1539830652 | 28;150 | 94.83;91.65 |
| AML02 | X60-4 | 8011357 | | 1426021546 | 28;150 | 94.53;91.15 |
| AML02 | X60-1 | 95696643 | | 17034002454 | 28;150 | 94.59;94.29 |
| AML02 | X60-2 | 81109447 | | 14437481566 | 28;150 | 94.72;94.21 |
| AML02 | X60-3 | 75425467 | | 13425733126 | 28;150 | 94.73;94.17 |
| AML02 | X60-4 | 70594126 | | 12565754428 | 28;150 | 94.55;93.97 |
| AML03 | X50-1 | 9713029 | 343728771 | 1728919162 | 28;150 | 94.89;95.10 |
| AML03 | X50-2 | 7735670 | | 1376949260 | 28;150 | 95.12;95.30 |
| AML03 | X50-3 | 9518483 | | 1694289974 | 28;150 | 94.97;95.26 |
| AML03 | X50-4 | 11121748 | | 1979671144 | 28;150 | 94.91;95.07 |
| AML03 | X50-1 | 78286009 | | 13934009602 | 28;150 | 95.84;94.01 |
| AML03 | X50-2 | 62342425 | | 11096951650 | 28;150 | 95.96;94.20 |
| AML03 | X50-3 | 76100375 | | 13545866750 | 28;150 | 95.86;94.13 |
| AML03 | X50-4 | 88911032 | | 15826163696 | 28;150 | 95.86;94.00 |

**Supplementary Table 4. Summary of Reagents and Materials in *in vitro* assays.**

| Reagents or Materials | Source | Cat. No. | Country |
|---|---|---|---|
| CD3-PerCP (Clone HIT3a) | Biolegend | 317337 | USA |
| CD8 BV510 (Clone SK1) | Biolegend | 344732 | USA |
| CD56-APC-Cy7 (Clone NCAM) | Biolegend | 362512 | USA |
| KLRG1-BV421 (Clone SA231A2) | Biolegend | 367706 | USA |
| KLRG1-PE (Clone SA231A2) | Biolegend | 367711 | USA |
| CD107a-PE (Clone H4A3) | Biolegend | 328607 | USA |
| IFNγ-PECy7 (Clone 4S.B3) | Biolegend | 502527 | USA |
| TNFα-BV605 (Clone Mab11) | Biolegend | 502935 | USA |
| IL2-APC (Clone MQ1-17H12) | Biolegend | 500309 | USA |
| IL2-BV421 (Clone MQ1-17 H12) | Biolegend | 500327 | USA |
| Ki67-AF700 (Clone Ki67) | Biolegend | 350529 | USA |
| Ki67-PerCP 5.5 (Clone Ki67) | Biolegend | 350519 | USA |
| CD25-BV510 (clone BC96) | Biolegend | 302639 | USA |
| CD69- APC-Cy7 (clone FN50) | Biolegend | 310909 | USA |
| GZMB-AF647 (Clone QA16A02) | Biolegend | 372219 | USA |
| GZMK-FITC (Clone GM26E7) | BioLegend | 370507 | USA |
| Perforin-AF700 (Clone B-D48) | BioLegend | 353324 | USA |
| Annexin V-APC | BD Biosciences | 550474 | USA |
| 7AAD-PerCP | BD Biosciences | 559925 | USA |
| **Chemicals** | | | |
| RPMI 1640 medium | ThermoFisher Scientific | 11875093 | USA |
| FBS | ThermoFisher Scientific | 12483020 | USA |
| Antibiotic–antimycotic | ThermoFisher Scientific | 15240096 | USA |
| 2-mercaptoethanol | Sigma-Aldrich | 60-24-2 | USA |
| Ficoll-Paque | TBD | SZLTS1077 | China |
| IMDM | Thermo Fisher Scientific | 12440053 | USA |
| IL2 | Sigma-Aldrich | HIL2-RO | USA |
| BIT | Stem Cell Technologies | 99500 | Canada |
| Anti-PE MultiSort MicroBeads | Miltenyi Biotec | 130-048-801 | Germany |
| human T-Activator CD3/CD28 Dynabeads | Gibco | 1132D | USA |
| PMA | Sigma-Aldrich | P1585 | USA |
| Ionomycin | Sigma-Aldrich | I3909 | USA |
| BFA | BD | 555029 | USA |
| Transcription factor buffer set | BD Pharmigen | 562574 | USA |
| CellTrace Violet | Invitrogen | C34557 | USA |
| Binding buffer | BD Biosciences | 556454 | USA |
| LDH cytotoxicity assay detection kit | Roche | 11644793001 | Germany |

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Dr. Thomas Ottmann, Dr. Widmayer, Prof. Dr. Widmayer, Dr. Eberbach, Prof. Dr. Eberbach, Dr. Walter, Prof. Dr. Walter, Dr. Messerschmidt, Prof. Dr. Messerschmidt, Dr. Christof, Prof. Dr. Christof, Dr. Hromkovič, Prof. Dr. Hromkovič, Dr. Agnetis, Prof. Dr. Agnetis, Dr. Pesch, Prof. Dr. Pesch, Dr. Giel, Prof. Dr. Giel, Dr. Spieker, Prof. Dr. Spieker, Dr. Slomka, Prof. Dr. Slomka, Dr. Slany, Prof. Dr. Slany, Dr. Schwiegelshohn, Prof. Dr. Schwiegelshohn, Dr. Romeis, Prof. Dr. Romeis, Dr. Modica, Prof. Dr. Modica, Dr. Gal, Prof. Dr. Gal, Dr. Birnbaum, Prof. Dr. Birnbaum, Dr. Mathieson, Prof. Dr. Mathieson, Dr. Manthey, Prof. Dr. Manthey, Dr. Phillipson, Prof. Dr. Phillipson, Dr. Garg, Prof. Dr. Garg, Dr.Ettrich, Prof. Dr. Ettrich, Dr. Margraf, Prof. Dr. Margraf, Dr. Lengler, Prof. Dr. Lengler, Dr. Steger, Prof. Dr. Steger, Dr. Diekert, Prof. Dr. Diekert, Dr. Durr, Prof. Dr. Durr, Dr. Segerlind, Prof. Dr. Segerlind, Dr. Verbitsky, Prof. Dr. Verbitsky, Dr. Prasohn, Prof. Dr. Prasohn, Dr. 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Blondin Massé, Dr. Garon, Prof. Dr. Garon, Dr. Labbé, Prof. Dr. Labbé, Dr. Narbel, Prof. Dr. Narbel, Dr. Carton, Prof. Dr. Carton, Dr. Terlutte, Prof. Dr. Terlutte, Dr. Carayol, Prof. Dr. Carayol, Dr. Göös, Prof. Dr. Göös, Dr. Pitassi, Prof. Dr. Pitassi, Dr. Lovett, Prof. Dr. Lovett, Dr. Hahn, Prof. Dr. Hahn, Dr. Santha, Prof. Dr. Santha, Dr. Qiu, Prof. Dr. Qiu, Dr. Hayman, Prof. Dr. Hayman, Dr. Miller, Prof. Dr. Miller, Dr. Manokaran, Prof. Dr. Manokaran, Dr. Vondrák, Prof. Dr. Vondrák, Dr. Tetali, Prof. Dr. Tetali, Dr. Vishnoi, Prof. Dr. Vishnoi, Dr. Raghavendra, Prof. Dr. Raghavendra, Dr. Feldman, Prof. Dr. Feldman, Dr. Dinur, Prof. Dr. Dinur, Dr. Kesselman, Prof. Dr. Kesselman, Dr. Kothari, Prof. Dr. Kothari, Dr. Venkatesan, Prof. Dr. Venkatesan, Dr. Zuckerman, Prof. Dr. Zuckerman, Dr. Beame, Prof. Dr. Beame, Dr. Harsha, Prof. Dr. Harsha, Dr. Srivastava, Prof. Dr. Srivastava, Dr. Saxena, Prof. Dr. Saxena, Dr. Barak, Prof. Dr. Barak, Dr. Goldreich, Prof. Dr. Goldreich, Dr. Rao, 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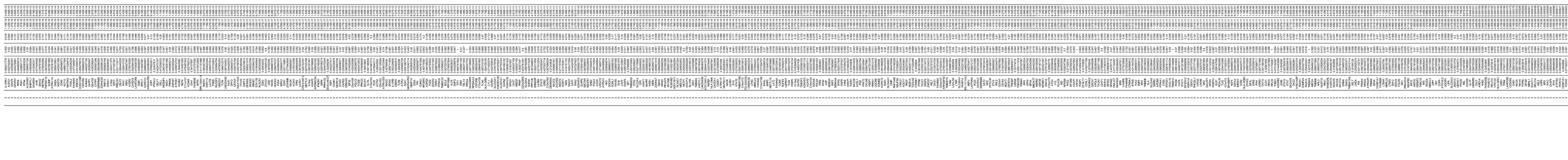

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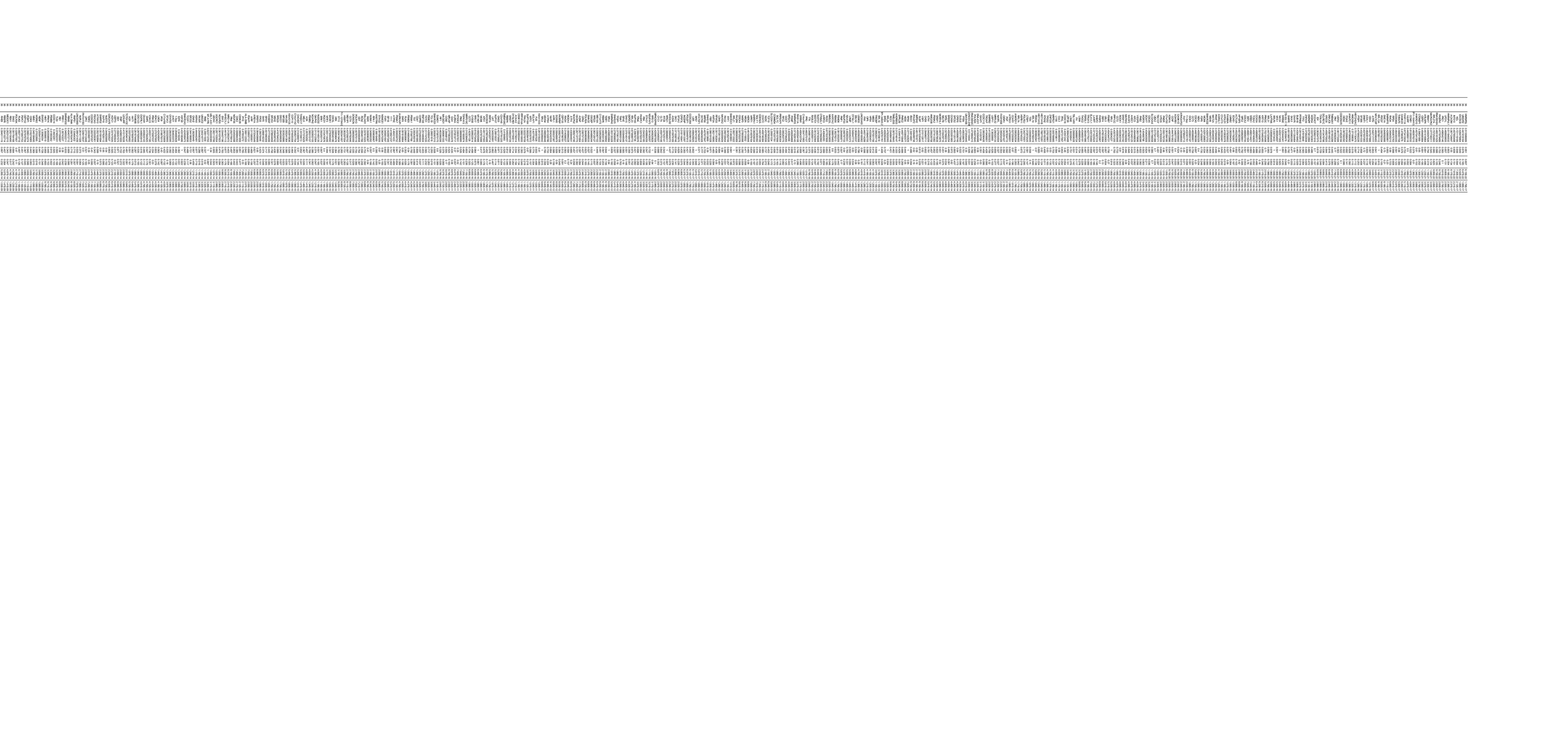

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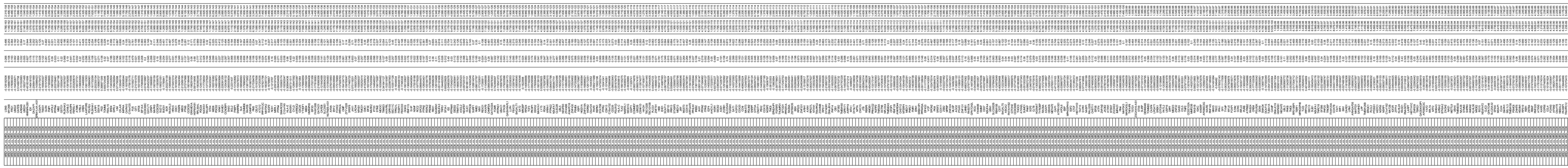

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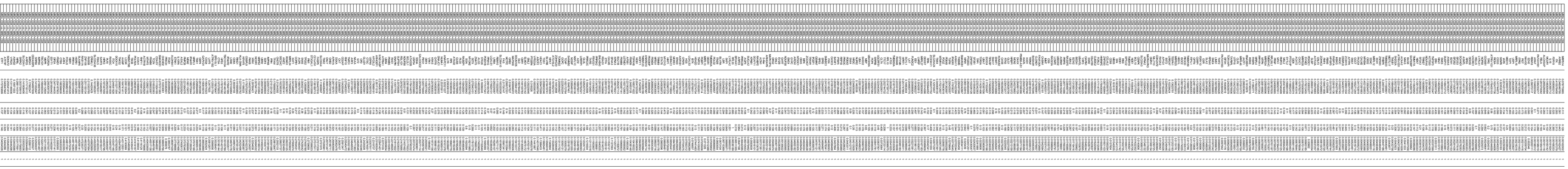

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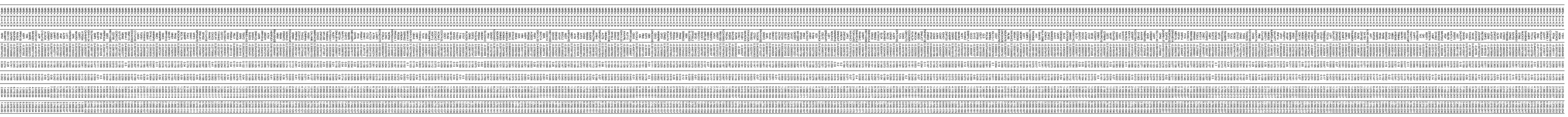
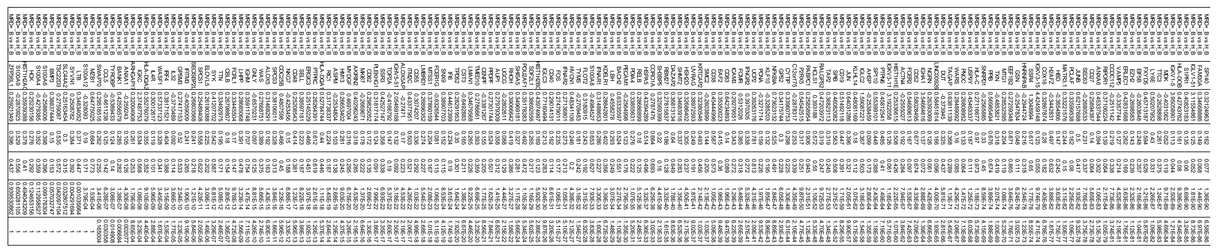
| Study | Year | Country | Sex | Age | Dietary assessment method | Food groups | Food items | Adjustment | Risk estimate | Lower CI | Upper CI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chen et al | 2011 | Taiwan | Both | 18-64 | FFQ | Total meat | Total meat | Age, sex, smoking status, alcohol consumption, physical activity, BMI, waist circumference, hypertension, diabetes, hyperlipidemia, family history of diabetes, total energy intake, fiber intake, SFA intake, PUFA intake, MUFA intake, cholesterol intake, fruit intake, vegetable intake, soy intake, nuts intake, sugar-sweetened beverages intake, coffee intake, tea intake, multivitamin intake, vitamin C intake, vitamin E intake, folate intake, calcium intake, magnesium intake, potassium intake, sodium intake, iron intake, zinc intake, selenium intake, glycemic load, glycemic index, dietary pattern | 1.00 | Ref | Ref |





**Supplementary Table 8. Tumor immunesuppresive genes in MRD+_B and MRD+_M clusters.**

| Gene | Clusters | Cancers | Significance | Reference |
|---|---|---|---|---|
| **B cells** | | | | |
| *CD37* | C4 | AML | CD37 is a membrane protein expressed prominently on B cells. CD37 was | *Biosci Rep.* 2020;40(5):BSR20200008. |
| *TCL1A* | C4, C30 | B-cell tumor | TCL1A expression is restricted to early B cells and involved in development of | *Cells.* 2021;10(6):1367. |
| *BACH2* | C4, C30 | B16 melanoma and EL-4 lym | BACH2 is a B-cell-specific transcription factor and could promote tumor | *J Clin Invest.* 2016;126(2):599-604. |
| *CD24* | C4, C30 | AML | Breg cells were usually marked by a CD19+CD24+CD38+ phenotype. For | *Med Sci Monit.* 2019;25:3026-31. |
| *CD38* | C4, C22, C30 | AML | Same as above. | *Med Sci Monit.* 2019;25:3026-31. |
| *TNFRSF17* | C22 | MM | TNFRSF17 is also named B-cell maturation antigen (BCMA) and is a surface | *Blood.* 2016;127(25):3225-36. |
| *IGHG1* | C4, C22, C30 | NSCLC | Single cell sequencing for NSCLC identified one cell cluster, which expressed | *Genome Biol. 2020;21(1):152.* |
| *CD138* | C30 | DLBCL | Positive expression of CD138 and BCL-6 was shown in 39% and 78% of the | *Asian Pac J Cancer Prev.* 2012;13(7):3037-46. |
| *IGKC* | C22 | NSCLC | Single cell sequencing for NSCLC identified one cell cluster, which expressed | *Genome Biol.* 2020;21(1):152. |
| **Monocytes** | | | | |
| *CD302* | C1, C23, C24 | Lung cancer | Related to M2-type macrophages | *J Clin Invest.* 2018;128(12):5647-5662. |
| *ENO1* | C1, C23, C24 | PDA | Anti-α-enolase antibody attenuates the restraining effector T cell response | *Oncoimmunology.* 2015;5(5):e1112940. |
| *MS4A6A* | C1, C23, C24 | AML | Related to M2-type macrophages | *Biomark Res.* 2021;9(1):15. |
| *MS4A7* | C1, C24 | Mouse colon cancer | Related to Arginase positive M2-type macrophages | *Theranostics.* 2018;8(21):5842-54. |
| *CFD* | C1, C23, C24 | AML | Related to malignant monocyte-like cells. | *Cell.* 2019; 176(6): 1265–1281.e24. |
| *TYROBP* | C1, C24 | LGG | Related to the infiltration of monocytes, dendritic cells (DCs) and | *BMC Cancer.* 2021;21(1):723. |
| *VCAN* | C1 | Colorectal Cancer | An Anti-inflammatory cytokine from monocyte-derived monocytes and related | *PLoS One.* 2016; 11(8):e0160891. |
| *FCN1* | C1, C24 | Hepatocellular Carcinoma | Marker of myeloid-derived suppressor cells (MDSC). | *Cell.* 2019; 179(4):829–845. |
| *HMOX1* | C1, C24 | AML | Related to malignant monocyte-like cells. | *Cell.* 2019; 176(6): 1265–1281.e24. |
| *IFITM3* | C1, C24 | HNSCC | Related to inhibitory immune checkpoint receptors and markers of tumor | *Am J Clin Pathol.* 2020; 15:153(5):618-629. |
| *IL10RA* | C24 | AML | Related to malignant monocyte-like cells. | *Cell.* 2019; 176(6): 1265–1281.e24. |
| *LILRB1* | C24 | AML | Related to malignant monocyte-like cells. | *Cell.* 2019; 176(6): 1265–1281.e24. |
| *LILRB2* | C1, C24 | AML | Related to malignant monocyte-like cells. | *Cell.* 2019; 176(6): 1265–1281.e24. |
| *LILRB3* | C1, C24 | Mouse lymphoma model | Ligation of LILRB3 on monocytes by an agonistic antibody induced an | *JCI Insight.* 2020;5(18):e141593. |
| *LILRB4* | C24 | AML | Immune inhibitory receptors expressed on monocytes. | *Nature. 2018;562(7728):605-609.* |
| *LGALS9* | C1, C24 | AML | Related to malignant monocyte-like cells. | *Cell.* 2019; 176(6): 1265–1281.e24. |
| *CD68* | C1, C24 | Adenoma | Promoting the formation of tumor-associated immunosuppressive | *Cell Rep.* 2021;36(10):109674. |
| *CD74* | C1, C24 | Adenoma | Anagonism of CD74 reduced the expression of immunosuppressive molecules | *Front Immunol.* 2018;9:1132. |
| *CD86* | C24 | AML | Related to malignant monocyte-like cells. | *Cell.* 2019; 176(6): 1265–1281.e24. |
| *TNFAIP2* | C1, C24 | AML | Related to malignant monocyte-like cells. | *Cell.* 2019; 176(6): 1265–1281.e24. |
| *TNFSF10* | C1, C24 | AML | Related to malignant monocyte-like cells. | *Cell.* 2019; 176(6): 1265–1281.e24. |
| *TNFSF13* | C1, C24 | CLL | Monocytes expressingTNFSF13 could be nurse cells for the growth of | *Blood.* 2005;106(3):1012-20. |
| *FTH1* | C1, C24 | HNSCC | Related to the infiltration of macrophages and indicated to poor prognosis. | *Front Cell Dev Biol.* 2021;9:727762. |
| *CSF1R* | C24 | Lung cancer | Related to M2-type macrophages. | *J Clin Invest.* 2020;130(4):2081-96. |

Abbreviations: AML, acute myeloid leukemia; MM, multiple myeloma; OS, overall survival; NSCLC, non-small cell lung cancer; LGG, low grade glioma; DLBCL, diffuse large B-cell lymphoma; Mo: monocyte; CLL, chronic lymphoblastic leukemia; CTL: cytotoxicitic T cells; BCMA,B-cell maturation antigen; DC, dendritic cells; WBC: white blood cell; HNSCC, head and neck squamous cell carcinoma;MDSC, myeloidderivedsuppressor cells; PDA, pancreaticductal adenocarcinoma.

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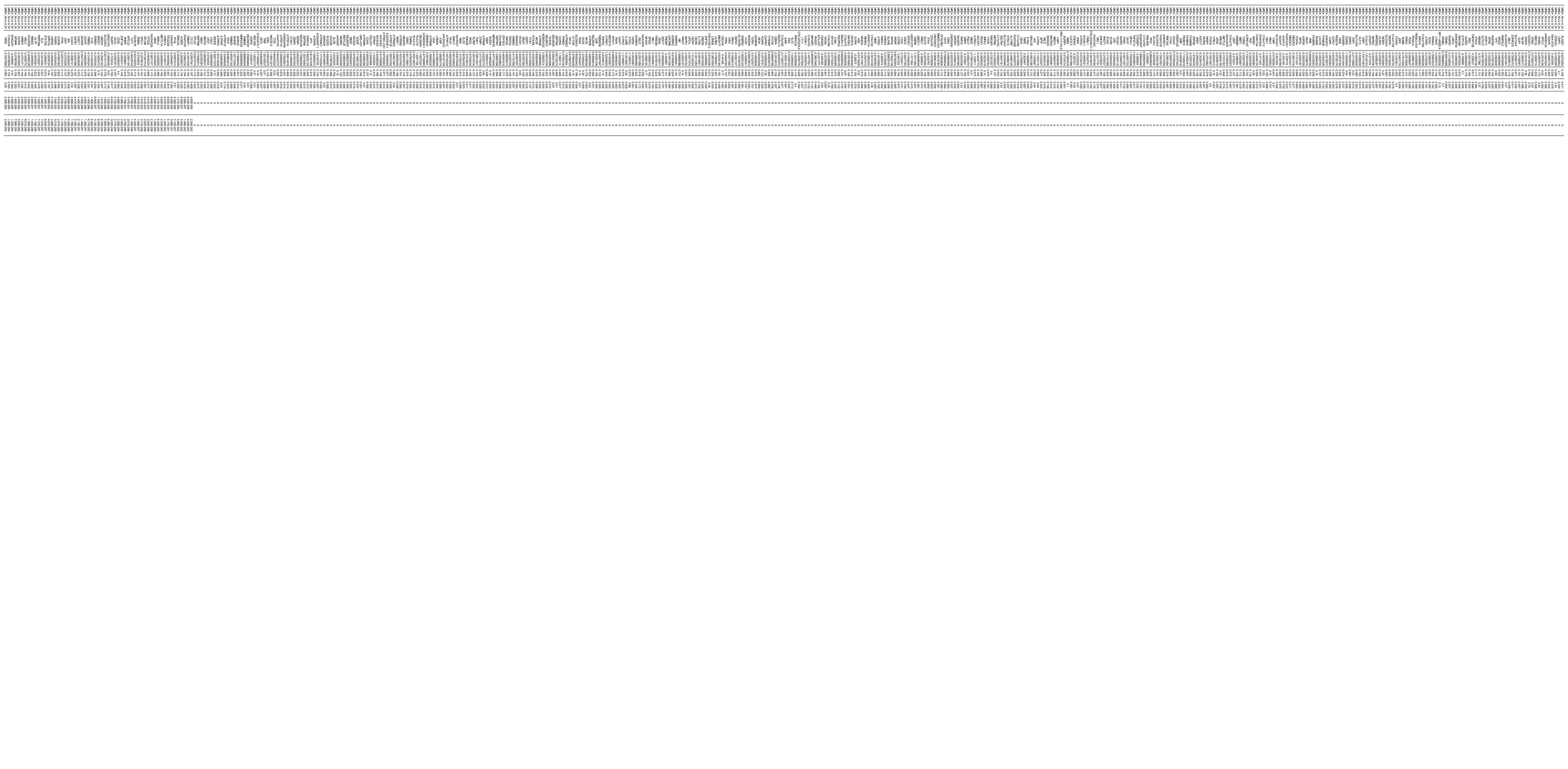

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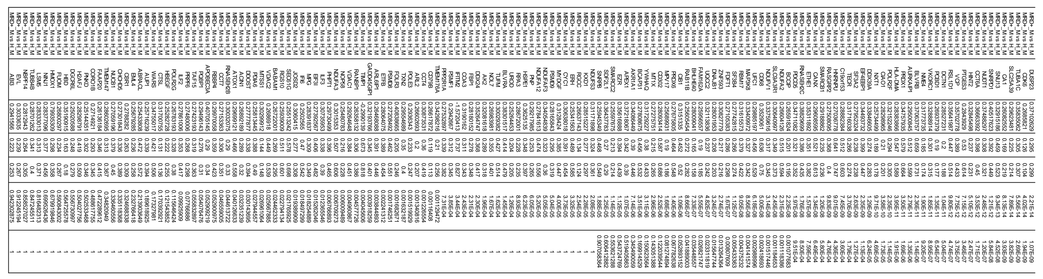

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**Supplementary Table 11. Characteristics of 6 patients who received preemptive interferon-α treatment in scRNA sequencing.**

| No. | Name of sample | Age | Sex | Status before transplantation | HLA type | Types of MRD | MRD levels before treatment, (%) | Response |
|---|---|---|---|---|---|---|---|---|
| 1 | AML02 | 17 | Male | CR2 | HLA-identical sibling donor | RUNX1-RUNX1T1 | 0.16 | Yes |
| 2 | AML21 | 14 | Male | CR1 | HLA-haploidentical related donor | RUNX1-RUNX1T1 | 0.067 | Yes |
| 3 | AML23 | 38 | Male | CR1 | HLA-haploidentical related donor | RUNX1-RUNX1T1 | 3.9 | Yes |
| 4 | AML04 | 31 | Male | CR1 | HLA-haploidentical related donor | RUNX1-RUNX1T1 | 0.42 | No |
| 5 | AML22 | 30 | Male | CR2 | HLA-haploidentical related donor | RUNX1-RUNX1T1 | 0.12 | No |
| 6 | AML27 | 63 | Female | CR1 | HLA-haploidentical related donor | TLS-ERG | 0.081 | No |

Abbreviations: scRNA, single cell; CR, complete remission; HLA, human leukocyte antigen; MRD, measurable residual disease.

**Supplementary Table 12. Quality controls of bulk RNA sequencing.**

| Name of sample | INDEX | RAW_READS | RAW_BASES | READ_LENGTH | RawQ30 | GC_PERCENT |
|---|---|---|---|---|---|---|
| HA210667 | 155A55 | 23,642,408 | 7,092,722,400 | 150;150 | 93.96;92.03 | 52.15;51.80 |
| HA211050 | 373X73 | 24,390,770 | 7,317,231,000 | 150;150 | 93.96;92.74 | 50.80;50.62 |
| HA210554 | 314X14 | 34,859,247 | 10,457,774,100 | 150;150 | 93.57;92.33 | 51.10;50.85 |
| HA210555 | 152A52 | 31,798,824 | 9,539,647,200 | 150;150 | 93.69;92.81 | 52.66;52.44 |
| HA210568 | 153A53 | 29,798,286 | 8,939,485,800 | 150;150 | 93.82;92.38 | 51.68;51.39 |
| HA210638 | 154A54 | 21,556,412 | 6,466,923,600 | 150;150 | 93.67;92.25 | 50.18;49.92 |
| HA210726 | 156A56 | 28,369,756 | 8,510,926,800 | 150;150 | 93.68;92.55 | 50.01;49.76 |
| HA210778 | 157A57 | 28,006,231 | 8,401,869,300 | 150;150 | 93.07;91.21 | 50.86;50.71 |
| HA210819 | 158A58 | 24,574,918 | 7,372,475,400 | 150;150 | 93.69;91.99 | 51.84;51.52 |
| HA210868 | 159A59 | 22,870,366 | 6,861,109,800 | 150;150 | 93.00;91.31 | 50.74;50.60 |
| HA210885 | 160A60 | 21,913,133 | 6,573,939,900 | 150;150 | 93.43;92.11 | 51.18;50.94 |
| HA210913 | 161A61 | 24,398,055 | 7,319,416,500 | 150;150 | 93.71;92.59 | 50.44;50.20 |
| HA210939 | 162A62 | 22,927,630 | 6,878,289,000 | 150;150 | 93.54;92.65 | 50.83;50.65 |
| HA211007 | 163A63 | 29,097,408 | 8,729,222,400 | 150;150 | 93.44;92.22 | 51.31;51.12 |
| HA211047 | 164A64 | 26,013,933 | 7,804,179,900 | 150;150 | 93.63;91.63 | 51.41;51.04 |
| HA211052 | 166A66 | 22,688,117 | 6,806,435,100 | 150;150 | 93.38;92.60 | 50.80;50.62 |
| HA211067 | 167A67 | 23,922,714 | 7,176,814,200 | 150;150 | 93.10;91.44 | 50.87;50.71 |
| HA211089 | 168A68 | 23,496,859 | 7,049,057,700 | 150;150 | 93.56;92.28 | 52.10;51.76 |
| HA211108 | 169A69 | 25,773,415 | 7,732,024,500 | 150;150 | 92.52;90.43 | 51.13;51.04 |
| HA211145 | 170A70 | 24,890,100 | 7,467,030,000 | 150;150 | 93.63;92.30 | 51.91;51.64 |
| HA211177 | 171A71 | 26,907,523 | 8,072,256,900 | 150;150 | 93.15;91.40 | 50.27;50.13 |
| HA211179 | 172A72 | 25,950,920 | 7,785,276,000 | 150;150 | 93.21;91.69 | 50.64;50.40 |
| HA211240 | 173A73 | 23,094,157 | 6,928,247,100 | 150;150 | 93.43;92.20 | 51.61;51.41 |
| HA211246 | 174A74 | 21,978,842 | 6,593,652,600 | 150;150 | 93.27;92.39 | 50.86;50.68 |
| HA211250 | 175A75 | 31,233,080 | 9,369,924,000 | 150;150 | 92.76;91.27 | 50.64;50.54 |
| HA211308 | 176A76 | 28,926,790 | 8,678,037,000 | 150;150 | 93.38;92.15 | 50.71;50.45 |
| HA211321 | 381X81 | 24,510,004 | 7,353,001,200 | 150;150 | 93.40;91.34 | 50.67;50.49 |
| HA211405 | 178A78 | 26,950,395 | 8,085,118,500 | 150;150 | 93.45;91.63 | 50.24;50.00 |
| HA211510 | 179A79 | 26,311,943 | 7,893,582,900 | 150;150 | 93.49;92.55 | 50.71;50.46 |
| HA211544 | 180A80 | 24,020,844 | 7,206,253,200 | 150;150 | 93.53;92.60 | 51.03;50.77 |
| HA211548 | 181A81 | 23,031,755 | 6,909,526,500 | 150;150 | 92.80;90.73 | 50.37;50.29 |
| HA211593 | 394X94 | 23,211,912 | 6,963,573,600 | 150;150 | 93.29;92.59 | 49.87;49.67 |
| HA211628 | 183A83 | 26,802,042 | 8,040,612,600 | 150;150 | 93.52;92.55 | 50.96;50.71 |
| HA211647 | 184A84 | 22,652,998 | 6,795,899,400 | 150;150 | 92.97;90.95 | 50.18;50.05 |
| HA211648 | 185A85 | 27,293,923 | 8,188,176,900 | 150;150 | 93.63;92.68 | 50.25;49.95 |
| HA211649 | 186A86 | 29,793,468 | 8,938,040,400 | 150;150 | 93.68;92.71 | 50.13;49.86 |
| HA211663 | 187A87 | 29,008,636 | 8,702,590,800 | 150;150 | 93.68;92.40 | 50.92;50.63 |
| HA211762 | 188A88 | 30,379,599 | 9,113,879,700 | 150;150 | 93.10;91.59 | 50.80;50.57 |
| HA211768 | 189A89 | 29,122,174 | 8,736,652,200 | 150;150 | 93.65;92.40 | 51.52;51.28 |
| HA211913 | 190A90 | 24,275,623 | 7,282,686,900 | 150;150 | 93.55;91.93 | 50.97;50.72 |
| HA210732 | 301X01 | 28,669,648 | 8,600,894,400 | 150;150 | 93.99;91.61 | 51.00;50.72 |
| HA210930 | 304X04 | 26,911,812 | 8,073,543,600 | 150;150 | 94.10;92.30 | 52.68;52.47 |
| HA210963 | 305X05 | 29,190,024 | 8,757,007,200 | 150;150 | 94.14;91.17 | 52.01;51.80 |
| HA211110 | 152A52 | 26,565,221 | 7,969,566,300 | 150;150 | 93.69;92.33 | 51.83;51.68 |
| HA211114 | 307X07 | 27,558,528 | 8,267,558,400 | 150;150 | 93.90;90.98 | 52.25;52.07 |
| HA211163 | 308X08 | 29,001,600 | 8,700,480,000 | 150;150 | 94.00;92.07 | 53.29;53.04 |
| HA211193 | 311X11 | 24,729,574 | 7,418,872,200 | 150;150 | 93.96;92.43 | 53.21;53.05 |
| HA211202 | 312X12 | 23,235,750 | 6,970,725,000 | 150;150 | 94.13;92.32 | 52.86;52.63 |
| HA211264 | 314X14 | 26,425,858 | 7,927,757,400 | 150;150 | 93.77;91.62 | 51.74;51.53 |
| HA211273 | 316X16 | 21,979,217 | 6,593,765,100 | 150;150 | 93.55;91.61 | 51.15;50.99 |
| HA211298 | 175A75 | 26,587,820 | 7,976,346,000 | 150;150 | 93.09;90.82 | 52.11;52.03 |
| HA211315 | 318X18 | 26,080,590 | 7,824,177,000 | 150;150 | 93.63;91.58 | 52.09;51.88 |
| HA211333 | 319X19 | 26,030,804 | 7,809,241,200 | 150;150 | 93.70;91.65 | 50.87;50.68 |
| HA211361 | 320X20 | 24,878,192 | 7,463,457,600 | 150;150 | 93.53;91.11 | 51.38;51.24 |
| HA211407 | 321X21 | 22,559,252 | 6,767,775,600 | 150;150 | 93.63;91.25 | 51.87;51.67 |
| HA211411 | 322X22 | 25,222,048 | 7,566,614,400 | 150;150 | 93.61;92.14 | 51.72;51.55 |
| HA211418 | 323X23 | 21,199,858 | 6,359,957,400 | 150;150 | 93.55;90.84 | 51.94;51.67 |
| HA211500 | 324X24 | 24,170,964 | 7,251,289,200 | 150;150 | 93.56;91.81 | 52.41;52.26 |
| HA211517 | 325X25 | 29,536,194 | 8,860,858,200 | 150;150 | 93.61;91.03 | 51.56;51.41 |
| HA211575 | 326X26 | 25,300,030 | 7,590,009,000 | 150;150 | 93.44;90.88 | 51.31;51.20 |
| HA211589 | 328X28 | 25,311,578 | 7,593,473,400 | 150;150 | 93.74;91.68 | 51.77;51.55 |
| HA211592 | 329X29 | 23,881,316 | 7,164,394,800 | 150;150 | 93.57;91.66 | 51.26;51.09 |
| HA211600 | 330X30 | 25,503,954 | 7,651,186,200 | 150;150 | 93.21;91.28 | 51.58;51.44 |
| HA211603 | 332X32 | 25,011,496 | 7,503,448,800 | 150;150 | 93.42;91.40 | 52.41;52.26 |
| HA211605 | 333X33 | 30,168,703 | 9,050,610,900 | 150;150 | 93.69;91.87 | 52.79;52.55 |
| HA211606 | 334X34 | 24,720,032 | 7,416,009,600 | 150;150 | 93.68;92.12 | 52.73;52.56 |
| HA211654 | 335X35 | 21,152,435 | 6,345,730,500 | 150;150 | 93.57;91.00 | 51.34;51.17 |
| HA211662 | 336X36 | 25,572,542 | 7,671,762,600 | 150;150 | 93.66;91.68 | 51.66;51.53 |
| HA211670 | 337X37 | 24,779,790 | 7,433,937,000 | 150;150 | 93.73;91.48 | 51.84;51.58 |
| HA211681 | 338X38 | 26,100,975 | 7,830,292,500 | 150;150 | 93.44;91.64 | 50.98;50.84 |
| HA211702 | 339X39 | 34,001,535 | 10,200,460,500 | 150;150 | 93.12;90.57 | 50.93;50.84 |
| HA211718 | 340X40 | 25,975,355 | 7,792,606,500 | 150;150 | 93.46;91.12 | 51.08;50.92 |
| HA211742 | 341X41 | 24,692,559 | 7,407,767,700 | 150;150 | 93.71;91.51 | 52.13;51.89 |
| HA211759 | 342X42 | 25,256,466 | 7,576,939,800 | 150;150 | 93.59;91.62 | 52.98;52.81 |
| HA211797 | 343X43 | 23,231,179 | 6,969,353,700 | 150;150 | 93.64;91.46 | 51.25;51.03 |
| HA211803 | 344X44 | 24,057,766 | 7,217,329,800 | 150;150 | 93.65;92.04 | 50.60;50.46 |
| HA211833 | 345X45 | 30,329,840 | 9,098,952,000 | 150;150 | 93.14;90.60 | 51.66;51.54 |
| HA211841 | 346X46 | 28,634,498 | 8,590,349,400 | 150;150 | 93.17;90.72 | 51.14;51.02 |
| HA211853 | 347X47 | 25,610,986 | 7,683,295,800 | 150;150 | 93.66;91.79 | 51.83;51.60 |
| HA211867 | 349X49 | 29,339,209 | 8,801,762,700 | 150;150 | 93.29;90.99 | 51.79;51.70 |
| HA211870 | 350X50 | 24,558,630 | 7,367,589,000 | 150;150 | 93.79;91.96 | 51.46;51.25 |
| HA211874 | 351X51 | 22,049,137 | 6,614,741,100 | 150;150 | 93.66;91.41 | 51.57;51.33 |
| HA211878 | 352X52 | 24,719,579 | 7,415,873,700 | 150;150 | 93.66;91.16 | 51.72;51.50 |
| HA211885 | 353X53 | 27,910,888 | 8,373,266,400 | 150;150 | 93.65;91.75 | 53.68;53.39 |
| HA211898 | 356X56 | 32,378,733 | 9,713,619,900 | 150;150 | 93.68;91.67 | 51.03;50.82 |
| HA211936 | 357X57 | 26,467,949 | 7,940,384,700 | 150;150 | 93.81;92.32 | 53.28;53.05 |
| HA211947 | 358X58 | 21,131,597 | 6,339,479,100 | 150;150 | 93.53;91.17 | 51.97;51.84 |
| HA212011 | 370X70 | 32,819,792 | 9,845,937,600 | 150;150 | 93.65;91.51 | 50.55;50.39 |
| HA212173 | 359X59 | 23,039,828 | 6,911,948,400 | 150;150 | 93.32;91.45 | 51.35;51.18 |
| HA212186 | 305X05 | 26,966,505 | 8,089,951,500 | 150;150 | 93.63;91.71 | 48.80;48.60 |
| HA212265 | 307X07 | 28,921,300 | 8,676,390,000 | 150;150 | 92.68;90.53 | 47.73;47.58 |
| HA212277 | 360X60 | 4,573,511 | 1,372,053,300 | 150;150 | 93.02;90.96 | 50.62;50.46 |
| HA212277 | 360X60 | 19,312,034 | 5,793,610,200 | 150;150 | 93.51;91.42 | 50.57;50.37 |
| HA212299 | 361X61 | 25,768,944 | 7,730,683,200 | 150;150 | 93.42;91.45 | 49.66;49.48 |
| HA212301 | 371X71 | 27,335,563 | 8,200,668,900 | 150;150 | 93.59;91.51 | 51.29;51.18 |
| HA212327 | 363X63 | 31,623,502 | 9,487,050,600 | 150;150 | 93.50;91.20 | 49.86;49.75 |
| HA212357 | 309X09 | 33,689,951 | 10,106,985,300 | 150;150 | 92.00;90.04 | 50.39;50.31 |
| HA212362 | 364X64 | 23,543,020 | 7,062,906,000 | 150;150 | 93.21;90.97 | 51.13;50.96 |
| HA212383 | 311X11 | 27,803,640 | 8,341,092,000 | 150;150 | 93.51;92.80 | 47.65;47.58 |
| HA212407 | 365X65 | 27,137,965 | 8,141,389,500 | 150;150 | 93.47;91.53 | 48.94;48.73 |
| HA212434 | 312X12 | 24,450,228 | 7,335,068,400 | 150;150 | 93.53;92.34 | 47.24;47.13 |
| HA212438 | 366X66 | 23,281,204 | 6,984,361,200 | 150;150 | 93.57;91.78 | 49.48;49.24 |
| HA212442 | 368X68 | 23,647,612 | 7,094,283,600 | 150;150 | 93.63;92.26 | 48.33;48.12 |
| HA212448 | 313X13 | 27,095,239 | 8,128,571,700 | 150;150 | 93.11;91.96 | 45.82;45.75 |
| HA212454 | 369X69 | 23,328,736 | 6,998,620,800 | 150;150 | 93.06;90.77 | 50.24;50.09 |
| HA212480 | 370X70 | 26,635,504 | 7,990,651,200 | 150;150 | 93.55;90.69 | 51.82;51.65 |
| HA212563 | 324X24 | 26,487,713 | 7,946,313,900 | 150;150 | 93.49;91.94 | 46.48;46.41 |
| HA212592 | 325X25 | 29,757,437 | 8,927,231,100 | 150;150 | 93.43;91.89 | 46.91;46.85 |
| HA212646 | 326X26 | 35,901,458 | 10,770,437,400 | 150;150 | 92.86;90.87 | 49.15;49.02 |
| HA212669 | 372X72 | 22,024,584 | 6,607,375,200 | 150;150 | 93.45;91.12 | 51.26;51.12 |
| HA212681 | 327X27 | 31,048,456 | 9,314,536,800 | 150;150 | 92.75;90.71 | 46.73;46.74 |
| HA212682 | 373X73 | 29,297,266 | 8,789,179,800 | 150;150 | 92.88;91.61 | 50.95;50.77 |
| HA212687 | 371X71 | 26,268,534 | 7,880,560,200 | 150;150 | 93.27;91.18 | 50.94;50.79 |
| HA212692 | 372X72 | 4,051,858 | 1,215,557,400 | 150;150 | 92.90;90.98 | 49.70;49.58 |
| HA212692 | 372X72 | 18,442,567 | 5,532,770,100 | 150;150 | 93.18;91.00 | 49.66;49.52 |
| HA212711 | 374X74 | 25,904,221 | 7,771,266,300 | 150;150 | 93.19;90.08 | 50.01;49.90 |
| HA212789 | 328X28 | 24,289,645 | 7,286,893,500 | 150;150 | 92.54;90.84 | 47.60;47.37 |
| HA212800 | 366X66 | 31,931,010 | 9,579,303,000 | 150;150 | 93.98;91.90 | 50.37;50.18 |
| HA212806 | 373X73 | 21,032,084 | 6,309,625,200 | 150;150 | 93.69;91.86 | 49.42;49.20 |
| HA212808 | 368X68 | 27,221,499 | 8,166,449,700 | 150;150 | 94.00;92.27 | 50.59;50.36 |
| HA212809 | 375X75 | 29,645,234 | 8,893,570,200 | 150;150 | 93.86;91.33 | 49.80;49.57 |
| HA212833 | 374X74 | 23,920,896 | 7,176,268,800 | 150;150 | 93.22;91.24 | 51.66;51.55 |
| HA212893 | 375X75 | 26,806,089 | 8,041,826,700 | 150;150 | 93.66;91.34 | 50.97;50.73 |
| HA212906 | 376X76 | 30,223,274 | 9,066,982,200 | 150;150 | 93.70;91.57 | 52.16;51.98 |
| HA212938 | 377X77 | 26,662,203 | 7,998,660,900 | 150;150 | 93.64;91.18 | 51.35;51.13 |
| HA212944 | 378X78 | 20,280,277 | 6,084,083,100 | 150;150 | 92.95;91.88 | 50.14;49.97 |
| HA212952 | 379X79 | 22,214,624 | 6,664,387,200 | 150;150 | 93.56;90.74 | 51.51;51.34 |
| HA212961 | 380X80 | 25,586,588 | 7,675,976,400 | 150;150 | 93.71;91.74 | 50.75;50.49 |
| HA212972 | 381X81 | 24,227,482 | 7,268,244,600 | 150;150 | 92.93;90.03 | 51.34;51.21 |
| HA213017 | 383X83 | 29,797,938 | 8,939,381,400 | 150;150 | 92.93;89.51 | 53.22;53.03 |
| HA213022 | 369X69 | 24,693,650 | 7,408,095,000 | 150;150 | 93.66;90.97 | 51.55;51.44 |
| HA213037 | 384X84 | 27,781,718 | 8,334,515,400 | 150;150 | 93.22;89.96 | 51.35;51.16 |
| HA213050 | 386X86 | 30,413,386 | 9,124,015,800 | 150;150 | 93.77;92.12 | 52.50;52.29 |
| HA213061 | 387X87 | 23,218,073 | 6,965,421,900 | 150;150 | 93.49;91.72 | 51.08;50.88 |
| HA213068 | 389X89 | 23,230,027 | 6,969,008,100 | 150;150 | 93.77;91.88 | 52.03;51.78 |
| HA213076 | 391X91 | 23,851,387 | 7,155,416,100 | 150;150 | 93.67;91.62 | 50.23;50.00 |
| HA213078 | 392X92 | 31,472,000 | 9,441,600,000 | 150;150 | 93.51;91.32 | 53.40;53.20 |
| HA213079 | 393X93 | 28,376,221 | 8,512,866,300 | 150;150 | 93.66;91.38 | 54.20;53.98 |
| HA213082 | 394X94 | 21,374,792 | 6,412,437,600 | 150;150 | 93.46;91.21 | 50.50;50.32 |
| HA213088 | 395X95 | 22,067,584 | 6,620,275,200 | 150;150 | 93.72;91.09 | 51.07;50.85 |
| HA213117 | 302X02 | 25,497,796 | 7,649,338,800 | 150;150 | 93.13;90.39 | 52.70;52.60 |
| HA213156 | 303X03 | 23,451,185 | 7,035,355,500 | 150;150 | 92.73;88.28 | 53.70;53.73 |
| HA213167 | 309X09 | 28,969,002 | 8,690,700,600 | 150;150 | 92.44;89.81 | 49.98;49.89 |
| HA213174 | 310X10 | 26,476,930 | 7,943,079,000 | 150;150 | 93.01;90.06 | 51.43;51.32 |
| HA213184 | 313X13 | 29,336,176 | 8,800,852,800 | 150;150 | 93.50;91.61 | 53.42;53.30 |
| HA213198 | 315X15 | 22,604,460 | 6,781,338,000 | 150;150 | 93.16;91.09 | 50.66;50.52 |
| HA212145 | 324X24 | 20112342 | 6033702600 | 150;150 | 92.06;89.02 | 48.59;48.68 |
| HA212145 | 324X24 | 3,953,681 | 1,186,104,300 | 150;150 | 93.45;90.76 | 48.76;48.70 |
| HA212633 | 325X25 | 28093510 | 8428053000 | 150;150 | 92.18;88.27 | 47.05;47.13 |
| HA212756 | 326X26 | 18928512 | 5678553600 | 150;150 | 92.14;88.59 | 47.09;47.18 |
| HA212756 | 326X26 | 4,497,754 | 1,349,326,200 | 150;150 | 93.49;90.30 | 47.27;47.22 |
| HA212867 | 327X27 | 20477775 | 6143332500 | 150;150 | 91.59;87.45 | 48.28;48.49 |
| HA212867 | 327X27 | 3,134,257 | 940,277,100 | 150;150 | 92.98;89.31 | 48.49;48.52 |
| HA213009 | 328X28 | 17473287 | 5241986100 | 150;150 | 92.50;89.53 | 49.27;49.26 |
| HA213009 | 328X28 | 4,583,875 | 1,375,162,500 | 150;150 | 93.90;91.35 | 49.45;49.33 |
| HA213163 | 329X29 | 24410822 | 7323246600 | 150;150 | 93.34;91.70 | 51.15;51.16 |
| HA213191 | 330X30 | 22135421 | 6640626300 | 150;150 | 91.79;88.31 | 49.19;49.34 |
| HA213224 | 331X31 | 26058363 | 7817508900 | 150;150 | 93.08;90.93 | 48.49;48.53 |
| HA213234 | 332X32 | 28762531 | 8628759300 | 150;150 | 92.99;90.97 | 51.68;51.72 |
| HA213265 | 333X33 | 27001901 | 8100570300 | 150;150 | 93.46;91.77 | 49.37;49.36 |
| HA213272 | 334X34 | 23840229 | 7152068700 | 150;150 | 93.41;92.02 | 52.54;52.48 |
| HA213278 | 335X35 | 21051281 | 6315384300 | 150;150 | 93.28;91.09 | 48.81;48.76 |
| HA213291 | 336X36 | 25737411 | 7721223300 | 150;150 | 93.47;91.39 | 49.36;49.30 |
| HA213315 | 337X37 | 23210604 | 6963181200 | 150;150 | 93.55;91.47 | 49.60;49.51 |
| HA213396 | 338X38 | 24892620 | 7467786000 | 150;150 | 93.12;91.67 | 51.50;51.48 |
| HA213397 | 339X39 | 25961450 | 7788435000 | 150;150 | 92.91;90.85 | 49.37;49.35 |
| HA213419 | 340X40 | 21279529 | 6383858700 | 150;150 | 93.17;90.80 | 48.70;48.68 |
| HA213439 | 341X41 | 22651170 | 6795351000 | 150;150 | 93.42;91.45 | 50.20;50.13 |
| HA213441 | 342X42 | 4990415 | 1497124500 | 150;150 | 93.35;91.27 | 48.68;48.61 |
| HA213441 | 342X42 | 20130644 | 6039193200 | 150;150 | 93.44;91.26 | 48.86;48.76 |
| HA213479 | 343X43 | 24702635 | 7410790500 | 150;150 | 93.38;91.23 | 48.62;48.52 |
| HA213495 | 344X44 | 4136715 | 1241014500 | 150;150 | 93.43;91.68 | 47.74;47.69 |
| HA213495 | 344X44 | 18483209 | 5544962700 | 150;150 | 93.49;91.64 | 47.91;47.84 |
| HA213500 | 345X45 | 24924347 | 7477304100 | 150;150 | 92.77;90.44 | 47.33;47.33 |
| HA213506 | 346X46 | 4483422 | 1345026600 | 150;150 | 92.78;90.94 | 48.68;48.69 |
| HA213506 | 346X46 | 15623948 | 4687184400 | 150;150 | 92.98;91.13 | 48.87;48.84 |
| HA213507 | 347X47 | 1648619 | 494585700 | 150;150 | 93.47;91.72 | 48.85;48.81 |
| HA213507 | 347X47 | 19664932 | 5899479600 | 150;150 | 93.04;91.46 | 48.86;48.77 |
| HA213515 | 348X48 | 20796346 | 6238903800 | 150;150 | 89.55;87.81 | 52.65;52.80 |
| HA213544 | 349X49 | 21190100 | 6357030000 | 150;150 | 92.30;89.93 | 48.53;48.58 |
| HA213550 | 350X50 | 21445666 | 6433699800 | 150;150 | 93.48;91.64 | 48.70;48.58 |
| HA213578 | 351X51 | 5134144 | 1540243200 | 150;150 | 93.85;92.16 | 48.59;48.51 |
| HA213578 | 351X51 | 18697662 | 5609298600 | 150;150 | 93.24;91.19 | 48.74;48.63 |
| HA213637 | 352X52 | 3221891 | 966567300 | 150;150 | 93.57;91.03 | 48.43;48.41 |
| HA213637 | 352X52 | 19883253 | 5964975900 | 150;150 | 93.04;91.10 | 48.52;48.45 |
| HA213645 | 353X53 | 23763344 | 7129003200 | 150;150 | 93.14;91.62 | 48.26;48.19 |
| HA213679 | 354X54 | 25160212 | 7548063600 | 150;150 | 92.77;90.45 | 50.30;50.32 |
| HA213710 | 355X55 | 5363738 | 1609121400 | 150;150 | 92.71;90.10 | 48.76;48.81 |
| HA213710 | 355X55 | 19437321 | 5831196300 | 150;150 | 92.91;90.44 | 48.93;48.93 |
| HA213715 | 356X56 | 23851382 | 7155414600 | 150;150 | 93.53;91.51 | 48.75;48.66 |
| HA213738 | 357X57 | 21186355 | 6355906500 | 150;150 | 93.54;91.93 | 47.97;47.87 |
| HA213813 | 358X58 | 23328838 | 6998651400 | 150;150 | 93.25;91.00 | 49.03;49.02 |
| HA213846 | 359X59 | 23522116 | 7056634800 | 150;150 | 93.19;91.19 | 48.87;48.82 |
| HA213863 | 360X60 | 27145925 | 8143777500 | 150;150 | 93.53;91.55 | 48.65;48.55 |
| HA213876 | 361X61 | 21667037 | 6500111100 | 150;150 | 92.21;89.03 | 47.28;47.34 |
| HA213912 | 362X62 | 4115016 | 1234504800 | 150;150 | 92.51;89.03 | 48.64;48.80 |
| HA213912 | 362X62 | 17740218 | 5322065400 | 150;150 | 91.94;89.10 | 48.71;48.79 |
| HA213929 | 363X63 | 23138251 | 6941475300 | 150;150 | 92.85;90.67 | 49.30;49.24 |
| HA213959 | 364X64 | 28849852 | 8654955600 | 150;150 | 93.22;91.31 | 50.42;50.37 |
| HA213992 | 365X65 | 26450095 | 7935028500 | 150;150 | 93.36;91.53 | 49.22;49.14 |
| HA214007 | 366X66 | 23777838 | 7133351400 | 150;150 | 93.63;91.92 | 48.94;48.85 |
| HA214019 | 368X68 | 36184072 | 10855221600 | 150;150 | 92.54;90.38 | 48.90;48.91 |
| HA214031 | 369X69 | 23096189 | 6928856700 | 150;150 | 91.76;88.78 | 48.71;48.83 |
| HA214053 | 370X70 | 28549495 | 8564848500 | 150;150 | 93.29;91.22 | 48.44;48.41 |
| HA214061 | 371X71 | 26,239,398 | 7,871,819,400 | 150;150 | 92.99;90.61 | 47.62;47.67 |
| HA214066 | 372X72 | 23693649 | 7108094700 | 150;150 | 93.10;91.49 | 49.28;49.23 |
| HA214083 | 373X73 | 20956360 | 6286908000 | 150;150 | 92.18;89.76 | 49.51;49.56 |
| HA214093 | 374X74 | 21024079 | 6307223700 | 150;150 | 93.27;91.03 | 48.82;48.78 |
| HA214102 | 375X75 | 22866861 | 6860058300 | 150;150 | 93.45;91.80 | 49.80;49.71 |
| HA214122 | 376X76 | 23522208 | 7056662400 | 150;150 | 93.43;91.49 | 49.02;48.96 |
| HA214185 | 377X77 | 28140037 | 8442011100 | 150;150 | 93.56;91.49 | 51.30;51.19 |
| HA214210 | 378X78 | 22793989 | 6838196700 | 150;150 | 92.68;91.95 | 48.99;48.95 |
| HA214229 | 379X79 | 23322126 | 6996637800 | 150;150 | 92.92;89.75 | 50.25;50.19 |
| HA214235 | 380X80 | 23783950 | 7135185000 | 150;150 | 93.40;90.86 | 49.73;49.58 |
| HA214247 | 381X81 | 23711590 | 7113477000 | 150;150 | 92.31;88.26 | 50.69;50.64 |
| HA214337 | 382X82 | 23481207 | 7044362100 | 150;150 | 92.83;90.62 | 50.26;50.26 |
| HA214338 | 383X83 | 25807248 | 7742174400 | 150;150 | 93.14;90.82 | 50.67;50.57 |
| HA214341 | 384X84 | 26492781 | 7947834300 | 150;150 | 93.55;91.31 | 48.92;48.89 |
| HA214342 | 385X85 | 22976219 | 6892865700 | 150;150 | 92.94;90.46 | 50.80;50.77 |
| HA214364 | 386X86 | 29878655 | 8963596500 | 150;150 | 93.31;91.41 | 50.56;50.45 |
| HA214427 | 387X87 | 22538618 | 6761585400 | 150;150 | 93.29;91.35 | 49.38;49.33 |
| HA214441 | 388X88 | 21585982 | 6475794600 | 150;150 | 92.43;89.49 | 50.67;50.72 |
| HA214480 | 389X89 | 25852073 | 7755621900 | 150;150 | 93.52;91.65 | 48.61;48.56 |
| HA214497 | 390X90 | 21789078 | 6536723400 | 150;150 | 92.16;89.04 | 49.50;49.57 |
| HA214556 | 391X91 | 22915400 | 6874620000 | 150;150 | 93.63;91.61 | 50.47;50.38 |
| HA214566 | 392X92 | 25569096 | 7670728800 | 150;150 | 92.98;90.32 | 51.06;51.08 |

**Supplementary Table 13. Clinical characteristics of 12 patients received preemptive interferon-α treatment in bulk RNA sequencing.**

| Characteristics | N=12 |
|---|---|
| **Age (years)** | |
| mean±SD | 23.9±14.9 |
| **Gender，n (%)** | |
| Male | 5 (41.7) |
| Female | 7 (58.3) |
| **Duration of follow-up (days)** | |
| mean±SD | 254.8±37.4 |
| **Disease risk index at diagnosis，n (%)** | |
| Low risk | 3 (25.0) |
| Intermediate risk | 8 (66.7) |
| High risk | 1 (8.3) |
| **Number of chemotherapies to achieve CR，n (%)** | |
| 1 | 10 (83.3) |
| >1 | 2 (16.7) |
| **Numbers of chemotherapies before transplantation** | |
| mean±SD | 4.3±1.7 |
| **Disease status at transplantation，n (%)** | |
| CR1 | 11 (91.7) |
| >CR1 | 1 (8.3) |
| **Types of grafts，n (%)** | |
| PB | 12 (100.0) |
| BM+PB | 0 (0.0) |
| **Donor type，n (%)** | |
| HLA-identical sibling donor | 2 (16.7) |
| HLA-haploidentical related donor | 10 (83.3) |
| **Donor–recipient sex match，n (%)** | |
| Female–male | 2 (16.7) |
| Others | 10 (83.3) |
| **Blood group matched，n (%)** | |
| Matched | 9 (75.0) |
| Major mismatched | 2 (16.7) |
| Minor mismatched | 1 (8.3) |
| Major-minor mismatched | 0 (0.0) |
| **Preconditioning regimens，n (%)** | |
| Chemotherapy-based | 11 (91.7) |
| TBI-based | 1 (8.3) |
| **Time from transplantation to MRD positive (days)** | |
| mean±SD | 116.6±48.3 |
| **Time from transplantation to preemptive interferon-α treatment** | |
| mean±SD | 120.8±42.2 |
| **Treatment efficacy，n (%)** | |
| Response | 8 (66.7) |
| Nonresponse | 4 (33.3) |

Abbreviations: SD, standard derivation; CR, complete remission; PB, peripheral blood; BM, bone marrow; HLA, human leukocyte antigen; TBI, total body irradiation; MRD, measurable residual disease; NA, not applicable.

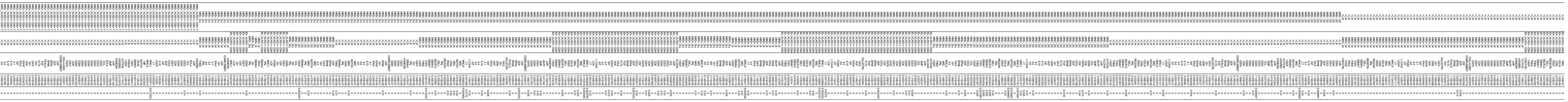
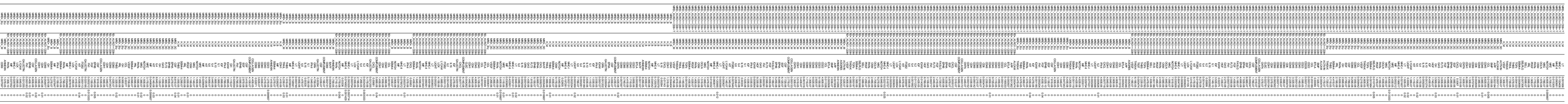
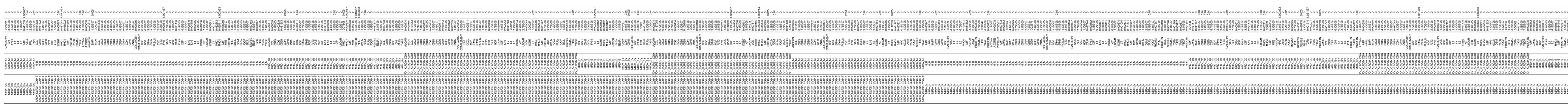
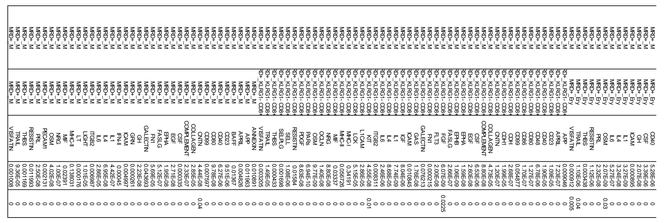
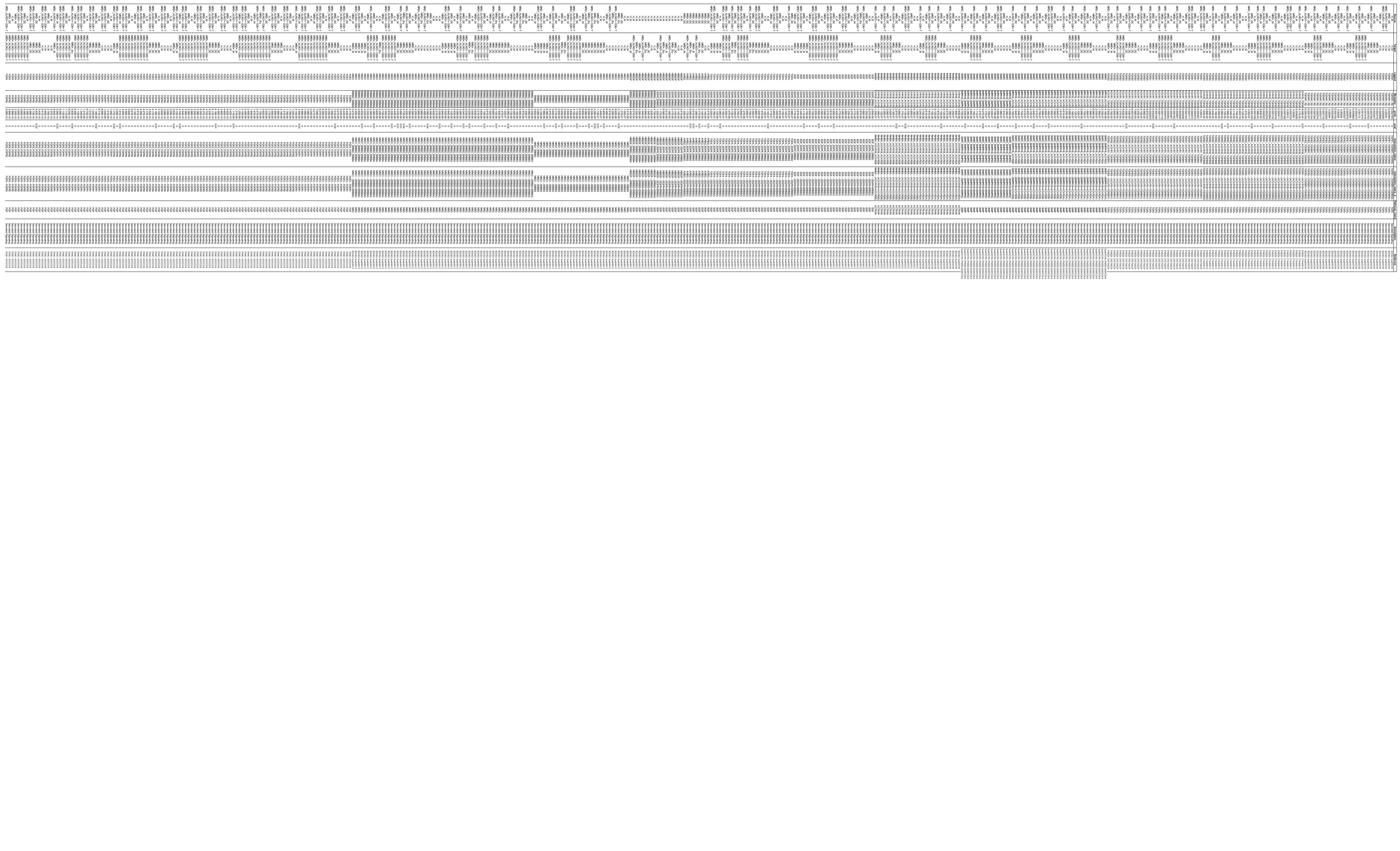
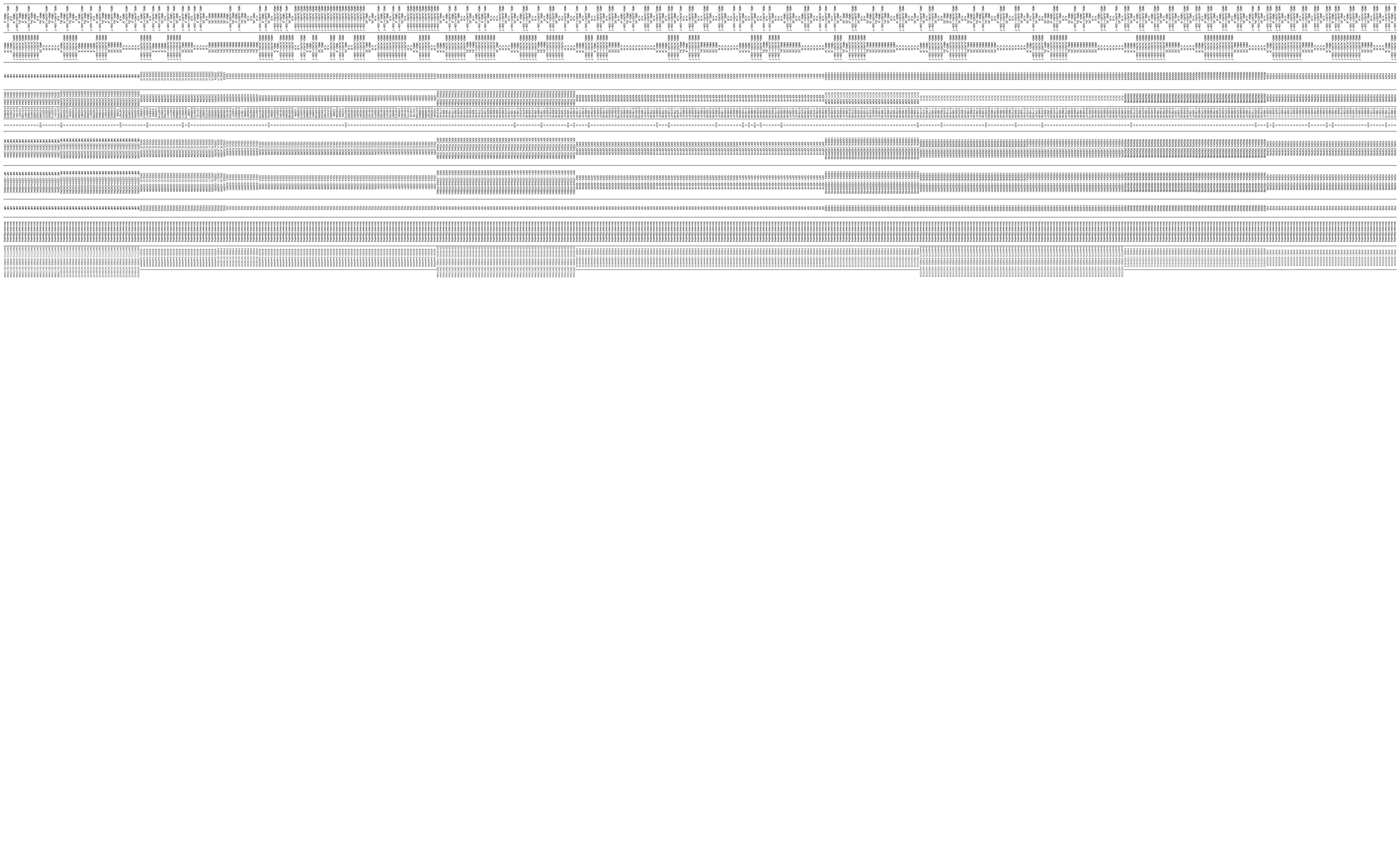
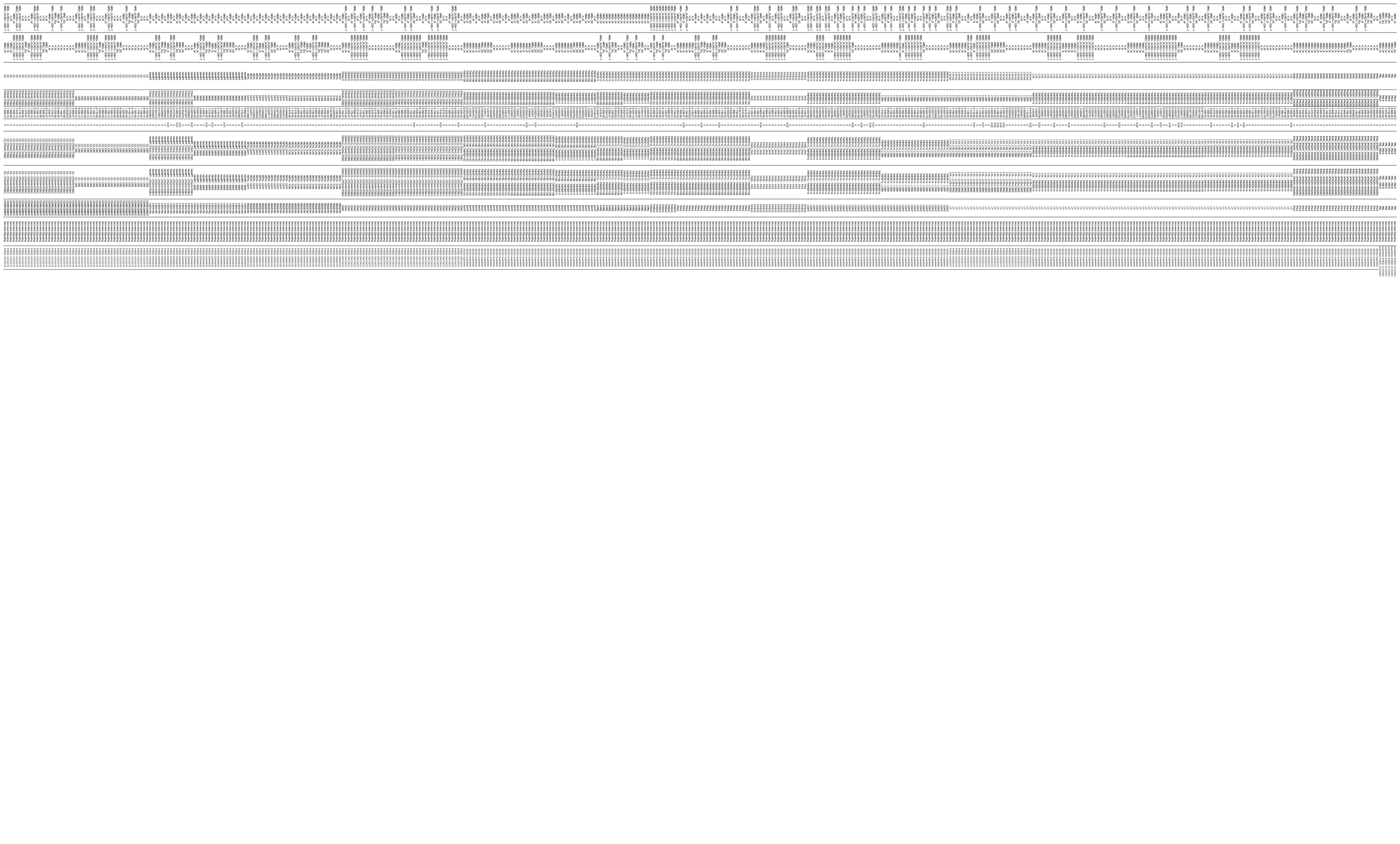
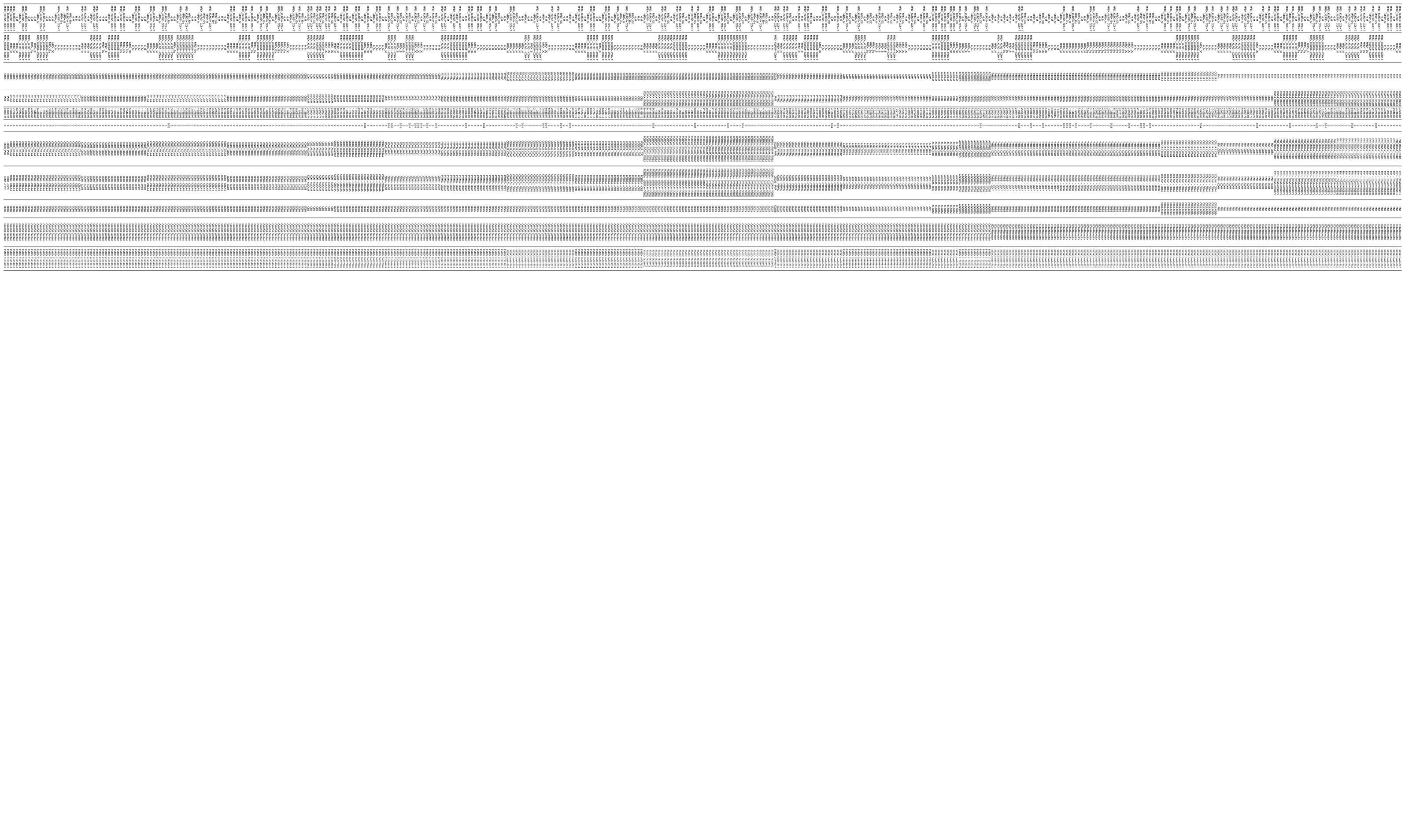
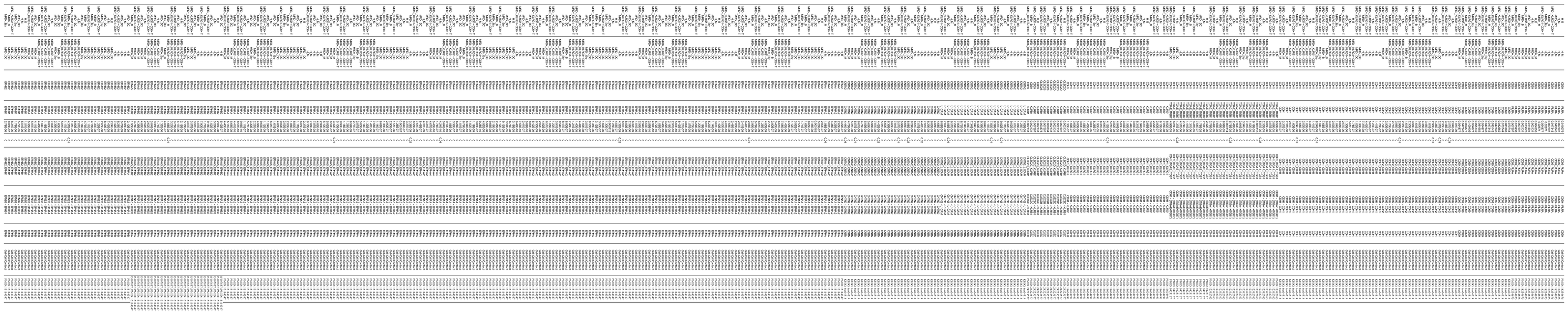
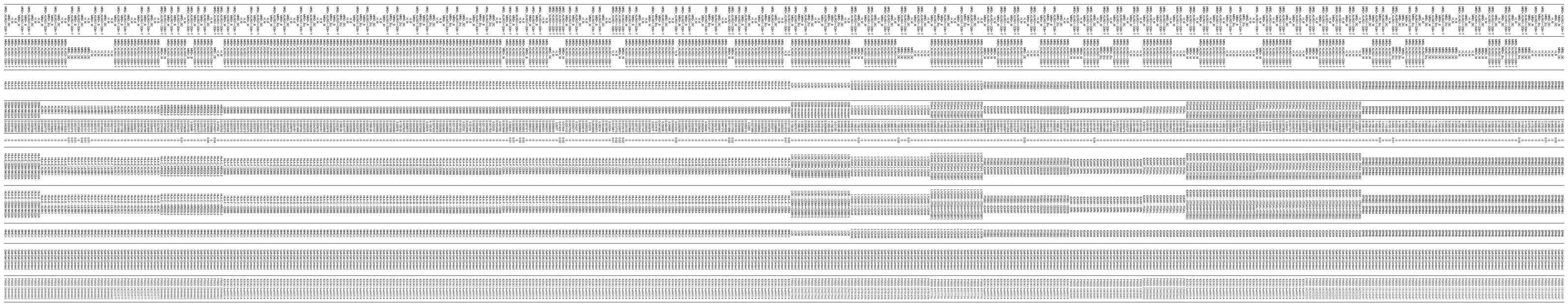
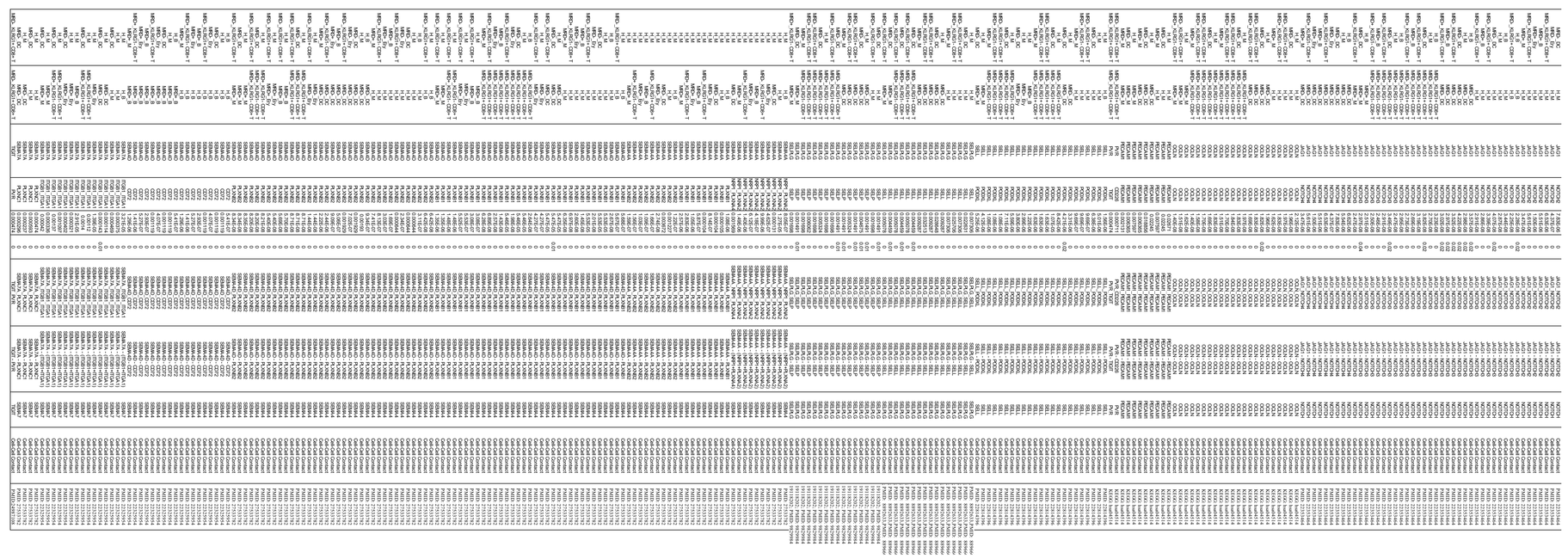
**Supplementary Table 14. Characteristics of the 5 immune models.**

| Characteristics | IM1 (n=19) | IM2 (n=5) | IM3 (n=16) | IM4 (n=8) | IM5 (n=12) | *P* |
|---|---|---|---|---|---|---|
| **Age (years)** | | | | | | 0.783 |
| mean±SD | 31.3±4.0 | 27.0±5.4 | 23.7±3.3 | 25.3±6.3 | 28.7±5.9 | |
| **Gender，n (%)** | | | | | | 0.120 |
| Male | 10 (52.6) | 0 (0.0) | 8 (50.0) | 6 (75.0) | 5 (41.7) | |
| Female | 9 (47.4) | 5 (100.0) | 8 (50.0) | 2 (25.0) | 7 (58.3) | |
| **Duration of follow-up, (days)** | | | | | | 0.352 |
| mean±SD | 221.1±11.2 | 207.0±23.3 | 236.9±11.5 | 237.6±15.8 | 252.6±14.0 | |
| **Disease risk index at diagnosis，n (%)** | | | | | | 0.087 |
| Low risk | 1 (5.3) | 0 (0.0) | 4 (25) | 2 (25.0) | 2 (16.7) | |
| Intermediate risk | 13 (68.4) | 1 (20.0) | 6 (37.5) | 6 (75.0) | 5 (41.7) | |
| High risk | 5 (26.3) | 4 (80.0) | 6 (37.5) | 0 (0.0) | 5 (41.7) | |
| **Numbers of chemotherapies to achieve CR, n (%)** | | | | | | 0.765 |
| 1 | 16 (84.2) | 4 (80.0) | 11 (68.8) | 7 (87.5) | 10 (83.3) | |
| >1 | 3 (15.8) | 1 (20.0) | 5 (31.2) | 1 (12.5) | 2 (16.7) | |
| **Numbers of chemotherapies before transplantation** | | | | | | 0.101 |
| mean±SD | 4.3±0.3 | 3.0±0.3 | 4.5±0.5 | 5.4±0.6 | 3.5±0.6 | |
| **Disease status at transplantation，n (%)** | | | | | | 0.483 |
| CR1 | 17 (89.5) | 4 (80.0) | 14 (87.5) | 5 (62.5) | 9 (75.0) | |
| >CR1 | 2 (10.5) | 1 (20.0) | 2 (12.5) | 3 (37.5) | 3 (25.0) | |
| **Types of grafts，n (%)** | | | | | | 0.592 |
| PB | 19 (100.0) | 5 (100.0) | 15 (93.8) | 8 (100.0) | 12 (100.0) | |
| BM+PB | 0 (0.0) | 0 (0.0) | 1 (6.3) | 0 (0.0) | 0 (0.0) | |
| **Donor type，n (%)** | | | | | | 0.082 |
| HLA-identical sibling donor | 6 (31.6) | 2 (40.0) | 3 (18.8) | 0 (0.0) | 0 (0.0) | |
| HLA-haploidentical related donor | 13 (68.4) | 3 (60.0) | 13 (81.2) | 8 (100.0) | 12 (100.0) | |
| **Donor–recipient relationship，n (%)** | | | | | | 0.224 |
| Mother–child | 0 (0.0) | 0 (0.0) | 2 (12.5) | 0 (0.0) | 0 (0.0) | |
| Others | 19 (100.0) | 5 (100.0) | 14 (87.5) | 8 (100.0) | 12 (100.0) | |
| **Donor–recipient sex matched，n (%)** | | | | | | 0.643 |
| Female–male | 2 (10.5) | 0 (0.0) | 3 (18.8) | 2 (25.0) | 1 (8.3) | |
| Others | 17 (89.5) | 5 (100.0) | 13 (81.2) | 6 (75.0) | 11 (91.7) | |
| **Blood group matched，n (%)** | | | | | | 0.794 |
| Matched | 12 (63.2) | 3 (60.0) | 7 (43.8) | 5 (62.5) | 6 (50.0) | |
| Mismatched | 7 (36.8) | 2 (40.0) | 9 (56.2) | 3 (37.5) | 6 (50.0) | |
| **Conditioning regimen，n (%)** | | | | | | 0.837 |
| Chemotherapy-based | 17 (89.5) | 5 (100.0) | 15 (93.8) | 8 (100.0) | 11 (91.7) | |
| TBI-based | 2 (10.5) | 0 (0.0) | 1 (6.2) | 0 (0.0) | 1 (8.3) | |

Abbreviations: IM, immune models; SD, standard derivation; CR, complete remission; PB, peripheral blood; BM, bone marrow; HLA, human leukocyte antigen; TBI, total body irradiation.

**Supplementary Table 15. Characteristics of 15 MRD positive and 23 MRD negative patients for flow cytometry analysis.**

| Characteristics | MRD positive（n=15） | MRD negative (n=23) | *P* |
|---|---|---|---|
| **Age (years)** | 35.6±3.2 | 35.9±3.2 | 0.93 |
| mean±SD | | | |
| **Gender，n (%)** | | | 0.944 |
| Male | 8 (53.3) | 12 (52.2) | |
| Female | 7 (46.7) | 11 (47.8) | |
| **Time from transplantation to sample collection (months)** | 5.6±0.7 | 5.5±0.8 | 0.883 |
| mean±SD | | | |
| **Duration of follow-up (days)** | 243.7±5.5 | 237.4±4.1 | 0.791 |
| mean±SD | | | |
| **Disease risk index at diagnosis，n (%)** | | | 0.733 |
| Low risk | 6 (40.0) | 7 (30.4) | |
| Intermediate risk | 6 (40.0) | 9 (39.2) | |
| High risk | 3 (20.0) | 7 (30.4) | |
| **Numbers of chemotherapies to achieve CR，n (%)** | | | 0.367 |
| 1 | 9 (60.0) | 17 (73.9) | |
| >1 | 6 (40.0) | 6 (26.1) | |
| **Numbers of chemotherapies before** | | | 0.172 |
| mean±SD | 3.5±0.4 | 4.4±0.6 | |
| **Disease status at transplantation, n(%)** | | | 0.28 |
| CR1 | 12 (80.0) | 22 (95.7) | |
| >CR1 | 3 (20.0) | 1 (4.3) | |
| **Types of grafts, n (%)** | | | 1 |
| PB | 15 (100.0) | 22 (95.7) | |
| BM+PB | 0 (0.0) | 1 (4.3) | |
| **Donor types，n (%)** | | | 1 |
| HLA-identical sibling donor | 3 (20.0) | 6 (26.1) | |
| HLA-haploidentical related donor | 12 (80.0) | 17 (73.9) | |
| **Donor–recipient sex match，n (%)** | | | 0.371 |
| Female–male | 1 (6.7) | 5 (21.7) | |
| Others | 14 (93.3) | 18 (78.3) | |
| **Blood group matched，n (%)** | | | 0.118 |
| Matched | 9 (60.0) | 11 (47.8) | |
| Major mismatched | 6 (40.0) | 5 (21.7) | |
| Minor mismatched | 0 (0.0) | 2 (8.8) | |
| Major-minor mismatched | 0 (0.0) | 5 (21.7) | |

Abbreviations: MRD, measurable residual disease; SD, standard deviation; CR, complete remission; PB, peripheral blood; BM, bone marrow; HLA, human leukocyte antigen.

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