**Supplement**

**Study measures:**

*Demographics* included: age, gender, race, admission type (elective, emergency department, transfer), body mass index (BMI), prior intensive care unit (ICU) admission, rapid response team (RRT) alert prior to the Early Warning and Response System for Sepsis (EWRS) notification, admitting service (medicine, surgery, other), and comorbidities as measured by the Charlson index score at admission. *Clinical process measures* included: new orders for antibiotics, fluid boluses (a 500cc bolus or higher), serum lactate, and blood cultures within 3 hours of the alert; new orders for blood gases, labs (basic metabolic panel or complete blood count), naloxone, atrioventricular nodal blockade, loop diuretics, vasopressors (dopamine, norepinephrine, phenylephrine, vasopressin), blood product transfusions (red blood cell, plasma, or platelet transfusion), chest radiography, computed tomography (head, chest and abdomen), and cardiac monitoring (electrocardiogram or telemetry), as well as bronchodilator administration (albuterol, ipratropium, levalbuterol) within 6 hours. *Clinical outcome measures* included: hospital length of stay (LOS), ICU LOS, any ICU transfer, and ICU transfer within 6 and 24 hours and anytime after the alert, time to first ICU transfer after the alert, any RRT, and RRT within 6 hours of the alert, disposition location (home, skilled nursing facility, rehabilitation facility, long term care, other hospital, inpatient hospice, other hospice, death, other location), mortality 30 days post alert, total mortality, mortality of those admitted to the ICU after the alert, a composite of mortality and inpatient hospice, documentation of a diagnosis of sepsis at discharge (ICD9 codes: 790.7, 995.94, 995.92, 995.90, 995.91, 995.93, or 785.52), and a composite of ICU transfer, RRT and mortality for our analyses estimating test characteristics. ICUs included cardiac care units, medical ICUs (MICUs), surgical ICUs (SICUs), Neuro ICUs, Cardio-Thoracic ICUs and Medical-Surgical ICUs. We also examined *utilization measures* in our post period, including: the services on which the EWRS alert triggered, the proportion of providers who were automatically sent a notification, the proportion of nurses viewing the initial alert, the proportion of nurses completing the verification task, the proportion of coordinators completing the follow up documentation, and the responses to the follow-up survey, including the percentage of time all team members gathered at the bedside within 30 minutes, and whether there was any change in patient management.

**Tables:**

**Table 1. Number and proportion of patients meeting early warning and response system criteria in our derivation cohort**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | Max Composite Score | | | | | | | All Scores |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Cohort number | n | 499 | 1,796 | 1,481 | 619 | 166 | 13 | 1 | 4,575 |
| ICU transfer during hospital encounter | n (%) | 36  (7%) | 65  (4%) | 63  (4%) | 42  (7%) | 32  (19%) | 5  (38%) | 0  (0%) | 243 |
| RRT during hospital encounter | n (%) | 6  (1%) | 16  (1%) | 27  (2%) | 20  (3%) | 14  (8%) | 4  (31%) | 1  (100%) | 88 |
| Death during hospital encounter | n (%) | 3  (1%) | 5  (0%) | 10  (1%) | 19  (3%) | 12  (7%) | 2  (15%) | 1  (100%) | 52 |
| ICU, RRT or death | n (%) | 40  (8%) | 74  (4%) | 82  (6%) | 54  (9%) | 37  (22%) | 8  (62%) | 1  (100%) | 296 |
| Sepsis diagnostic code | n (%) | 40  (8%) | 74  (4%) | 82  (6%) | 54  (9%) | 37  (22%) | 8  (62%) | 1  (100%) | 198 |

ICU: intensive care unit, RRT: rapid response team.

**Table 2. Number and proportion of patients in our derivation cohort meeting early warning and response system threshold >=4 and time to clinical events by hospital and healthcare system**



ICU: intensive care unit, RRT: rapid response team, STD: standard deviation.

**Table 3. Early warning and response system utilization measures for the healthcare system**

|  | | Hospitals A-C |
| --- | --- | --- |
| N alerts |  | 545 |
| Provider name available |  | 525/545 (96.3%) |
| Notification sent to provider |  | 413/545 (75.8%) |
| Nurse viewed alert |  | 396/545 (72.7%) |
| Nursing task: Vital signs verified |  | 522/523 (99.8%) |
| Nursing task: Adverse trends detected |  | 275/523 (52.6%) |
| Team at bedside in 30 min |  | 481/523 (92.0%) |
| Pt condition suspicious for: | Sepsis | 194/523 (37.1%) |
|  | Other CI | 98/523 (18.7%) |
|  | No CI | 231/523 (44.2%) |
| If sepsis, was team aware before alert |  | 183/194 (94.3%) |
| If sepsis, was there a change in management |  | 96/194 (49.5%) |
| Any change in management |  | 169/523(32.3%) |

CI: critical illness.

**Table 4. Sepsis Mortality Index in the study population before and after implementation of the early warning and response system by hospital and healthcare system**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |
| Hospital | Study period | N septic patients | Observed mortality | Expected mortality | O-E mortality | p-value |
| Hospital A | Pre | 181 | 26 | 23.4 | 1.11 | 0.16 |
| Post | 183 | 22 | 22.3 | 0.99 |
| Hospital B | Pre | 21 | 4 | 2.4 | 1.69 | 0.76 |
| Post | 34 | 5 | 4.5 | 1.12 |
| Hospital C | Pre | 28 | 8 | 2 | 4.05 | 0.59 |
| Post | 30 | 4 | 2.5 | 1.57 |
| Hospital A-C | Pre | 230 | 38 | 27.7 | 1.37 | 0.18 |
| Post | 247 | 31 | 29.3 | 1.06 |
|  |  |  |  |  |  |  |

O/E: observed to expected mortality ratio.

**Table 5. *Clinical process measures* before and after early warning and response system implementation for the *population discharged with a sepsis diagnosis***

|  | Hospitals A-C | | |
| --- | --- | --- | --- |
|  | Pre | Post | p-value |
| N alerts | 230 | 247 |  |
| >=500cc IV bolus order < 3hrs | 61 (27%) | 92 (37%) | 0.01 |
| IV/PO antibiotic order < 3hrs | 48 (21%) | 85 (34%) | <.01 |
| IV/PO sepsis antibiotic order < 3hrs | 42 (18%) | 66 (27%) | 0.03 |
| Lactic acid order < 3hrs | 43 (19%) | 88 (36%) | <.01 |
| Blood culture order < 3hrs | 44 (19%) | 60 (24%) | 0.17 |
| Blood gas order < 6hrs | 32 (14%) | 36 (15%) | 0.84 |
| CBC or BMP < 6hrs | 107 (47%) | 115 (47%) | 0.99 |
| Vasopressor < 6hrs | 10 (4%) | 14 (6%) | 0.51 |
| Bronchodilator administration < 6hrs | 25 (11%) | 30 (12%) | 0.66 |
| RBC, plasma or platelet transfusion order < 6hrs | 19 (8%) | 32 (13%) | 0.10 |
| Naloxone order < 6hrs | 0 (0%) | 1 (0%) | 0.33 |
| AV node blocker order < 6hrs | 12 (5%) | 5 (2%) | 0.06 |
| Loop diuretic order < 6hrs | 7 (3%) | 12 (5%) | 0.31 |
| CXR < 6hrs | 44 (19%) | 63 (26%) | 0.10 |
| CT head, chest or abd < 6 hrs | 21 (9%) | 22 (9%) | 0.93 |
| Cardiac monitoring (EKG or telemetry) < 6hrs | 31 (13%) | 42 (17%) | 0.29 |

AV: atrioventricular, ABD: abdomen, BMP: basic metabolic panel, CBC: complete blood count, CXR: chest radiograph, CT: computed tomography, EKG: electrocardiogram, HRS: hours, IV: intravenous, PO: oral, RBC: red blood cell.

**Table 6. *Clinical outcome measures* before and after early warning and response system implementation by healthcare system for the *population discharged with a sepsis diagnosis***

|  | | Hospitals A-C | | |
| --- | --- | --- | --- | --- |
|  | | Pre | Post | p-value |
| N alerts |  | 230 | 247 |  |
| Hospital LOS (days) | Median (IQR) | 14.9 (6.3 - 27.8) | 15.6 (7.1 - 28.7) | 0.91 |
| ICU LOS (days) after alert | Median (IQR) | 4.3 (2.3 - 8.3) | 4.0 (1.9 - 7.2) | 0.45 |
| ICU transfer <6 hrs |  | 22 (10%) | 36 (15%) | 0.09 |
| ICU transfer <24 hrs |  | 40 (17%) | 54 (22%) | 0.22 |
| ICU transfer any time after alert |  | 81 (35%) | 86 (35%) | 0.93 |
| Time (hrs) to first ICU after alert | Median (IQR) | 28.0 (5.6 - 67.0) | 11.0 (2.5 - 79.1) | 0.14 |
| RRT <=6 hrs after alert |  | 8 (3%) | 7 (3%) | 0.69 |
| Mortality (of all patients) |  | 38 (17%) | 31 (13%) | 0.22 |
| Mortality <= 30 days after alert |  | 34 (15%) | 23 (9%) | 0.07 |
| Mortality (of those transferred to ICU) |  | 34 (42%) | 28 (33%) | 0.21 |
| Deceased or inpatient hospice |  | 61 (27%) | 45 (18%) | 0.03 |
| Discharge to home |  | 110 (48%) | 137 (55%) | 0.10 |
| Disposition location | Home | 110 (48%) | 137 (55%) | 0.07 |
|  | SNF | 33 (14%) | 36 (15%) | . |
|  | Rehab | 11 (5%) | 8 (3%) | . |
|  | LTC | 3 (1%) | 5 (2%) | . |
|  | Other hospital | 6 (3%) | 1 (0%) | . |
|  | Expired | 38 (17%) | 31 (13%) | . |
|  | Hospice IP | 23 (10%) | 14 (6%) | . |
|  | Hospice other | 5 (2%) | 9 (4%) | . |
|  | Other location | 1 (0%) | 6 (2%) | . |

ICU: intensive care unit, IP: inpatient, IQR: interquartile range, HRS: hours, LTC: long term care, LOS: length of stay, O/E: observed to expected, REHAB: rehabilitation, RRT: rapid response team, SNF: skilled nursing facility.

Table 7. *Clinical outcome measures* before and after early warning and response system implementation by healthcare system for the *population that did not trigger the early warning and response system*

|  | | Hospitals A-C | | |
| --- | --- | --- | --- | --- |
|  | | Pre | Post | p-value |
| N encounters |  | 14,963 | 14,966 |  |
| Hospital LOS (days) | Median (IQR) | 3.9 (2.2 - 7.0) | 3.7 (2.1 - 7.0) | 0.02 |
| Hospital LOS (of ICU transfers) | Median (IQR) | 10.2 (6.8 - 16.3) | 10.4 (6.7 - 16.9) | 0.53 |
| ICU LOS (days) | Median (IQR) | 2.3 (1.1 - 4.7) | 2.0 (1.0 - 4.2) | 0.04 |
| ICU transfer |  | 900 (6%) | 883 (6%) | 0.67 |
| RRT during encounter |  | 243 (2%) | 205 (1%) | 0.07 |
| Mortality (of all patients) |  | 222 (1%) | 205 (1%) | 0.41 |
| Mortality (of ICU transfers) |  | 63 (7%) | 54 (6%) | 0.45 |
| Deceased or inpatient hospice |  | 354 (2%) | 317 (2%) | 0.23 |
| Discharge to home |  | 11,838 (79%) | 11,696 (80%) | 0.28 |
| Disposition location | Home | 11,838 (79%) | 11,696 (80%) | 0.29 |
|  | SNF | 1,502 (10%) | 1,443 (10%) | . |
|  | Rehab | 493 (3%) | 422 (3%) | . |
|  | LTC | 82 (1%) | 95 (1%) | . |
|  | Other hospital | 369 (2%) | 388 (3%) | . |
|  | Expired | 222 (1%) | 205 (1%) | . |
|  | Hospice IP | 132 (1%) | 112 (1%) | . |
|  | Hospice other | 90 (1%) | 102 (1%) | . |
|  | Other location | 209 (1%) | 201 (1%) | . |

ICU: intensive care unit, IP: inpatient, IQR: interquartile range, LTC: long term care, LOS: length of stay, O/E: observed to expected, REHAB: rehabilitation, RRT: rapid response team, SNF: skilled nursing facility.

Table 8. *Clinical outcome measures* before and after early warning and response system implementation by healthcare system for the *population discharged with a sepsis diagnosis who did not trigger the early warning and response system*

|  | | Hospitals A-C | | |
| --- | --- | --- | --- | --- |
|  | | Pre | Post | p-value |
| N encounters |  | 830 | 842 |  |
| Hospital LOS (days) | Median (IQR) | 8.5 (4.9 - 15.8) | 7.5 (4.1 - 14.2) | 0.01 |
| Hospital LOS (of ICU transfers) | Median (IQR) | 14.7 (9.1 - 22.3) | 15.0 (8.7 - 26.3) | 0.68 |
| ICU LOS (days) | Median (IQR) | 3.7 (1.8 - 8.1) | 3.4 (1.7 - 7.7) | 0.68 |
| ICU transfer |  | 159 (19%) | 132 (16%) | 0.06 |
| RRT during encounter |  | 61 (7%) | 32 (4%) | <.01 |
| Mortality (of all patients) |  | 101 (12%) | 93 (11%) | 0.47 |
| Mortality (of ICU transfers) |  | 33 (21%) | 30 (23%) | 0.68 |
| Deceased or inpatient hospice |  | 136 (16%) | 121 (14%) | 0.25 |
| Discharge to home |  | 453 (55%) | 471 (56%) | 0.59 |
| Disposition location | Home | 453 (55%) | 471 (56%) | 0.59 |
|  | SNF | 137 (17%) | 149 (18%) | . |
|  | Rehab | 23 (3%) | 22 (3%) | . |
|  | LTC | 37 (4%) | 29 (3%) | . |
|  | Other hospital | 18 (2%) | 20 (2%) | . |
|  | Expired | 101 (12%) | 93 (11%) | . |
|  | Hospice IP | 35 (4%) | 28 (3%) | . |
|  | Hospice other | 10 (1%) | 19 (2%) | . |
|  | Other location | 13 (2%) | 9 (1%) | . |

ICU: intensive care unit, IP: inpatient, IQR: interquartile range, LTC: long term care, LOS: length of stay, O/E: observed to expected, REHAB: rehabilitation, RRT: rapid response team, SNF: skilled nursing facility.

Table 9. *Adjusted analysis* for *clinical outcome measures* for the *population that did not trigger the early warning response system*

|  | All non-alerted patients | | Discharged with sepsis code\* | |
| --- | --- | --- | --- | --- |
|  | Unadjusted  estimate | Adjusted  estimate^ | Unadjusted  estimate | Adjusted  estimate^ |
| Hospital LOS (days)a | 1.00  (0.98 - 1.02) | 0.99  (0.97 - 1.01) | 0.91  (0.84 - 0.99) | 0.91  (0.84 - 0.99) |
| ICU transferb | 0.98  (0.89 - 1.08) | 0.97  (0.88 - 1.07) | 0.78  (0.61 - 1.01) | 0.81  (0.62 - 1.06) |
| ICU LOS (days)a | 1.00  (0.91 - 1.10) | 1.03  (0.94 - 1.13) | 1.11  (0.86 - 1.43) | 1.03  (0.80 - 1.33) |
| RRT b | 0.84  (0.70 - 1.01) | 0.85  (0.71 - 1.03) | 0.50  (0.32 - 0.77) | 0.50  (0.32 - 0.78) |
| Mortalityb | 0.92  (0.76 - 1.12) | 0.92  (0.76 - 1.12) | 0.90  (0.66 - 1.21) | 1.00  (0.73 - 1.36) |
| Mortality or IP hospice transferb | 0.91  (0.78 - 1.06) | 0.91  (0.78 - 1.07) | 0.86  (0.66 - 1.12) | 0.94  (0.71 - 1.24) |
| Discharge to homeb | 1.03  (0.97 - 1.09) | 1.03  (0.97 - 1.10) | 1.05  (0.87 - 1.28) | 1.00  (0.81 - 1.23) |
| Sepsis discharge diagnosisb | 1.02  (0.92 - 1.12) | 1.04  (0.94 - 1.16) | N/A | N/A |

ICU: intensive care unit, IP: inpatient, LOS: length of stay, NA: not applicable, RRT: rapid response team.

\*Sepsis definition based on ICD-9 diagnosis at discharge ('790.7','995.94','995.92','995.90','995.91','995.93','785.52').

^ Adjusted for gender, age, Present on Admission Charlson Comorbidity Score, admit service, hospital, and admission month (June, July or August + Sep).

For each outcome, the estimate is identified as: a, Coefficient; b, Odds Ratio; or c, Hazard Ratio. Estimates compare the mean, odds, or hazard of the outcome after versus before implementation of the early warning system.

**Figures:**

**Figure 1. Screen shot of the post early warning response system assessment to be completed by the rapid response coordinator**

EWS Fig 1.TIF

**Figure 2. Screen shot of the early warning response system notification to be viewed by the bedside nurse**

EWS Fig 2.tif

**Figure 3. Screen shot of the nursing task for which the nurse reviews and confirms the vital sign and laboratory value abnormalities**

EWS Fig 3.tif

**Figure 4. Kaplan Meier curve for time from early warning response system alert to intensive care unit transfer for *all study patients***

Censored at 48 hours. P-value of 0.31 between groups by log rank (Mantel-Cox) test.

Figure 5. Kaplan Meier curve for time from early warning response system alert to intensive care unit transfer for *patients with a sepsis discharge diagnosis*

Censored at 48 hours. P-value of 0.32 between groups by log rank (Mantel-Cox) test.