**Supplementary Table 1: Cancer-attributable mortality rates, according to individual and transplant characteristics and cancer site**

|  |  | Cancer cases | Deaths with prior cancer, pd (%) | PAF | 95%CI | Cancer-attributable mortality rate |
| --- | --- | --- | --- | --- | --- | --- |
| **Age** |  |  |  |  |  |  |
| 0-17 | Lung | 0 | 0.0 | 0.0 |  | 0 |
|  | NHL | 297 | 5.2 | 4.1 | (1.0, 7.2) | 71 |
|  | Colorectum | 1 | 0.1 | 0.1 | (-0.3, 0.4) | 1 |
|  | Kidney | 9 | 0.1 | 0.1 | (-0.3, 0.4) | 1 |
|  | Pancreas | 0 | 0.0 | 0.0 |  | 0 |
|  | Stomach | 0 | 0.0 | 0.0 |  | 0 |
|  | Breast | 0 | 0.0 | 0.0 |  | 0 |
|  | Bladder | 2 | 0.1 | 0.1 | (-0.4, 0.6) | 2 |
|  | Melanoma | 1 | 0.1 | 0.1 | (-0.3, 0.4) | 1 |
|  | Liver | 5 | 0.1 | 0.1 | (-0.4, 0.6) | 2 |
|  | All | 438 | 7.5 | 6.1 | (2.5, 9.8) | 107 |
| 18-34 | Lung | 16 | 0.3 | 0.2 | (-0.2, 0.7) | 5 |
|  | NHL | 321 | 3.3 | 2.7 | (1.2, 4.1) | 55 |
|  | Colorectum | 31 | 0.3 | 0.3 | (-0.2, 0.7) | 5 |
|  | Kidney | 109 | 0.5 | 0.4 | (-0.2, 1.0) | 8 |
|  | Pancreas | 7 | 0.1 | 0.1 | (-0.2, 0.5) | 3 |
|  | Stomach | 6 | 0.1 | 0.1 | (-0.2, 0.5) | 3 |
|  | Breast | 64 | 0.5 | 0.4 | (-0.2, 0.9) | 8 |
|  | Bladder | 12 | 0.1 | 0.1 | (-0.2, 0.3) | 2 |
|  | Melanoma | 40 | 0.2 | 0.1 | (-0.2, 0.4) | 2 |
|  | Liver | 8 | 0.2 | 0.2 | (-0.2, 0.5) | 3 |
|  | All | 1017 | 8.9 | 7.3 | (4.9, 9.7) | 151 |
| 35-49 | Lung | 347 | 2.1 | 2.0 | (1.4, 2.5) | 62 |
|  | NHL | 562 | 2.3 | 1.8 | (1.2, 2.4) | 57 |
|  | Colorectum | 206 | 0.8 | 0.6 | (0.3, 0.9) | 18 |
|  | Kidney | 430 | 0.8 | 0.4 | (0.1, 0.8) | 14 |
|  | Pancreas | 54 | 0.4 | 0.3 | (0.1, 0.6) | 11 |
|  | Stomach | 55 | 0.3 | 0.3 | (0.1, 0.5) | 10 |
|  | Breast | 262 | 0.6 | 0.4 | (0.1, 0.6) | 11 |
|  | Bladder | 63 | 0.2 | 0.2 | (0.0, 0.4) | 6 |
|  | Melanoma | 137 | 0.4 | 0.3 | (0.0, 0.5) | 9 |
|  | Liver | 49 | 0.3 | 0.3 | (0.1, 0.5) | 8 |
|  | All | 3637 | 13.1 | 10.5 | (9.1, 11.9) | 329 |
| 50-64 | Lung | 1319 | 4.8 | 4.3 | (3.8, 4.8) | 228 |
|  | NHL | 832 | 2.2 | 1.7 | (1.4, 2.0) | 90 |
|  | Colorectum | 468 | 1.2 | 0.8 | (0.6, 1.1) | 44 |
|  | Kidney | 514 | 0.9 | 0.5 | (0.3, 0.7) | 26 |
|  | Pancreas | 146 | 0.6 | 0.6 | (0.4, 0.7) | 29 |
|  | Stomach | 139 | 0.5 | 0.4 | (0.3, 0.6) | 23 |
|  | Breast | 388 | 0.6 | 0.2 | (0.0, 0.4) | 11 |
|  | Bladder | 201 | 0.5 | 0.4 | (0.2, 0.6) | 21 |
|  | Melanoma | 300 | 0.6 | 0.3 | (0.2, 0.5) | 17 |
|  | Liver | 95 | 0.3 | 0.3 | (0.2, 0.4) | 16 |
|  | All | 7736 | 19.7 | 15.5 | (14.5, 16.5) | 818 |
| 65+ | Lung | 351 | 4.2 | 3.7 | (2.9, 4.4) | 292 |
|  | NHL | 228 | 2.2 | 1.7 | (1.1, 2.2) | 134 |
|  | Colorectum | 171 | 1.6 | 1.1 | (0.6, 1.5) | 87 |
|  | Kidney | 122 | 0.9 | 0.6 | (0.2, 0.9) | 44 |
|  | Pancreas | 66 | 0.9 | 0.8 | (0.5, 1.2) | 68 |
|  | Stomach | 33 | 0.4 | 0.4 | (0.1, 0.6) | 28 |
|  | Breast | 87 | 0.5 | 0.2 | (-0.1, 0.4) | 14 |
|  | Bladder | 67 | 0.6 | 0.4 | (0.2, 0.7) | 35 |
|  | Melanoma | 103 | 0.7 | 0.3 | (0.0, 0.6) | 25 |
|  | Liver | 20 | 0.2 | 0.2 | (0.0, 0.4) | 17 |
|  | All | 2185 | 20.3 | 15.5 | (13.8, 17.1) | 1229 |
| **Organ Transplanted** | | |  |  |  |  |
| Kidney | Lung | 891 | 3.2 | 3.0 | (2.4, 3.5) | 93 |
|  | NHL | 1039 | 2.1 | 1.7 | (1.2, 2.1) | 53 |
|  | Colorectum | 440 | 1.1 | 0.8 | (0.5, 1.1) | 25 |
|  | Kidney | 909 | 1.1 | 0.6 | (0.3, 0.9) | 19 |
|  | Pancreas | 157 | 0.6 | 0.6 | (0.3, 0.8) | 18 |
|  | Stomach | 123 | 0.4 | 0.4 | (0.2, 0.6) | 12 |
|  | Bladder | 196 | 0.5 | 0.4 | (0.2, 0.6) | 12 |
|  | Melanoma | 335 | 0.6 | 0.3 | (0.1, 0.5) | 10 |
|  | Liver | 82 | 0.3 | 0.3 | (0.1, 0.4) | 8 |
|  | All | 8029 | 16.6 | 13.1 | (11.9, 14.3) | 410 |
| Liver | Lung | 397 | 3.2 | 2.9 | (2.2, 3.5) | 118 |
|  | NHL | 488 | 2.4 | 1.8 | (1.2, 2.4) | 74 |
|  | Colorectum | 221 | 1.2 | 0.9 | (0.5, 1.3) | 36 |
|  | Kidney | 77 | 0.3 | 0.2 | (0.0, 0.4) | 8 |
|  | Pancreas | 63 | 0.6 | 0.6 | (0.3, 0.9) | 24 |
|  | Stomach | 48 | 0.4 | 0.4 | (0.1, 0.6) | 15 |
|  | Bladder | 45 | 0.3 | 0.2 | (0.0, 0.4) | 9 |
|  | Melanoma | 84 | 0.3 | 0.2 | (0.0, 0.4) | 7 |
|  | Liver | 66 | 0.5 | 0.5 | (0.2, 0.7) | 19 |
|  | All | 2781 | 15.8 | 13.0 | (11.6, 14.5) | 531 |
| Heart | Lung | 496 | 5.1 | 4.6 | (3.8, 5.4) | 251 |
|  | NHL | 391 | 3.2 | 2.4 | (1.8, 3.0) | 132 |
|  | Colorectum | 114 | 1.0 | 0.7 | (0.4, 1.0) | 39 |
|  | Kidney | 126 | 0.8 | 0.4 | (0.1, 0.7) | 23 |
|  | Pancreas | 33 | 0.3 | 0.3 | (0.1, 0.5) | 18 |
|  | Stomach | 40 | 0.4 | 0.4 | (0.2, 0.6) | 22 |
|  | Bladder | 64 | 0.5 | 0.3 | (0.1, 0.5) | 18 |
|  | Melanoma | 118 | 0.8 | 0.4 | (0.2, 0.7) | 23 |
|  | Liver | 20 | 0.2 | 0.2 | (0.0, 0.4) | 11 |
|  | All | 2628 | 20.9 | 16.4 | (14.8, 17.9) | 891 |
| Lung | Lung | 207 | 3.5 | 3.0 | (2.3, 3.6) | 349 |
|  | NHL | 162 | 2.4 | 1.7 | (1.1, 2.2) | 198 |
|  | Colorectum | 67 | 0.9 | 0.5 | (0.2, 0.8) | 59 |
|  | Kidney | 27 | 0.4 | 0.3 | (0.1, 0.5) | 36 |
|  | Pancreas | 8 | 0.2 | 0.1 | (0.0, 0.3) | 18 |
|  | Stomach | 16 | 0.2 | 0.2 | (0.0, 0.4) | 24 |
|  | Bladder | 22 | 0.3 | 0.2 | (0.0, 0.4) | 27 |
|  | Melanoma | 22 | 0.3 | 0.1 | (-0.1, 0.3) | 14 |
|  | Liver | 5 | 0.1 | 0.0 | (-0.1, 0.1) | 5 |
|  | All | 942 | 13.9 | 10.5 | (9.2, 11.8) | 1241 |
| Other | Lung | 42 | 1.1 | 1.0 | (0.2, 1.9) | 37 |
|  | NHL | 160 | 3.6 | 3.1 | (1.6, 4.6) | 108 |
|  | Colorectum | 35 | 0.6 | 0.4 | (-0.2, 1.0) | 15 |
|  | Kidney | 45 | 0.7 | 0.5 | (-0.2, 1.1) | 16 |
|  | Pancreas | 12 | 0.4 | 0.4 | (-0.1, 0.9) | 14 |
|  | Stomach | 6 | 0.2 | 0.1 | (-0.2, 0.5) | 5 |
|  | Bladder | 18 | 0.3 | 0.3 | (-0.2, 0.7) | 9 |
|  | Melanoma | 22 | 0.3 | 0.3 | (-0.2, 0.7) | 9 |
|  | Liver | 4 | 0.1 | 0.1 | (-0.2, 0.4) | 4 |
|  | All | 633 | 11.8 | 9.8 | (7.0, 12.6) | 342 |
| Time since transplant, years | | | |  |  |  |
| 3 months-1.99 | Lung | 464 | 1.9 | 1.8 | (1.0, 2.6) | 68 |
|  | NHL | 869 | 2.3 | 2.1 | (1.2, 3.0) | 80 |
|  | Colorectum | 200 | 0.3 | 0.3 | (-0.1, 0.6) | 11 |
|  | Kidney | 325 | 0.3 | 0.3 | (-0.1, 0.6) | 10 |
|  | Pancreas | 74 | 0.4 | 0.3 | (0.0, 0.7) | 13 |
|  | Stomach | 49 | 0.2 | 0.1 | (-0.1, 0.4) | 6 |
|  | Breast | 193 | 0.1 | 0.1 | (-0.1, 0.3) | 3 |
|  | Bladder | 70 | 0.2 | 0.2 | (-0.1, 0.4) | 6 |
|  | Melanoma | 187 | 0.2 | 0.2 | (-0.1, 0.5) | 7 |
|  | Liver | 39 | 0.1 | 0.1 | (-0.1, 0.4) | 5 |
|  | All | 4159 | 8.9 | 8.1 | (6.4, 9.9) | 313 |
| 2-4.99 | Lung | 825 | 4.0 | 3.7 | (2.6, 4.9) | 126 |
|  | NHL | 939 | 1.8 | 1.5 | (0.7, 2.2) | 50 |
|  | Colorectum | 401 | 1.0 | 0.8 | (0.2, 1.3) | 26 |
|  | Kidney | 548 | 0.8 | 0.5 | (0.0, 1.0) | 18 |
|  | Pancreas | 101 | 0.6 | 0.6 | (0.1, 1.0) | 19 |
|  | Stomach | 94 | 0.5 | 0.4 | (0.0, 0.8) | 14 |
|  | Breast | 401 | 0.5 | 0.2 | (-0.1, 0.6) | 8 |
|  | Bladder | 132 | 0.3 | 0.2 | (-0.1, 0.5) | 7 |
|  | Melanoma | 317 | 0.5 | 0.3 | (-0.1, 0.7) | 9 |
|  | Liver | 75 | 0.3 | 0.3 | (0.0, 0.7) | 11 |
|  | All | 6864 | 16.1 | 13.5 | (11.3, 15.7) | 456 |
| 5-9.99 | Lung | 887 | 4.3 | 3.8 | (2.9, 4.7) | 159 |
|  | NHL | 1116 | 2.9 | 2.2 | (1.5, 2.9) | 92 |
|  | Colorectum | 489 | 1.5 | 1.0 | (0.5, 1.5) | 42 |
|  | Kidney | 649 | 0.9 | 0.5 | (0.1, 0.9) | 20 |
|  | Pancreas | 96 | 0.6 | 0.6 | (0.2, 0.9) | 24 |
|  | Stomach | 105 | 0.5 | 0.5 | (0.2, 0.8) | 19 |
|  | Breast | 517 | 0.8 | 0.3 | (0.0, 0.7) | 15 |
|  | Bladder | 212 | 0.7 | 0.5 | (0.2, 0.9) | 22 |
|  | Melanoma | 344 | 0.7 | 0.4 | (0.0, 0.7) | 15 |
|  | Liver | 69 | 0.3 | 0.3 | (0.1, 0.6) | 13 |
|  | All | 8018 | 21.3 | 16.0 | (14.1, 18.0) | 673 |
| 10+ | Lung | 396 | 4.0 | 3.3 | (2.2, 4.3) | 168 |
|  | NHL | 645 | 3.3 | 1.9 | (1.0, 2.9) | 99 |
|  | Colorectum | 290 | 1.9 | 1.1 | (0.4, 1.8) | 56 |
|  | Kidney | 403 | 1.6 | 0.7 | (0.1, 1.4) | 36 |
|  | Pancreas | 37 | 0.5 | 0.5 | (0.1, 0.9) | 24 |
|  | Stomach | 39 | 0.5 | 0.4 | (0.0, 0.8) | 22 |
|  | Breast | 308 | 1.2 | 0.4 | (-0.2, 0.9) | 19 |
|  | Bladder | 87 | 0.6 | 0.4 | (0.0, 0.8) | 20 |
|  | Melanoma | 171 | 0.9 | 0.3 | (-0.2, 0.7) | 14 |
|  | Liver | 36 | 0.3 | 0.3 | (0.0, 0.6) | 15 |
|  | All | 4411 | 25.5 | 15.7 | (13.0, 18.4) | 810 |
| **Race/ethnicity** | | |  |  |  |  |
| Non-Hispanic white | Lung | 1602 | 3.9 | 3.5 | (3.1, 3.9) | 149 |
| NHL | 1656 | 2.7 | 2.1 | (1.7, 2.4) | 87 |
| Colorectum | 629 | 1.1 | 0.8 | (0.6, 1.0) | 32 |
|  | Kidney | 612 | 0.7 | 0.4 | (0.2, 0.6) | 17 |
|  | Pancreas | 166 | 0.4 | 0.4 | (0.3, 0.6) | 18 |
|  | Stomach | 146 | 0.4 | 0.3 | (0.2, 0.5) | 14 |
|  | Breast | 529 | 0.5 | 0.2 | (0.1, 0.3) | 8 |
|  | Bladder | 282 | 0.5 | 0.4 | (0.2, 0.5) | 15 |
|  | Melanoma | 556 | 0.7 | 0.4 | (0.2, 0.5) | 16 |
|  | Liver | 106 | 0.3 | 0.2 | (0.1, 0.3) | 10 |
|  | All | 10755 | 18.0 | 14.2 | (13.4, 15.1) | 600 |
| Non-Hispanic black | Lung | 275 | 2.7 | 2.5 | (1.7, 3.3) | 104 |
| NHL | 204 | 1.2 | 0.9 | (0.4, 1.4) | 38 |
| Colorectum | 138 | 1.0 | 0.7 | (0.3, 1.2) | 31 |
|  | Kidney | 366 | 1.3 | 0.7 | (0.2, 1.2) | 30 |
|  | Pancreas | 54 | 0.6 | 0.5 | (0.2, 0.9) | 22 |
|  | Stomach | 45 | 0.4 | 0.4 | (0.1, 0.7) | 15 |
|  | Breast | 147 | 0.7 | 0.4 | (0.1, 0.8) | 18 |
|  | Bladder | 25 | 0.2 | 0.1 | (-0.1, 0.3) | 5 |
|  | Melanoma | 7 | 0.0 | 0.0 | (0.0, 0.0) | 0 |
|  | Liver | 32 | 0.3 | 0.3 | (0.0, 0.5) | 12 |
|  | All | 2241 | 13.4 | 10.2 | (8.5, 11.8) | 423 |
| Hispanic | Lung | 91 | 1.5 | 1.4 | (0.5, 2.2) | 39 |
|  | NHL | 258 | 2.6 | 2.2 | (1.1, 3.3) | 64 |
|  | Colorectum | 68 | 0.7 | 0.5 | (0.0, 1.0) | 14 |
|  | Kidney | 157 | 0.8 | 0.5 | (-0.1, 1.1) | 15 |
|  | Pancreas | 38 | 0.7 | 0.7 | (0.1, 1.2) | 19 |
|  | Stomach | 18 | 0.3 | 0.3 | (-0.1, 0.7) | 9 |
|  | Breast | 82 | 0.5 | 0.4 | (-0.1, 0.8) | 10 |
|  | Bladder | 30 | 0.4 | 0.4 | (-0.1, 0.8) | 10 |
|  | Melanoma | 13 | 0.2 | 0.2 | (-0.1, 0.5) | 5 |
|  | Liver | 30 | 0.4 | 0.4 | (-0.1, 0.8) | 10 |
|  | All | 1411 | 13.0 | 10.7 | (8.3, 13.0) | 303 |
| Asian/Pacific islander | Lung | 51 | 2.5 | 2.3 | (0.4, 4.3) | 59 |
| NHL | 105 | 3.2 | 2.8 | (0.5, 5.0) | 70 |
| Colorectum | 41 | 1.3 | 1.0 | (-0.4, 2.4) | 25 |
|  | Kidney | 37 | 0.7 | 0.4 | (-0.6, 1.4) | 10 |
|  | Pancreas | 13 | 0.7 | 0.7 | (-0.4, 1.8) | 18 |
|  | Stomach | 24 | 1.0 | 1.0 | (-0.3, 2.2) | 24 |
|  | Breast | 40 | 0.5 | 0.4 | (-0.5, 1.2) | 9 |
|  | Bladder | 8 | 0.1 | 0.1 | (-0.3, 0.5) | 2 |
|  | Melanoma | 4 | 0.0 | 0.0 |  | 0 |
|  | Liver | 9 | 0.3 | 0.3 | (-0.4, 1.0) | 7 |
|  | All | 531 | 16.0 | 13.8 | (9.0, 18.6) | 350 |
| Other | Lung | 14 | 4.4 | 4.1 | (-0.8, 9.0) | 168 |
|  | NHL | 17 | 3.0 | 2.2 | (-2.0, 6.5) | 92 |
|  | Colorectum | 1 | 0.3 | 0.3 | (-1.1, 1.8) | 14 |
|  | Kidney | 12 | 0.7 | 0.2 | (-1.8, 2.3) | 10 |
|  | Pancreas | 2 | 0.7 | 0.7 | (-1.4, 2.7) | 27 |
|  | Stomach | 0 | 0.0 | 0.0 |  | 0 |
|  | Breast | 3 | 0.3 | 1.3 | (-322.4, 324.9) | 51 |
|  | Bladder | 0 | 0.0 | 0.0 |  | 0 |
|  | Melanoma | 1 | 0.0 | 0.0 |  | 0 |
|  | Liver | 0 | 0.0 | 0.0 |  | 0 |
|  | All | 75 | 14.8 | 12.4 | (3.4, 21.4) | 506 |
| **Sex** |  |  |  |  |  |  |
| Female | Lung | 645 | 2.8 | 2.5 | (2.0, 3.0) | 91 |
|  | NHL | 764 | 2.1 | 1.6 | (1.2, 2.1) | 59 |
|  | Colorectum | 359 | 1.1 | 0.8 | (0.5, 1.1) | 28 |
|  | Kidney | 333 | 0.6 | 0.4 | (0.1, 0.6) | 13 |
|  | Pancreas | 97 | 0.5 | 0.5 | (0.3, 0.7) | 17 |
|  | Stomach | 67 | 0.3 | 0.2 | (0.1, 0.4) | 8 |
|  | Breast | 769 | 1.5 | 0.7 | (0.3, 1.0) | 24 |
|  | Bladder | 83 | 0.3 | 0.3 | (0.1, 0.4) | 9 |
|  | Melanoma | 154 | 0.3 | 0.1 | (0.0, 0.3) | 4 |
|  | Liver | 33 | 0.1 | 0.1 | (0.0, 0.2) | 4 |
|  | All | 4972 | 14.1 | 11.1 | (10.0, 12.2) | 404 |
| Male | Lung | 1388 | 3.8 | 3.4 | (3.0, 3.9) | 141 |
|  | NHL | 1476 | 2.6 | 2.1 | (1.7, 2.4) | 86 |
|  | Colorectum | 518 | 1.0 | 0.7 | (0.5, 0.9) | 30 |
|  | Kidney | 851 | 0.9 | 0.5 | (0.3, 0.7) | 22 |
|  | Pancreas | 176 | 0.5 | 0.5 | (0.3, 0.7) | 20 |
|  | Stomach | 166 | 0.5 | 0.4 | (0.3, 0.6) | 17 |
|  | Breast | 32 | 0.0 | 0.0 | (0.0, 0.1) | 1 |
|  | Bladder | 262 | 0.5 | 0.3 | (0.2, 0.5) | 14 |
|  | Melanoma | 427 | 0.6 | 0.4 | (0.2, 0.5) | 16 |
|  | Liver | 144 | 0.4 | 0.3 | (0.2, 0.5) | 14 |
|  | All | 10041 | 18.1 | 14.4 | (13.4, 15.3) | 590 |
| Overall and cancer-attributable mortality rates are per 100,000 person-years. Cancers are ordered by overall PAF. | | | | | | |

**Statistical appendix**

We calculate the smoking-adjusted HR using the method of Steenland and Greenland.31 Since smoking is hypothesized to be the strongest potential confounder of the association between lung cancer and mortality, the focus of this analysis is to apply this methodology to smoking as a potential confounder of the lung cancer estimate.

Let “exp” denote transplant recipients who developed an incident cancer and “nonexp” denote those who did not develop lung cancer. Let , and be the mortality rate among those with lung cancer in the transplant population overall, and among smokers and non-smokers, respectively and let and be the proportions of current smokers and non-smokers among transplant recipients with lung cancer. Let , and be the mortality rate among those without lung cancer in the transplant population overall, and among smokers and non-smokers, respectively and let and be the proportions of current smokers and non-smokers among transplant recipients without lung cancer. Then

Let be the RR for death among smokers vs. non-smokers in the transplant population. Assume the same RR between smoking and death for transplant recipients with lung cancer and those without.

The term inside the brackets in the last two lines above is termed the “bias factor.” The parameters used to estimate the bias factor are shown in Supplementary Table 2.

**Supplementary Table 2: Parameter estimates used in bias factor analysis**

|  |  |
| --- | --- |
| **Parameter** | **Estimate** |
| : Relative risk of death for current vs. never smokers in the transplant population[1-3] | 2 |
| : prevalence of smoking among transplant recipients without incident lung cancer[1-3] | Range 10-30%; Assume 20% |
| : prevalence of smoking among transplant recipients with incident lung cancer | Assume 100% to maximize the bias factor correction |

1. Hurst FP, Altieri M, Patel PP, et al: Effect of smoking on kidney transplant outcomes: analysis of the United States Renal Data System. Transplantation 92:1101-7, 2011

2. Leithead JA, Ferguson JW, Hayes PC: Smoking-related morbidity and mortality following liver transplantation. Liver Transpl 14:1159-64, 2008

3. Weinrauch LA, Claggett B, Liu J, et al: Smoking and outcomes in kidney transplant recipients: a post hoc survival analysis of the FAVORIT trial. Int J Nephrol Renovasc Dis 11:155-164, 2018