Follow-Up Data and Machine Learning [Improve Mortality Predictions for Patients with Mechanical Circulatory Support](https://www.ahajournals.org/doi/pdf/10.1161/CIRCGEN.119.002877)

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**MAIN RESULTS**

Table 1: Patient characteristics selected for inclusion in the 1-month mortality risk prediction model.

|  | | | **Hazard ratio (95% CI)** | |
| --- | --- | --- | --- | --- |
| **label** | **Number (%) missing values** | **Mean (SD) or Number (%)** | **Unadjusted** | **Adjusted** |
| *Pre-implant variables* | | | | |
| Age, years | 0 (0.00%) | 57.0 (12.9) | 1.35 (1.30, 1.41) | 1.21 (1.16, 1.26) |
| *Week 1 variables* | | | | |
| BUN, mg/dL | 121 (0.96%) | 30.2 (20.8) | 1.40 (1.35, 1.45) | 1.05 (1.01, 1.10) |
| Platelet count | 94 (0.74%) | 219 (99.9) | 0.70 (0.67, 0.72) | 0.94 (0.89, 0.98) |
| *Month 1 variables* | | | | |
| BUN, mg/dL | 319 (2.5%) | 22.9 (16.9) | 1.53 (1.48, 1.58) | 1.18 (1.13, 1.23) |
| Platelet count | 337 (2.7%) | 296 (108) | 0.66 (0.63, 0.68) | 0.88 (0.84, 0.92) |
| Total bilirubin, mg/dL | 2,668 (21%) | 1.19 (2.69) | 1.32 (1.30, 1.35) | 1.16 (1.13, 1.18) |
| Intubated | 180 (1.4%) | 1119 (8.97%) | 3.76 (3.43, 4.13) | 1.39 (1.22, 1.58) |
| Right heart failure, INO | 139 (1.1%) | 2102 (16.8%) | 2.49 (2.30, 2.71) | 1.25 (1.13, 1.38) |
| Followup status: outpatient | 103 (0.81%) | 7229 (57.6%) | 0.44 (0.41, 0.48) | 0.81 (0.74, 0.89) |
| White blood cell count | 334 (2.6%) | 9.24 (4.16) | 1.21 (1.19, 1.23) | 1.10 (1.08, 1.13) |
| SGOT | 2,703 (21%) | 41.0 (149) | 1.09 (1.08, 1.10) | 1.02 (1.00, 1.05) |
| LDH | 2,719 (21%) | 399 (305) | 1.11 (1.09, 1.14) | 1.05 (1.02, 1.08) |
| NYHA 4: unable to carry on minimal physical activity | 3,674 (29%) | 1492 (16.6%) | 2.37 (2.19, 2.56) | 1.18 (1.07, 1.30) |
| Albumin, g/dL | 3,010 (24%) | 3.21 (0.63) | 0.74 (0.71, 0.76) | 0.96 (0.93, 1.00) |
| On dialysis | 201 (1.6%) | 771 (6.19%) | 3.73 (3.36, 4.14) | 1.07 (0.93, 1.22) |
| Respiratory adverse event count | 0 (0.00%) | 0.14 (0.41) | 2.02 (1.91, 2.13) | 1.10 (1.00, 1.20) |
| Sodium, meq/L | 283 (2.2%) | 137 (3.97) | 1.01 (0.97, 1.05) | 0.99 (0.95, 1.02) |
| Days w/out respiratory adverse event | 0 (0.00%) | 0.96 (0.17) | 0.78 (0.76, 0.81) | 0.98 (0.94, 1.01) |
| Warfarin | 63 (0.50%) | 11444 (90.9%) | 0.38 (0.35, 0.42) | 0.82 (0.74, 0.91) |
| Pre-albumin, mg/dL | 9,251 (73%) | 17.9 (6.70) | 0.81 (0.78, 0.85) | 0.92 (0.88, 0.95) |

Table 2: Incidence rates and ratios for patients classified as high or low risk at pre-implant and one month following implant of mechanical circulatory support device.

|  | **1-year Mortality risk classification** | | | | |
| --- | --- | --- | --- | --- | --- |
|  | **Overall** | **Low risk at both visits** | **High risk at pre-implant only** | **High risk at month 1 only** | **High risk at both visits** |
| *Overall* | | | | | |
| Number (%) of patients | 12,655 (100%) | 9,109 (72%) | 1,233 (9.7%) | 1,251 (9.9%) | 1,062 (8.4%) |
| Number of events | 3,157 | 1,614 | 388 | 586 | 569 |
| Months of follow up | 241,282 | 180,597 | 26,928 | 17,871 | 15,886 |
| Incidence rate (95% CI) | 13 (13, 14) | 8.9 (8.5, 9.4) | 14 (13, 16) | 33 (30, 36) | 36 (33, 39) |
| Incidence ratio (95% CI) | --- | 1 (ref) | 1.6 (1.4, 1.8) | 3.6 (3.3, 4.0) | 4.0 (3.6, 4.4) |
| *Patient profile 1: Critical cardiogenic shock* | | | | | |
| Number (%) of patients | 1,851 (100%) | 1,091 (59%) | 234 (13%) | 219 (12%) | 307 (17%) |
| Number of events | 481 | 181 | 51 | 100 | 149 |
| Months of follow up | 30,097 | 19,355 | 4,040 | 2,941 | 3,761 |
| Incidence rate (95% CI) | 16 (15, 17) | 9.4 (8.1, 11) | 13 (9.5, 16) | 34 (28, 41) | 40 (34, 46) |
| Incidence ratio (95% CI) | --- | 1 (ref) | 1.4 (0.99, 1.8) | 3.5 (2.8, 4.5) | 4.1 (3.3, 5.1) |
| *Patient profile 2: Progressive decline* | | | | | |
| Number (%) of patients | 4,360 (100%) | 3,066 (70%) | 446 (10%) | 462 (11%) | 386 (8.9%) |
| Number of events | 1,097 | 527 | 146 | 213 | 211 |
| Months of follow up | 81,088 | 58,922 | 9,830 | 6,335 | 6,001 |
| Incidence rate (95% CI) | 14 (13, 14) | 8.9 (8.2, 9.7) | 15 (13, 17) | 34 (29, 38) | 35 (31, 40) |
| Incidence ratio (95% CI) | --- | 1 (ref) | 1.7 (1.4, 2.0) | 3.7 (3.2, 4.4) | 3.9 (3.3, 4.6) |
| *Patient profile 3: Stable but inotrope dependent* | | | | | |
| Number (%) of patients | 4,484 (100%) | 3,434 (77%) | 382 (8.5%) | 414 (9.2%) | 254 (5.7%) |
| Number of events | 1,063 | 611 | 124 | 197 | 131 |
| Months of follow up | 87,594 | 68,523 | 8,637 | 6,132 | 4,302 |
| Incidence rate (95% CI) | 12 (11, 13) | 8.9 (8.2, 9.6) | 14 (12, 17) | 32 (28, 37) | 30 (26, 36) |
| Incidence ratio (95% CI) | --- | 1 (ref) | 1.6 (1.3, 1.9) | 3.6 (3.1, 4.3) | 3.4 (2.8, 4.1) |
| *Patient profile 4 or higher* | | | | | |
| Number (%) of patients | 1,956 (100%) | 1,515 (77%) | 171 (8.7%) | 155 (7.9%) | 115 (5.9%) |
| Number of events | 513 | 293 | 67 | 75 | 78 |
| Months of follow up | 42,463 | 33,758 | 4,420 | 2,462 | 1,823 |
| Incidence rate (95% CI) | 12 (11, 13) | 8.7 (7.7, 9.7) | 15 (12, 19) | 30 (24, 38) | 43 (34, 53) |
| Incidence ratio (95% CI) | --- | 1 (ref) | 1.8 (1.3, 2.3) | 3.5 (2.7, 4.5) | 4.9 (3.8, 6.3) |

Figure 1: Benchmark comparison of modeling algorithms.



Figure 2: Incidence of death by risk group at month-1.



**SUPPLEMENT**

Table S1: Patient characteristics selected for inclusion in the pre-implant mortality risk prediction model.

|  | | | **Hazard ratio (95% CI)** | |
| --- | --- | --- | --- | --- |
| **label** | **Number (%) missing values** | **Mean (SD) or Number (%)** | **Unadjusted** | **Adjusted** |
| *Pre-implant variables* | | | | |
| Age, years | 0 (0.00%) | 57.0 (12.9) | 1.35 (1.30, 1.41) | 1.24 (1.18, 1.30) |
| Left-ventricular end diastolic dimension | 2,668 (21%) | 6.84 (1.10) | 0.87 (0.84, 0.90) | 0.90 (0.87, 0.94) |
| BUN, mg/dL | 41 (0.32%) | 28.9 (17.7) | 1.24 (1.19, 1.28) | 1.11 (1.06, 1.15) |
| Platelet count | 46 (0.36%) | 198 (79.1) | 0.90 (0.87, 0.94) | 0.97 (0.93, 1.01) |
| Total bilirubin, mg/dL | 708 (5.6%) | 1.33 (1.68) | 1.06 (1.03, 1.09) | 1.03 (1.01, 1.06) |
| Albumin, g/dL | 847 (6.7%) | 3.42 (0.64) | 0.90 (0.87, 0.93) | 0.95 (0.92, 0.99) |
| Hemoglobin, g/dL | 44 (0.35%) | 11.3 (2.13) | 0.86 (0.83, 0.89) | 0.92 (0.88, 0.95) |
| Device type: LVAD | 0 (0.00%) | 12283 (97.1%) | 0.50 (0.42, 0.60) | 0.60 (0.47, 0.77) |
| No previous cardiac operation | 0 (0.00%) | 0.69 (0.46) | 0.84 (0.81, 0.86) | 0.95 (0.91, 1.00) |
| Previous operation: CABG | 0 (0.00%) | 2474 (19.5%) | 1.54 (1.42, 1.66) | 1.12 (0.99, 1.26) |
| Destination therapy | 0 (0.00%) | 5908 (46.7%) | 1.43 (1.33, 1.53) | 1.14 (1.06, 1.23) |
| Concomitant RVAD implant | 1 (0.01%) | 209 (1.65%) | 2.36 (1.89, 2.94) | 1.39 (1.03, 1.88) |
| Surgery time | 5,195 (41%) | 289 (109) | 1.10 (1.07, 1.14) | 1.03 (0.99, 1.07) |
| ECG Rhythm: sinus | 283 (2.2%) | 5878 (47.5%) | 0.73 (0.68, 0.79) | 0.85 (0.78, 0.91) |
| CV pressure | 6,199 (49%) | 10.7 (6.13) | 1.09 (1.06, 1.13) | 1.07 (1.03, 1.11) |
| Lymph count, percent | 5,100 (40%) | 18.1 (9.83) | 0.86 (0.82, 0.89) | 0.95 (0.91, 0.99) |
| KCCQ12 | 5,896 (47%) | 34.5 (21.5) | 0.92 (0.88, 0.95) | 0.95 (0.91, 0.99) |
| Creatinine, mg/dL | 11 (0.09%) | 1.39 (0.68) | 1.11 (1.08, 1.14) | 1.03 (0.99, 1.07) |
| Body mass index | 65 (0.51%) | 28.6 (7.21) | 1.01 (0.98, 1.05) | 1.07 (1.04, 1.11) |
|  |  |  |  |  |
|  |  |  |  | 0.97 (0.93, 1.01) |

Table S2: Patient characteristics selected for inclusion in the 1-week mortality risk prediction model.

|  | | | **Hazard ratio (95% CI)** | |
| --- | --- | --- | --- | --- |
| **label** | **Number (%) missing values** | **Mean (SD) or Number (%)** | **Unadjusted** | **Adjusted** |
| *Pre-implant variables* | | | | |
| Age, years | 0 (0.00%) | 57.0 (12.9) | 1.35 (1.30, 1.41) | 1.19 (1.14, 1.25) |
| Left-ventricular end diastolic dimension | 2,668 (21%) | 6.84 (1.10) | 0.87 (0.84, 0.90) | 0.91 (0.88, 0.95) |
| Sodium, meq/L | 9 (0.07%) | 135 (4.75) | 0.96 (0.93, 0.99) | 0.94 (0.91, 0.97) |
| Hemoglobin, g/dL | 44 (0.35%) | 11.3 (2.13) | 0.86 (0.83, 0.89) | 0.94 (0.90, 0.97) |
| SGPT ALT | 684 (5.4%) | 61.8 (192) | 1.02 (0.98, 1.05) | 1.00 (0.97, 1.03) |
| Previous operation: CABG | 0 (0.00%) | 2474 (19.5%) | 1.54 (1.42, 1.66) | 1.19 (1.10, 1.29) |
| Destination therapy | 0 (0.00%) | 5908 (46.7%) | 1.43 (1.33, 1.53) | 1.16 (1.07, 1.25) |
| *Week 1 variables* | | | | |
| BUN, mg/dL | 121 (0.96%) | 30.2 (20.8) | 1.40 (1.35, 1.45) | 1.20 (1.14, 1.26) |
| Platelet count | 94 (0.74%) | 219 (99.9) | 0.70 (0.67, 0.72) | 0.87 (0.83, 0.91) |
| Systolic blood pressure, mm Hg | 4,757 (38%) | 95.0 (14.8) | 0.90 (0.87, 0.93) | 0.96 (0.92, 1.00) |
| Total bilirubin, mg/dL | 2,458 (19%) | 2.13 (3.23) | 1.17 (1.14, 1.20) | 1.06 (1.04, 1.10) |
| Intubated | 274 (2.2%) | 3119 (25.2%) | 1.62 (1.50, 1.75) | 1.08 (0.99, 1.19) |
| On dialysis | 275 (2.2%) | 748 (6.04%) | 2.51 (2.23, 2.82) | 1.56 (1.37, 1.78) |
| Sodium, meq/L | 94 (0.74%) | 136 (5.62) | 1.21 (1.17, 1.25) | 1.04 (1.00, 1.08) |
| Warfarin | 63 (0.50%) | 9753 (77.5%) | 0.59 (0.55, 0.64) | 0.77 (0.71, 0.83) |
| Number of respiratory events between week 1 and month 1 visit | 0 (0.00%) | 0.07 (0.27) | 2.02 (1.82, 2.24) | 1.30 (1.15, 1.46) |
| Total bilirubin peak | 5,785 (46%) | 3.44 (13.5) | 1.05 (1.03, 1.07) | 1.02 (0.99, 1.05) |
| CV pressure | 7,805 (62%) | 12.0 (5.17) | 1.09 (1.05, 1.13) | 1.08 (1.04, 1.11) |
| Creatinine, mg/dL | 30 (0.24%) | 1.23 (0.76) | 1.17 (1.15, 1.20) | 1.00 (0.95, 1.04) |
| Diastolic blood pressure, mm Hg | 5,100 (40%) | 71.9 (11.2) | 0.93 (0.90, 0.96) | 0.96 (0.92, 1.00) |

Table S3: Incidence rates and ratios for patients classified as high or low risk at pre-implant and one week following implant of mechanical circulatory support device.

|  | **1-year Mortality risk classification** | | | | |
| --- | --- | --- | --- | --- | --- |
|  | **Overall** | **Low risk at both visits** | **High risk at pre-implant only** | **High risk at month 1 only** | **High risk at both visits** |
| *Overall* | | | | | |
| Number (%) of patients | 12,655 (100%) | 9,144 (72%) | 934 (7.4%) | 1,216 (9.6%) | 1,361 (11%) |
| Number of events | 3,157 | 1,698 | 301 | 502 | 656 |
| Months of follow up | 241,282 | 177,850 | 19,546 | 20,618 | 23,268 |
| Incidence rate (95% CI) | 13 (13, 14) | 9.5 (9.1, 10) | 15 (14, 17) | 24 (22, 27) | 28 (26, 30) |
| Incidence ratio (95% CI) | --- | 1 (ref) | 1.6 (1.4, 1.8) | 2.5 (2.3, 2.8) | 3.0 (2.7, 3.2) |
| *Patient profile 1: Critical cardiogenic shock* | | | | | |
| Number (%) of patients | 1,851 (100%) | 1,076 (58%) | 196 (11%) | 234 (13%) | 345 (19%) |
| Number of events | 481 | 182 | 50 | 99 | 150 |
| Months of follow up | 30,097 | 18,655 | 3,121 | 3,641 | 4,680 |
| Incidence rate (95% CI) | 16 (15, 17) | 9.8 (8.4, 11) | 16 (12, 21) | 27 (22, 33) | 32 (27, 37) |
| Incidence ratio (95% CI) | --- | 1 (ref) | 1.6 (1.2, 2.2) | 2.8 (2.2, 3.6) | 3.2 (2.6, 4.0) |
| *Patient profile 2: Progressive decline* | | | | | |
| Number (%) of patients | 4,360 (100%) | 3,085 (71%) | 332 (7.6%) | 443 (10%) | 500 (11%) |
| Number of events | 1,097 | 561 | 118 | 179 | 239 |
| Months of follow up | 81,088 | 57,760 | 6,962 | 7,497 | 8,869 |
| Incidence rate (95% CI) | 14 (13, 14) | 9.7 (8.9, 11) | 17 (14, 20) | 24 (21, 28) | 27 (24, 31) |
| Incidence ratio (95% CI) | --- | 1 (ref) | 1.8 (1.4, 2.1) | 2.5 (2.1, 2.9) | 2.8 (2.4, 3.2) |
| *Patient profile 3: Stable but inotrope dependent* | | | | | |
| Number (%) of patients | 4,484 (100%) | 3,480 (78%) | 279 (6.2%) | 368 (8.2%) | 357 (8.0%) |
| Number of events | 1,063 | 656 | 86 | 152 | 169 |
| Months of follow up | 87,594 | 68,432 | 6,297 | 6,222 | 6,643 |
| Incidence rate (95% CI) | 12 (11, 13) | 9.6 (8.9, 10) | 14 (11, 17) | 24 (21, 29) | 25 (22, 29) |
| Incidence ratio (95% CI) | --- | 1 (ref) | 1.4 (1.1, 1.8) | 2.6 (2.1, 3.1) | 2.7 (2.2, 3.1) |
| *Patient profile 4 or higher* | | | | | |
| Number (%) of patients | 1,956 (100%) | 1,499 (77%) | 127 (6.5%) | 171 (8.7%) | 159 (8.1%) |
| Number of events | 513 | 296 | 47 | 72 | 98 |
| Months of follow up | 42,463 | 32,963 | 3,166 | 3,258 | 3,076 |
| Incidence rate (95% CI) | 12 (11, 13) | 9.0 (8.0, 10) | 15 (11, 20) | 22 (17, 28) | 32 (26, 39) |
| Incidence ratio (95% CI) | --- | 1 (ref) | 1.7 (1.2, 2.3) | 2.5 (1.9, 3.2) | 3.6 (2.8, 4.5) |

Figure S1: Benchmark comparison modeling algorithms.



Figure S2: Incidence of death by risk group at week-1.

