Mortality/graft loss prediction using CHD diagnosis data

Byron C. Jaeger

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**Table 1**: Characteristics of patients at listing

| **Characteristic1** |  | **1-year waitlist morality** | |
| --- | --- | --- | --- |
| **Overall, N = 5,986** | **No, N = 5,242** | **Yes, N = 744** |
| Age at time of listing, years | 3.5 (0.4, 12.1) | 4.4 (0.5, 12.8) | 0.7 (0.1, 3.2) |
| Blood Type |  |  |  |
| A | 2,113 (35) | 1,866 (36) | 247 (33) |
| AB | 216 (3.6) | 190 (3.6) | 26 (3.5) |
| B | 792 (13) | 693 (13) | 99 (13) |
| O | 2,858 (48) | 2,486 (47) | 372 (50) |
| Medical history at Listing, Neurologic | 295 (5.0) | 252 (4.9) | 43 (6.0) |
| Patient Dialysis | 80 (1.3) | 60 (1.1) | 20 (2.7) |
| ECMO at Listing | 353 (5.9) | 237 (4.5) | 116 (16) |
| Recipient Sex |  |  |  |
| Female | 2,684 (45) | 2,343 (45) | 341 (46) |
| Male | 3,302 (55) | 2,899 (55) | 403 (54) |
| Height at Listing, cm | 93 (62, 144) | 99 (64, 148) | 65 (52, 92) |
| Recipient Temporary Device IABP | 8 (0.1) | 8 (0.2) | 0 (0) |
| Recipient on Life Support | 4,004 (67) | 3,400 (65) | 604 (81) |
| Recipient Other Life Support | 192 (3.2) | 183 (3.5) | 9 (1.2) |
| Most Recent Serum Creatinine | 0.41 (0.30, 0.60) | 0.42 (0.30, 0.60) | 0.40 (0.30, 0.60) |
| Pulmonary Wedge Pressure, mean | 15 (11, 20) | 15 (11, 20) | 15 (10, 20) |
| Recipient stent or prostaglandin infusion | 242 (4.1) | 183 (3.6) | 59 (8.1) |
| Congenital surgery prior to listing | 2,906 (49) | 2,489 (47) | 417 (56) |
| Recipient Prior to Listing Pam | 22 (16, 30) | 22 (16, 30) | 21 (16, 28) |
| Recipient Hispanic or Latino | 1,224 (21) | 1,073 (21) | 151 (21) |
| Recipient on Ventilator | 1,415 (24) | 1,077 (21) | 338 (47) |
| Weight at Listing, kg | 13 (6, 38) | 15 (6, 41) | 7 (4, 13) |
| Prior Heart Transplant Failure | 317 (5.3) | 266 (5.1) | 51 (6.9) |
| Recipient Primary Diagnosis |  |  |  |
| Cardiomyopathy | 2,700 (45) | 2,472 (47) | 228 (31) |
| Congenital HD | 3,090 (52) | 2,596 (50) | 494 (66) |
| Myocarditis | 149 (2.5) | 135 (2.6) | 14 (1.9) |
| Other | 47 (0.8) | 39 (0.7) | 8 (1.1) |
| Cardiomyopathy Type |  |  |  |
| DCM | 2,031 (75) | 1,865 (75) | 166 (73) |
| OtherCM | 149 (5.5) | 135 (5.5) | 14 (6.1) |
| RCM | 520 (19) | 472 (19) | 48 (21) |
| CHD Single Ventricle |  |  |  |
| biVentricle | 962 (31) | 778 (30) | 184 (37) |
| singleVentricle | 2,128 (69) | 1,818 (70) | 310 (63) |
| CHD Single Ventricle Dominant Ventricle |  |  |  |
| HLHS | 1,283 (75) | 1,095 (75) | 188 (76) |
| LVdom | 395 (23) | 334 (23) | 61 (24) |
| RVdom | 23 (1.4) | 23 (1.6) | 0 (0) |
| CHD Single Ventricle Stage |  |  |  |
| 0 | 185 (8.8) | 139 (7.8) | 46 (15) |
| 1 | 520 (25) | 407 (23) | 113 (37) |
| 2 | 619 (30) | 528 (29) | 91 (30) |
| 3 | 773 (37) | 719 (40) | 54 (18) |
| CHD Bi-Ventricle Cardiac Surgery |  |  |  |
| cbvSurgery | 711 (74) | 580 (75) | 131 (71) |
| noSurgery | 251 (26) | 198 (25) | 53 (29) |
| list\_year | 2,015.00 (2,013.00, 2,017.00) | 2,015.00 (2,013.00, 2,018.00) | 2,015.00 (2,012.00, 2,017.00) |
| Recipient Race |  |  |  |
| White | 3,963 (66) | 3,492 (67) | 471 (63) |
| Black | 1,114 (19) | 969 (18) | 145 (19) |
| Other | 909 (15) | 781 (15) | 128 (17) |
| 1Table values are median (25th percentile, 75th percentile) and percent for continuous and categorical variables, respectively. | | | |

**Table 2**: Characteristics of patients at transplant

| **Characteristic1** |  | **1-year transplant Mortality or graft loss** | |
| --- | --- | --- | --- |
| **Overall, N = 4,185** | **No, N = 3,881** | **Yes, N = 304** |
| Donor to Recipient Height Ratio | 1.12 (1.02, 1.26) | 1.12 (1.02, 1.26) | 1.14 (1.06, 1.30) |
| Recipient Dialysis since Listing | 37 (0.9) | 31 (0.8) | 6 (2.0) |
| Recipient ECMO at Transplant | 161 (3.9) | 116 (3.0) | 45 (15) |
| Recipient Most Recent Total Bilirubin at Transplant | 0.60 (0.40, 1.20) | 0.60 (0.37, 1.12) | 0.70 (0.40, 1.30) |
| Recipient Primary Diagnosis |  |  |  |
| Cardiomyopathy | 2,048 (49) | 1,989 (51) | 59 (19) |
| Congenital HD | 2,030 (49) | 1,798 (46) | 232 (76) |
| Myocarditis | 87 (2.1) | 76 (2.0) | 11 (3.6) |
| Other | 20 (0.5) | 18 (0.5) | 2 (0.7) |
| Recipient Ventilator at Transplant | 688 (17) | 595 (16) | 93 (32) |
| Cardiomyopathy Type |  |  |  |
| DCM | 1,540 (75) | 1,498 (75) | 42 (71) |
| OtherCM | 111 (5.4) | 106 (5.3) | 5 (8.5) |
| RCM | 397 (19) | 385 (19) | 12 (20) |
| CHD Single Ventricle |  |  |  |
| biVentricle | 632 (31) | 565 (31) | 67 (29) |
| singleVentricle | 1,398 (69) | 1,233 (69) | 165 (71) |
| CHD Single Ventricle Dominant Ventricle |  |  |  |
| HLHS | 830 (75) | 723 (74) | 107 (81) |
| LVdom | 258 (23) | 234 (24) | 24 (18) |
| RVdom | 20 (1.8) | 19 (1.9) | 1 (0.8) |
| CHD Single Ventricle Stage |  |  |  |
| 0 | 121 (8.7) | 108 (8.8) | 13 (7.9) |
| 1 | 309 (22) | 257 (21) | 52 (32) |
| 2 | 406 (29) | 367 (30) | 39 (24) |
| 3 | 561 (40) | 500 (41) | 61 (37) |
| CHD Bi-Ventricle Cardiac Surgery |  |  |  |
| cbvSurgery | 476 (75) | 421 (75) | 55 (82) |
| noSurgery | 156 (25) | 144 (25) | 12 (18) |
| txpl\_year | 2,015.00 (2,013.00, 2,018.00) | 2,015.00 (2,013.00, 2,018.00) | 2,015.00 (2,012.00, 2,017.00) |
| 1Table values are median (25th percentile, 75th percentile) and percent for continuous and categorical variables, respectively. | | | |

**Table 3**: Hazard ratios (95% confidence interval) for mortality within 1 year of listing among patients with congenital heart disease versus cardiomyopathy

| **Diagnostic group** | **N events / N at risk** | **Hazard ratio (95% CI)** | | **P-value** |
| --- | --- | --- | --- | --- |
| **Unadjusted** | **Adjusteda** |
| *Model 1* | | | | |
| Cardiomyopathy | 228 / 2,700 | 1 (ref) | 1 (ref) | -- |
| Congenital HD | 494 / 3,090 | 1.7 (1.5, 2.0) | 1.8 (1.4, 2.3) | <.001 |
| *Model 2* | | | | |
| Cardiomyopathy | 228 / 2,700 | 1 (ref) | 1 (ref) | -- |
| Congenital HD; bi-Ventricle | 184 / 962 | 2.4 (2.0, 2.9) | 1.9 (1.5, 2.4) | <.001 |
| Congenital HD; single-Ventricle | 310 / 2,128 | 1.5 (1.3, 1.8) | 1.7 (1.3, 2.3) | <.001 |
| *Model 3* | | | | |
| Cardiomyopathy | 228 / 2,700 | 1 (ref) | 1 (ref) | -- |
| Congenital HD; bi-Ventricle; CBV Surgery | 131 / 711 | 2.3 (1.8, 2.8) | 2.1 (1.4, 3.0) | <.001 |
| Congenital HD; bi-Ventricle; no Surgery | 53 / 251 | 2.7 (2.0, 3.6) | 1.8 (1.3, 2.4) | <.001 |
| Congenital HD; single-Ventricle; HLHS | 249 / 1,710 | 1.5 (1.2, 1.8) | 2.0 (1.4, 2.7) | <.001 |
| Congenital HD; single-Ventricle; LVdom | 61 / 395 | 1.7 (1.3, 2.2) | 1.6 (1.1, 2.3) | .01 |
| Congenital HD; single-Ventricle; RVdomb | -- / -- | 0.00 (0.00, NA) | 0.00 (0.00, NA) | .988 |
| *Model 4* | | | | |
| Cardiomyopathy | 228 / 2,700 | 1 (ref) | 1 (ref) | -- |
| Congenital HD; bi-Ventricle; CBV Surgery | 131 / 711 | 2.3 (1.8, 2.8) | 2.1 (1.4, 2.9) | <.001 |
| Congenital HD; bi-Ventricle; no Surgery | 53 / 251 | 2.7 (2.0, 3.6) | 1.8 (1.3, 2.5) | <.001 |
| Congenital HD; single-Ventricle; HLHS; Stage ≥2 | 131 / 1,206 | 1.0 (0.82, 1.3) | 1.8 (1.3, 2.6) | .001 |
| Congenital HD; single-Ventricle; HLHS; Stage <2 | 118 / 504 | 3.0 (2.4, 3.7) | 2.1 (1.5, 2.9) | <.001 |
| Congenital HD; single-Ventricle; LVdom; Stage ≥2 | 20 / 204 | 0.94 (0.59, 1.5) | 1.5 (0.89, 2.6) | .13 |
| Congenital HD; single-Ventricle; LVdom; Stage <2 | 41 / 191 | 2.8 (2.0, 3.9) | 1.7 (1.1, 2.5) | .01 |
| Congenital HD; single-Ventricle; RVdomb | -- / -- | 0.00 (0.00, NA) | 0.00 (0.00, NA) | .989 |
| aAdjusted for age at time of listing, blood type, medical history at listing, neurologic, patient dialysis, ECMO at listing, recipient sex, height at listing, recipient temporary device IABP, recipient on life support, recipient other life support, most recent serum creatinine, pulmonary wedge pressure, recipient stent or prostaglandin infusion, congenital surgery prior to listing, recipient prior to listing PAM, recipient hispanic or latino, recipient race, recipient on ventilator, weight at listing, and prior heart transplant failure | | | | |
| bDue to smaller sample size, stage was not analyzed in this group | | | | |

**Table 4**: Hazard ratios (95% confidence interval) for mortality within 1 year of listing among patients with cardiomyopathy versus congenital heart disease.

| **Diagnostic group** | **N events / N at risk** | **Hazard ratio (95% CI)** | | **P-value** |
| --- | --- | --- | --- | --- |
| **Unadjusted** | **Adjusted1** |
| *Model 1* | | | | |
| Congenital HD | 494 / 3,090 | 1 (ref) | 1 (ref) | -- |
| Cardiomyopathy | 228 / 2,700 | 0.57 (0.49, 0.67) | 0.55 (0.43, 0.70) | <.001 |
| *Model 2* | | | | |
| Congenital HD | 494 / 3,090 | 1 (ref) | 1 (ref) | -- |
| Cardiomyopathy; RCM | 48 / 520 | 0.50 (0.38, 0.68) | 0.82 (0.58, 1.2) | .28 |
| Cardiomyopathy; DCM | 166 / 2,031 | 0.59 (0.49, 0.70) | 0.50 (0.39, 0.64) | <.001 |
| Cardiomyopathy; OtherCM | 14 / 149 | 0.65 (0.38, 1.1) | 0.54 (0.31, 0.94) | .03 |
| 1Adjusted for age at time of listing, blood type, medical history at listing, neurologic, patient dialysis, ECMO at listing, recipient sex, height at listing, recipient temporary device IABP, recipient on life support, recipient other life support, most recent serum creatinine, pulmonary wedge pressure, recipient stent or prostaglandin infusion, congenital surgery prior to listing, recipient prior to listing PAM, recipient hispanic or latino, recipient race, recipient on ventilator, weight at listing, and prior heart transplant failure | | | | |

**Table 5**: Hazard ratios (95% confidence interval) for mortality or graft loss within 1 year of transplant among patients with congenital heart disease versus cardiomyopathy

| **Diagnostic group** | **N events / N at risk** | **Hazard ratio (95% CI)** | | **P-value** |
| --- | --- | --- | --- | --- |
| **Unadjusted** | **Adjusteda** |
| *Model 1* | | | | |
| Cardiomyopathy | 59 / 2,048 | 1 (ref) | 1 (ref) | -- |
| Congenital HD | 232 / 2,030 | 4.1 (3.1, 5.5) | 3.9 (2.9, 5.1) | <.001 |
| *Model 2* | | | | |
| Cardiomyopathy | 59 / 2,048 | 1 (ref) | 1 (ref) | -- |
| Congenital HD; bi-Ventricle | 67 / 632 | 3.8 (2.7, 5.4) | 3.4 (2.4, 4.9) | <.001 |
| Congenital HD; single-Ventricle | 165 / 1,398 | 4.3 (3.2, 5.8) | 4.0 (3.0, 5.5) | <.001 |
| *Model 3* | | | | |
| Cardiomyopathy | 59 / 2,048 | 1 (ref) | 1 (ref) | -- |
| Congenital HD; bi-Ventricle; CBV Surgery | 55 / 476 | 4.2 (2.9, 6.0) | 3.8 (2.6, 5.5) | <.001 |
| Congenital HD; bi-Ventricle; no Surgery | 12 / 156 | 2.7 (1.5, 5.1) | 2.4 (1.3, 4.5) | .006 |
| Congenital HD; single-Ventricle; HLHS | 140 / 1,120 | 4.6 (3.4, 6.2) | 4.3 (3.2, 5.9) | <.001 |
| Congenital HD; single-Ventricle; LVdom | 24 / 258 | 3.4 (2.1, 5.4) | 3.2 (2.0, 5.1) | <.001 |
| Congenital HD; single-Ventricle; RVdomb | 1 / 20 | 1.6 (0.23, 12) | 1.1 (0.15, 8.0) | .93 |
| *Model 4* | | | | |
| Cardiomyopathy | 59 / 2,048 | 1 (ref) | 1 (ref) | -- |
| Congenital HD; bi-Ventricle; CBV Surgery | 55 / 476 | 4.2 (2.9, 6.0) | 3.8 (2.6, 5.5) | <.001 |
| Congenital HD; bi-Ventricle; no Surgery | 12 / 156 | 2.7 (1.5, 5.1) | 2.4 (1.3, 4.6) | .005 |
| Congenital HD; single-Ventricle; HLHS; Stage ≥2 | 88 / 820 | 3.9 (2.8, 5.4) | 3.9 (2.8, 5.5) | <.001 |
| Congenital HD; single-Ventricle; HLHS; Stage <2 | 52 / 300 | 6.4 (4.4, 9.3) | 5.3 (3.6, 7.8) | <.001 |
| Congenital HD; single-Ventricle; LVdom; Stage ≥2 | 11 / 137 | 2.9 (1.5, 5.6) | 3.2 (1.7, 6.0) | <.001 |
| Congenital HD; single-Ventricle; LVdom; Stage <2 | 13 / 121 | 3.9 (2.1, 7.0) | 3.2 (1.8, 5.9) | <.001 |
| Congenital HD; single-Ventricle; RVdomb | 1 / 20 | 1.6 (0.23, 12) | 1.1 (0.15, 8.3) | .91 |
| aAdjusted for donor to recipient height ratio, recipient dialysis since listing, recipient ECMO at transplant, recipient most recent total bilirubin at transplant, recipient primary diagnosis, recipient ventilator at transplant, and recipient primary diagnosis | | | | |
| bDue to smaller sample size, stage was not analyzed in this group | | | | |

**Table 6**: Hazard ratios (95% confidence interval) for mortality or graft loss within 1 year of transplant among patients with cardiomyopathy versus congenital heart disease.

| **Diagnostic group** | **N events / N at risk** | **Hazard ratio (95% CI)** | | **P-value** |
| --- | --- | --- | --- | --- |
| **Unadjusted** | **Adjusted1** |
| *Model 1* | | | | |
| Congenital HD | 232 / 2,030 | 1 (ref) | 1 (ref) | -- |
| Cardiomyopathy | 59 / 2,048 | 0.24 (0.18, 0.32) | 0.26 (0.19, 0.35) | <.001 |
| *Model 2* | | | | |
| Congenital HD | 232 / 2,030 | 1 (ref) | 1 (ref) | -- |
| Cardiomyopathy; RCM | 12 / 397 | 0.26 (0.14, 0.46) | 0.28 (0.16, 0.51) | <.001 |
| Cardiomyopathy; DCM | 42 / 1,540 | 0.23 (0.16, 0.32) | 0.24 (0.18, 0.34) | <.001 |
| Cardiomyopathy; OtherCM | 5 / 111 | 0.38 (0.16, 0.92) | 0.40 (0.16, 0.96) | .04 |
| 1Adjusted for donor to recipient height ratio, recipient dialysis since listing, recipient ECMO at transplant, recipient most recent total bilirubin at transplant, recipient primary diagnosis, recipient ventilator at transplant, and recipient primary diagnosis | | | | |

**Table 7**: Area underneath the receiver operator characteristic curve when using variables in the existing UNOS risk model versus additional diagnostic variables.

| **Patient group** | **UNOS variables** | **UNOS + CHD variables** | **Difference** |
| --- | --- | --- | --- |
| Predicting death 1 years after listing | | | |
| Overall | 80.2 (76.7, 83.7) | 80.0 (76.3, 83.8) | -0.18 (-1.4, 0.73) |
| Cardiomyopathy | 73.0 (66.3, 79.4) | 71.2 (64.3, 78.3) | -1.8 (-4.9, 0.37) |
| Congenital HD; single ventricle | 83.6 (78.9, 88.3) | 83.6 (79.1, 88.4) | 0.00 (-1.1, 0.75) |
| Congenital HD; bi-ventricle | 81.6 (73.2, 89.0) | 81.5 (73.2, 89.2) | -0.16 (-2.3, 1.4) |
| Predicting death or graft loss 1 year after transplant | | | |
| Overall | 70.4 (65.9, 74.9) | 70.7 (66.2, 75.4) | 0.33 (-2.4, 2.7) |
| Cardiomyopathy | 56.7 (45.9, 66.3) | 54.9 (44.2, 64.5) | -1.8 (-9.1, 4.2) |
| Congenital HD; single ventricle | 58.1 (49.5, 65.9) | 59.5 (51.3, 66.6) | 1.4 (-6.0, 7.7) |
| Congenital HD; bi-ventricle | 60.7 (49.9, 70.2) | 62.3 (53.2, 70.6) | 1.6 (-4.1, 4.8) |

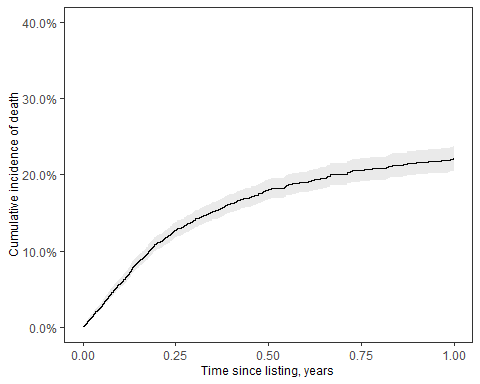
**Table 8**: P-value for poor calibration when using variables in the existing UNOS risk model versus additional diagnostic variables.

| **Patient group** | **UNOS variables** | **UNOS + CHD variables** | **Difference** |
| --- | --- | --- | --- |
| Predicting death 1 years after listing | | | |
| Overall | 29.1 (0.10, 88.8) | 27.4 (0.04, 86.3) | -1.7 (-52.7, 44.8) |
| Cardiomyopathy | 11.8 (0.00, 67.0) | 21.8 (0.00, 85.1) | 10.0 (-28.3, 63.8) |
| Congenital HD; single ventricle | 34.1 (0.05, 92.1) | 34.5 (0.12, 93.3) | 0.44 (-47.4, 50.0) |
| Congenital HD; bi-ventricle | 21.9 (0.06, 79.8) | 17.0 (0.00, 78.9) | -4.9 (-56.5, 41.7) |
| Predicting death or graft loss 1 year after transplant | | | |
| Overall | 32.8 (0.10, 91.4) | 26.9 (0.04, 85.6) | -5.8 (-67.7, 56.9) |
| Cardiomyopathy | 54.0 (6.0, 96.3) | 45.0 (0.75, 94.2) | -9.0 (-65.2, 37.3) |
| Congenital HD; single ventricle | 34.6 (0.12, 93.4) | 26.4 (0.00, 85.9) | -8.2 (-79.6, 54.5) |
| Congenital HD; bi-ventricle | 47.2 (6.0, 95.0) | 43.6 (3.2, 93.0) | -3.5 (-62.0, 54.5) |

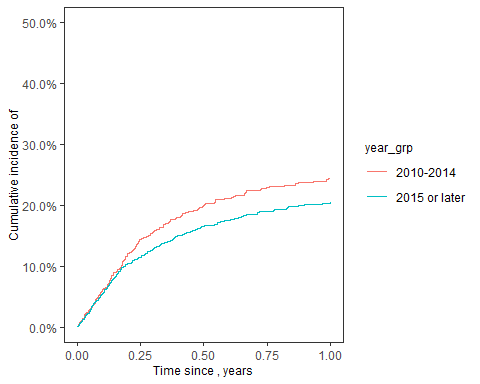
**Table 9**: Index of prediction accuracy when using variables in the existing UNOS risk model versus additional diagnostic variables.

| **Patient group** | **UNOS variables** | **UNOS + CHD variables** | **Difference** |
| --- | --- | --- | --- |
| Predicting death 1 years after listing | | | |
| Overall | 20.4 (14.4, 25.9) | 21.0 (14.7, 26.4) | 0.63 (-0.97, 2.0) |
| Cardiomyopathy | 7.7 (-3.8, 16.8) | 8.1 (-2.0, 15.4) | 0.45 (-2.9, 3.5) |
| Congenital HD; single ventricle | 25.2 (17.1, 32.8) | 26.0 (17.0, 34.4) | 0.81 (-1.3, 2.6) |
| Congenital HD; bi-ventricle | 22.6 (10.8, 33.6) | 23.6 (9.7, 35.6) | 0.94 (-3.8, 4.3) |
| Predicting death or graft loss 1 year after transplant | | | |
| Overall | 4.0 (-0.08, 7.1) | 3.9 (-0.54, 7.1) | -0.14 (-2.0, 1.2) |
| Cardiomyopathy | 0.34 (-1.3, 2.7) | -0.13 (-3.1, 2.3) | -0.48 (-2.1, 0.43) |
| Congenital HD; single ventricle | -0.20 (-6.3, 3.8) | 0.18 (-6.1, 3.5) | 0.38 (-2.4, 2.5) |
| Congenital HD; bi-ventricle | 4.1 (-4.1, 10.1) | 2.6 (-7.7, 10.1) | -1.5 (-6.2, 1.3) |

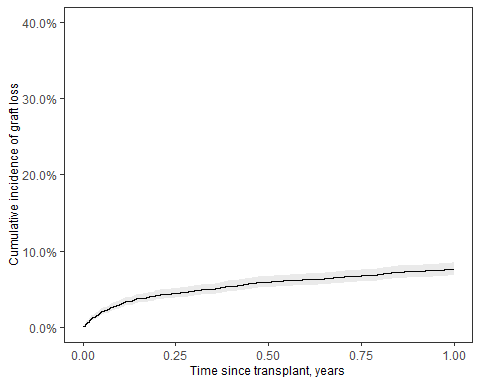
**Figure 1**: Cumulative incidence of mortality within 1 year of listing



**Figure 2**: Cumulative incidence of mortality within 1 year of listing, stratified by listing year.



**Figure 3**: Cumulative incidence of mortality or graft loss within 1 year of transplant



**Figure 4**: Cumulative incidence of mortality within 1 year of listing, stratified by listing year.

