

# **SUPPLEMENTAL MATERIAL**

**Table S1. Unplanned interventions and preceding other events.**

| <b>Event</b>   | <b>Preceding event % (n)</b> |
|--|------------------------------|
| Unplanned cardiac surgery due to catheterization complication                | 53% (122/232)                |
| Unplanned other surgery due to catheterization complication                  | 31% (47/153)                 |
| Unplanned vascular surgery due to catheterization complication               | 71% (36%)                    |
| Unplanned repeat cardiac catheterization due to catheterization complication | 35% (89)                     |

**Table S2. Individual proximal adverse events.**

|  |                     |
|--|---------------------|
| <b>Proximal adverse outcomes</b>                   | <b>4.4% (3,416)</b> |
| New arrhythmia requiring cardioversion             | 0.5% (352)          |
| New arrhythmia requiring antiarrhythmic medication | 0.9% (702)          |
| New arrhythmia requiring pacemaker                 | 0.2% (155)          |
| New heart valve regurgitation                      | 0.06% (49)          |
| Cardiac tamponade                                  | 0.08% (65)          |
| Air embolus  | 0.04% (29)          |
| Embolic stroke                                     | 0.05% (37)          |
| Device malposition/embolization                    | 0.3% (257)          |
| Airway event                                       | 0.5% (357)          |
| Initiation of dialysis                             | 0.02% (18)          |
| Bleeding event                                     | 1.0% (770)          |
| Vascular complications                             | 0.7% (541)          |

**Table S3. Other multivariable models of adverse events.**

|  | Composite AE excluding deaths |         | Proximal adverse events |         |
|--|-------------------------------|---------|-------------------------|---------|
|  | OR (95% CI)                   | p       | OR (95% CI)             | p       |
| <b>Age group</b>                                   |                               |         |                         |         |
| <30 days   | 2.36 (2.02 to 2.74)           | <0.0001 | 2.53 (2.19 to 2.94)     | <0.0001 |
| 30 days to 1 year                                  | 1.44 (1.28 to 1.61)           | <0.0001 | 1.50 (1.35 to 1.68)     | <0.0001 |
| 1 year to 8 years                                  | 1 (n/a)                       | n/a     | 1 (n/a)                 | n/a     |
| 8 years to 18 years                                | 1.01 (0.9 to 1.13)            | 0.87    | 1.01 (0.9 to 1.13)      | 0.87    |
| ≥18 years  | 0.92 (0.76 to 1.11)           | 0.40    | 0.92 (0.76 to 1.11)     | 0.37    |
| <b>Male sex</b>                                    | 1.07 (0.99 to 1.15)           | 0.08    | 1.07 (1.00 to 1.15)     | 0.06    |
| <b>Race</b>  |                               |         |                         |         |
| White  | 1 (n/a)                       | n/a     | 1 (n/a)                 | n/a     |
| Black  | 0.99 (0.89 to 1.10)           | 0.80    | 1.02 (0.92 to 1.13)     | 0.76    |
| Other  | 0.96 (0.85 to 1.08)           | 0.47    | 0.97 (0.86 to 1.09)     | 0.60    |
| <b>Surgery (previous 30 days)</b>                  | 10.45 (9.04 to 12.07)         | <0.0001 | 11.32 (9.81 to 13.06)   | <0.0001 |
| <b>Catheterization (previous 30 days)</b>          | 0.68 (0.55 to 0.84)           | 0.0003  | 0.63 (0.51 to 0.78)     | <0.0001 |
| <b>Preprocedure medications</b>                    |                               |         |                         |         |
| Inotrope   | 1.87 (1.67 to 2.09)           | <0.0001 | 2.13 (1.92 to 2.37)     | <0.0001 |
| Vasodilators                                       | 0.95 (0.84 to 1.08)           | 0.45    | 0.96 (0.85 to 1.08)     | 0.51    |
| <b>Preprocedure conditions</b>                     |                               |         |                         |         |
| Sepsis   | 0.88 (0.55 to 1.41)           | 0.59    | 1.06 (0.69 to 1.62)     | 0.79    |
| Chronic lung disease                               | 0.96 (0.83 to 1.11)           | 0.58    | 1.00 (0.87 to 1.15)     | 0.97    |
| Genetic syndrome                                   | 1.21 (1.09 to 1.34)           | 0.0005  | 1.23 (1.11 to 1.36)     | <0.0001 |
| Renal insufficiency                                | 1.11 (0.88 to 1.40)           | 0.39    | 1.27 (1.02 to 1.57)     | 0.03    |
| <b>Systemic arterial saturation</b>                |                               |         |                         |         |
| Low vs. normal                                     | 1.12 (1.02 to 1.22)           | 0.02    | 1.15 (1.05 to 1.25)     | 0.003   |
| Low vs. missing                                    | 0.95 (0.81 to 1.12)           | 0.55    | 0.96 (0.82 to 1.12)     | 0.60    |
| <b>Mixed venous saturation</b>                     |                               |         |                         |         |
| Low vs. normal                                     | 1.47 (1.32 to 1.6)            | <0.0001 | 1.47 (1.33 to 1.63)     | <0.0001 |
| Low vs. missing                                    | 1.14 (0.99 to 1.320)          | 0.07    | 1.17 (1.33 to 1.63)     | <0.0001 |
| <b>Pulmonary artery pressure</b>                   |                               |         |                         |         |
| High vs. normal                                    | 1.23 (1.11 to 1.37)           | <0.0001 | 1.34 (1.22 to 1.49)     | <0.0001 |
| High vs. missing                                   | 1.4 (1.18 to 1.66)            | <0.0001 | 1.31 (1.18 to 1.46)     | <0.0001 |
| <b>Systemic ventricular end-diastolic pressure</b> |                               |         |                         |         |
| High vs. normal                                    | 1.40 (1.18 to 1.66)           | 0.0001  | 1.36 (1.15 to 1.60)     | 0.0004  |
| High vs. missing                                   | 0.98 (0.89 to 1.07)           | 0.59    | 1.02 (0.93 to 1.11)     | 0.68    |
| <b>Procedure group</b>                             |                               |         |                         |         |
| 1  | 1 (n/a)                       | n/a     | 1 (n/a)                 | n/a     |
| 2  | 1.65 (1.46 to 1.86)           | <0.0001 | 1.61 (1.42 to 1.81)     | <0.0001 |
| 3  | 1.85 (1.63 to 2.1)            | <0.0001 | 1.81 (1.59 to 2.05)     | <0.0001 |
| 4  | 2.26 (1.95 to 2.62)           | <0.0001 | 2.18 (1.88 to 2.52)     | <0.0001 |
| <b>Trainee Present</b>                             | 1.07 (0.95 to 1.20)           | 0.26    | 1.05 (1.12 to 1.48)     | 0.40    |
| <b>General anesthesia vs. IV sedation</b>          | 1.22 (1.05 to 1.40)           | 0.008   | 1.29 (1.12 to 1.48)     | 0.0005  |
| <b>Hospital characteristics</b>                    |                               |         |                         |         |
| Adult cases >35% of total                          | 1.32 (0.78 to 2.22)           | 0.30    | 1.17 (0.68 to 2.02)     | 0.57    |
| University hospital                                | 1.24 (0.98 to 1.56)           | 0.07    | 1.23 (0.97 to 1.57)     | 0.08    |
| Annual catheterization volume (per 300 cases)      | 0.95 (0.82 to 1.10)           | 0.48    | 0.95 (0.81 to 1.10)     | 0.48    |

**Table S4. Failure to rescue model restricted to first catheterization per individual (n=53,056).**

|  | Failure to rescue   |         |
|--|---------------------|---------|
|  | OR (95% CI)         | p       |
| <b>Age group</b>                                   |                     |         |
| <30 days   | 0.75 (0.51 to 1.10) | 0.14    |
| 30 days to 1 year                                  | 1.19 (0.88 to 1.61) | 0.27    |
| 1 year to 8 years                                  | 1 (n/a)             | n/a     |
| 8 years to 18 years                                | 1.25 (0.93 to 1.69) | 0.14    |
| ≥18 years  | 1.27 (0.79 to 2.05) | 0.33    |
| <b>Male sex</b>                                    | 0.89 (0.73 to 1.07) | 0.22    |
| <b>Race</b>  |                     |         |
| White  | 1 (n/a)             | n/a     |
| Black  | 1.04 (0.80 to 1.36) | 0.74    |
| Other  | 1.21 (0.90 to 1.63) | 0.21    |
| <b>Surgery (previous 30 days)</b>                  | 0.17 (0.10 to 0.28) | <0.0001 |
| <b>Catheterization (previous 30 days)</b>          | 1.39 (0.75 to 2.58) | 0.30    |
| <b>Preprocedure medications</b>                    |                     |         |
| Inotrope   | 3.02 (2.38 to 3.83) | <0.0001 |
| Vasodilators                                       | 0.97 (0.72 to 1.30) | 0.82    |
| <b>Preprocedure conditions</b>                     |                     |         |
| Sepsis   | 2.69 (1.13 to 6.39) | 0.02    |
| Chronic lung disease                               | 0.58 (0.39 to 0.85) | 0.005   |
| Genetic syndrome                                   | 0.76 (0.57 to 1.00) | 0.05    |
| Renal insufficiency                                | 2.42 (1.49 to 3.92) | 0.0003  |
| <b>Systemic arterial saturation</b>                |                     |         |
| Low vs. normal                                     | 0.96 (0.77 to 1.20) | 0.71    |
| Low vs. missing                                    | 1.22 (0.87 to 1.71) | 0.21    |
| <b>Mixed venous saturation</b>                     |                     |         |
| Low vs. normal                                     | 1.36 (1.05 to 1.76) | 0.02    |
| Low vs. missing                                    | 1.22 (0.87 to 1.71) | 0.25    |
| <b>Pulmonary artery pressure</b>                   |                     |         |
| High vs. normal                                    | 0.95 (0.73 to 1.23) | 1.07    |
| High vs. missing                                   | 1.07 (0.82 to 1.40) | 0.61    |
| <b>Systemic ventricular end-diastolic pressure</b> |                     |         |
| High vs. normal                                    | 0.87 (0.57 to 1.32) | 0.50    |
| High vs. missing                                   | 1.15 (0.92 to 1.44) | 0.21    |
| <b>Procedure group</b>                             |                     |         |
| 1  | 1 (n/a)             | n/a     |
| 2  | 0.68 (0.50 to 0.94) | 0.02    |
| 3  | 0.73 (0.52 to 1.00) | 0.05    |
| 4  | 0.91 (0.62 to 1.32) | 0.62    |
| <b>Trainee Present</b>                             | 0.97 (0.75 to 1.25) | 0.81    |
| <b>General anesthesia vs. IV sedation</b>          | 1.19 (0.82 to 1.75) | 0.36    |
| <b>Hospital characteristics</b>                    |                     |         |
| Adult cases >35% of total                          | 0.17 (0.05 to 0.55) | 0.003   |
| University hospital                                | 1.03 (0.74 to 1.42) | 0.88    |
| Annual catheterization volume (per 300 cases)      | 0.68 (0.56 to 0.83) | 0.0002  |

**Table S5. Multivariable model for failure to rescue with hospital volume as the only hospital characteristic.**

|  | <b>OR (95% CI)</b>  | <b>p</b> |
|--|---------------------|----------|
| <b>Age group</b>                                   |                     |          |
| <30 days   | 0.82 (0.57 to 1.19) | 0.31     |
| 30 days to 1 year                                  | 1.21 (0.90 to 1.62) | 0.21     |
| 1 year to 8 years                                  | 1 (n/a)             | n/a      |
| 8 years to 18 years                                | 1.30 (0.97 to 1.74) | 0.08     |
| ≥18 years  | 1.26 (0.78 to 2.02) | 0.34     |
| <b>Male sex</b>                                    | 0.89 (0.74 to 1.07) | 0.21     |
| <b>Race</b>  |                     |          |
| White  | 1 (n/a)             | n/a      |
| Black  | 1.04 (0.8 to 1.34)  | 0.78     |
| Other  | 1.20 (0.89 to 1.61) | 0.23     |
| <b>Surgery (previous 30 days)</b>                  | 0.16 (0.10 to 0.25) | <0.0001  |
| <b>Catheterization (previous 30 days)</b>          | 1.26 (0.72 to 2.18) | 0.42     |
| <b>Pre-procedure medications</b>                   |                     |          |
| Inotrope   | 3.05 (2.43 to 3.84) | <0.0001  |
| Vasodilators                                       | 0.96 (0.72 to 1.28) | 0.78     |
| <b>Pre-procedure conditions</b>                    |                     |          |
| Sepsis   | 2.22 (0.96 to 5.14) | 0.06     |
| Chronic lung disease                               | 0.63 (0.44 to 0.91) | 0.01     |
| Genetic syndrome                                   | 0.75 (0.57 to 0.98) | 0.04     |
| Renal insufficiency                                | 2.41 (1.54 to 3.78) | 0.0001   |
| <b>Systemic arterial saturation</b>                |                     |          |
| Low vs. normal                                     | 0.95 (0.77 to 1.19) | 0.67     |
| Low vs. missing                                    | 1.16 (0.80 to 1.69) | 0.43     |
| <b>Mixed venous saturation</b>                     |                     |          |
| Low vs. normal                                     | 1.41 (1.10 to 1.80) | 0.007    |
| Low vs. missing                                    | 1.23 (0.89 to 1.70) | 0.21     |
| <b>Pulmonary artery pressure</b>                   |                     |          |
| High vs. normal                                    | 1.00 (0.78 to 1.29) | 0.99     |
| High vs. missing                                   | 1.09 (0.85 to 1.42) | 0.49     |
| <b>Systemic ventricular end-diastolic pressure</b> |                     |          |
| High vs. normal                                    | 0.85 (0.57 to 1.29) | 0.45     |
| High vs. missing                                   | 1.14 (0.92 to 1.42) | 0.23     |
| <b>Procedure group</b>                             |                     |          |
| 1  | 1 (n/a)             | n/a      |
| 2  | 0.70 (0.51 to 0.95) | 0.02     |
| 3  | 0.72 (0.53 to 0.99) | 0.05     |
| 4  | 0.89 (0.62 to 1.28) | 0.53     |
| <b>Trainee Present</b>                             | 0.89 (0.70 to 1.15) | 0.38     |
| <b>General anesthesia vs. IV sedation</b>          | 1.20 (0.83 to 1.73) | 0.34     |
| <b>Hospital characteristics</b>                    |                     |          |
| Annual catheterization volume (per 300 cases)      | 0.73 (0.59 to 0.9)  | 0.003    |

**Table S6. Multivariable model for failure to rescue with “university hospital” as the only hospital characteristic.**

|  | <b>OR (95% CI)</b>  | <b>p</b> |
|--|---------------------|----------|
| <b>Age group</b>                                   |                     |          |
| <30 days   | 0.83 (0.57 to 1.21) | 0.33     |
| 30 days to 1 year                                  | 1.21 (0.90 to 1.63) | 0.20     |
| 1 year to 8 years                                  | 1 (n/a)             | n/a      |
| 8 years to 18 years                                | 1.30 (0.97 to 1.74) | 0.08     |
| ≥18 years  | 1.29 (0.8 to 2.07)  | 0.29     |
| <b>Male sex</b>                                    | 0.89 (0.74 to 1.07) | 0.89     |
| <b>Race</b>  |                     |          |
| White  | 1 (n/a)             | n/a      |
| Black  | 1.04 (0.81 to 1.34) | 0.76     |
| Other  | 1.20 (0.89 to 1.61) | 0.23     |
| <b>Surgery (previous 30 days)</b>                  | 0.16 (0.10 to 0.25) | <0.0001  |
| <b>Catheterization (previous 30 days)</b>          | 1.25 (0.72 to 2.17) | 0.43     |
| <b>Preprocedure medications</b>                    |                     |          |
| Inotrope   | 3.03 (2.41 to 3.80) | <0.0001  |
| Vasodilators                                       | 0.95 (0.72 to 1.27) | 0.74     |
| <b>Preprocedure conditions</b>                     |                     |          |
| Sepsis   | 2.22 (0.95 to 5.15) | 0.06     |
| Chronic lung disease                               | 0.63 (0.44 to 0.91) | 0.01     |
| Genetic syndrome                                   | 0.75 (0.57 to 0.98) | 0.04     |
| Renal insufficiency                                | 2.37 (1.51 to 3.72) | 0.0002   |
| <b>Systemic arterial saturation</b>                |                     |          |
| Low vs. normal                                     | 0.95 (0.76 to 1.18) | 0.64     |
| Low vs. missing                                    | 1.16 (0.80 to 1.69) | 0.44     |
| <b>Mixed venous saturation</b>                     |                     |          |
| Low vs. normal                                     | 1.41 (1.10 to 1.80) | 0.007    |
| Low vs. missing                                    | 1.24 (0.89 to 1.71) | 0.20     |
| <b>Pulmonary artery pressure</b>                   |                     |          |
| High vs. normal                                    | 1.00 (0.78 to 1.29) | 1.00     |
| High vs. missing                                   | 1.09 (0.84 to 1.41) | 0.51     |
| <b>Systemic ventricular end-diastolic pressure</b> |                     |          |
| High vs. normal                                    | 0.85 (0.56 to 1.28) | 0.43     |
| High vs. missing                                   | 1.14 (0.92 to 1.42) | 0.22     |
| <b>Procedure group</b>                             |                     |          |
| 1  | 1 (n/a)             | n/a      |
| 2  | 0.70 (0.51 to 0.95) | 0.02     |
| 3  | 0.72 (0.53 to 0.99) | 0.04     |
| 4  | 0.88 (0.61 to 1.27) | 0.49     |
| <b>Trainee Present</b>                             | 0.83 (0.65 to 1.06) | 0.14     |
| <b>General anesthesia vs. IV sedation</b>          | 1.21 (0.84 to 1.76) | 0.31     |
| <b>Hospital characteristics</b>                    |                     |          |
| University hospital                                | 0.89 (0.61 to 1.30) | 0.55     |

**Table S7. Multivariable model for failure to rescue with large volume adult hospital as the only hospital characteristic.**

|  | OR (95% CI)         | p       |
|--|---------------------|---------|
| <b>Age group</b>                                   |                     |         |
| <30 days   | 0.83 (0.57 to 1.20) | 0.32    |
| 30 days to 1 year                                  | 1.22 (0.91 to 1.64) | 0.19    |
| 1 year to 8 years                                  | 1 (n/a)             | n/a     |
| 8 years to 18 years                                | 1.30 (0.97 to 1.74) | 0.08    |
| ≥18 years  | 1.31 (0.82 to 2.11) | 0.26    |
| <b>Male sex</b>                                    | 0.88 (0.73 to 1.06) | 0.19    |
| <b>Race</b>  |                     |         |
| White  | 1 (n/a)             | n/a     |
| Black  | 1.04 (0.81 to 1.35) | 0.74    |
| Other  | 1.20 (0.89 to 1.61) | 0.23    |
| <b>Surgery (previous 30 days)</b>                  | 0.16 (0.1 to 0.25)  | <0.0001 |
| <b>Catheterization (previous 30 days)</b>          | 1.23 (0.71 to 2.13) | 0.47    |
| <b>Preprocedure medications</b>                    |                     |         |
| Inotrope   | 3.01 (0.24 to 3.79) | <0.0001 |
| Vasodilators                                       | 0.95 (0.72 to 1.26) | 0.73    |
| <b>Preprocedure conditions</b>                     |                     |         |
| Sepsis   | 2.18 (0.94 to 5.06) | 0.07    |
| Chronic lung disease                               | 0.63 (0.44 to 0.91) | 0.01    |
| Genetic syndrome                                   | 0.76 (0.58 to 0.99) | 0.01    |
| Renal insufficiency                                | 2.37 (1.51 to 3.72) | 0.0002  |
| <b>Systemic arterial saturation</b>                |                     |         |
| Low vs. normal                                     | 0.95 (0.76 to 1.18) | 0.64    |
| Low vs. missing                                    | 1.16 (0.80 to 1.69) | 0.44    |
| <b>Mixed venous saturation</b>                     |                     |         |
| Low vs. normal                                     | 1.39 (1.09 to 1.79) | 0.009   |
| Low vs. missing                                    | 1.23 (0.89 to 1.71) | 0.21    |
| <b>Pulmonary artery pressure</b>                   |                     |         |
| High vs. normal                                    | 1.00 (0.78 to 1.29) | 0.99    |
| High vs. missing                                   | 1.10 (0.85 to 1.43) | 0.47    |
| <b>Systemic ventricular end-diastolic pressure</b> |                     |         |
| High vs. normal                                    | 0.85 (0.57 to 1.28) | 0.45    |
| High vs. missing                                   | 1.15 (0.93 to 1.43) | 0.20    |
| <b>Procedure group</b>                             |                     |         |
| 1  | 1 (n/a)             | n/a     |
| 2  | 0.70 (0.51 to 0.96) | 0.03    |
| 3  | 0.72 (0.52 to 0.99) | 0.04    |
| 4  | 0.88 (0.61 to 1.27) | 0.50    |
| <b>Trainee Present</b>                             | 0.84 (0.66 to 1.08) | 0.17    |
| <b>General anesthesia vs. IV sedation</b>          | 1.21 (0.83 to 1.75) | 0.32    |
| <b>Hospital characteristics</b>                    |                     |         |
| Adult cases >35% of total                          | 0.22 (0.06 to 0.78) | 0.02    |