# Respiratory events after intensive care unit discharge in trauma patients: Epidemiology, outcomes, and risk factors

**Joshua E. Rosen, MD, MHS, Eileen M. Bulger, MD, FACS,** *and* **Joseph Cuschieri, MD, FACS***, Seattle, Washington*

**BACKGROUND:** Respiratory complications are associated with significant morbidity and mortality in trauma patients. The care transition from the intensive care unit (ICU) to the acute care ward is a vulnerable time for injured patients. There is a lack of knowledge about the epidemiology of respiratory events and their outcomes during this transition.

**METHODS:** Retrospective cohort study in a single Level I trauma center of injured patients 18 years and older initially admitted to the ICU from 2015 to 2019 who survived initial transfer to the acute care ward. The primary outcome was occurrence of a respiratory event, defined as escalation in oxygen therapy beyond nasal cannula or facemask for three or more consecutive hours. Secondary outcomes included unplanned intubation for a primary pulmonary cause, adjudicated via manual chart review, as well as in-hospital mortality and length of stay. Multivariable logistic regression was used to examine patient characteristics associated with posttransfer respiratory events.

**RESULTS:** There were 6,561 patients that met the inclusion criteria with a mean age of 52.3 years and median Injury Severity Score of 18 (interquartile range, 13–26). Two hundred and sixty-two patients (4.0%) experienced a respiratory event. Respiratory events occurred early after transfer (median, 2 days, interquartile range, 1–5 days), and were associated with high mortality (16% vs. 1.8%, $p < 0.001$), and ICU readmission rates (52.6% vs. 4.7%, $p < 0.001$). Increasing age, male sex, severe chest injury, and comorbidities, including preexisting alcohol use disorder, congestive heart failure, and chronic obstructive pulmonary disease, were associated with increased odds of a respiratory event. Fifty-eight patients experienced an unplanned intubation for a primary pulmonary cause, which was associated with an in-hospital mortality of 39.7%.

**CONCLUSION:** Respiratory events after transfer to the acute care ward occur close to the time of transfer and are associated with high mortality. Interventions targeted at this critical time are warranted to improve patient outcomes. (*J Trauma Acute Care Surg.* 2022;92: 28–37. Copyright © 2021 American Association for the Surgery of Trauma.)

**LEVEL OF EVIDENCE:** Prognostic and Epidemiological study, level III.

**KEY WORDS:** Respiratory failure; care transition; respiratory event.



Respiratory complications are a significant source of morbidity and mortality in hospitalized trauma patients,[1,2] and are a leading cause of unplanned intensive care unit (ICU) readmissions.[3–6] During the past decades, efforts have focused on identifying high-risk groups[7,8] and developing care pathways aimed at decreasing their occurrence.[9,10] Currently, many institutions triage high-risk patients to the ICU for initial monitoring and stabilization, after which they are transferred to the acute care ward ("floor"). Care transitions represent a potentially vulnerable period for trauma patients, as they leave the highly monitored environment of the ICU and go to a floor bed with limited monitoring and less frequent nursing and respiratory therapy interventions, including those aimed at preventing respiratory complications, such as frequent coughing and deep breathing, effective analgesia, and aspiration prevention.[9,11]

Given the potential severity of respiratory complications in trauma patients data regarding the incidence and risk of respiratory complications following transfer from the ICU is needed to develop effective policies and practices to reduce these potentially morbid events. Existing work on respiratory complications following injury has typically focused on characterizing them either in the ICU,[7,12–15] in specific patient subgroups,[16–18] or predicting their occurrence across an entire hospitalization at the time of admission.[8,19–22] As a result, it is difficult to identify times and locations for targeted interventions. Furthermore, prior work solely using clinical registry data is limited to complications adjudicated by abstractors, which may miss clinically relevant events.

To address this knowledge gap, the present study describes the epidemiology of respiratory events in trauma patients after transfer from the ICU to the acute care ward. We hypothesized that posttransfer respiratory events are more common in the elderly and those with more severe chest trauma. We also hypothesized that posttransfer respiratory events are associated with increased morbidity and mortality.

## METHODS

### Data Source and Patient Selection

The institutional trauma registry at a regional Level I trauma center was queried for all nonburn trauma patients admitted to the

Submitted: June 11, 2021, Revised: July 9, 2021, Accepted: July 11, 2021, Published online: July 20, 2021.

From the Surgical Outcomes Research Center, Department of Surgery (J.E.R.), University of Washington; Department of Surgery (J.E.R., E.M.B.), Harborview Medical Center, Seattle, Washington; and Department of Surgery (J.C.), University of California San Francisco, San Francisco, California.

This study was presented at the 80th Annual Meeting of the American Association for the Surgery of Trauma, September 29 to October 2, 2021 in Atlanta, GA.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text, and links to the digital files are provided in the HTML text of this article on the journal's Web site (www.jtrauma.com).

Address for reprints: Joshua Rosen, MD, MHS, Department of Surgery, University of Washington, 1959 NE Pacific St, Box 356410, Seattle, WA 98195; email: jerosen@uw.edu.

DOI: 10.1097/TA.0000000000003362

hospital from 2015 to 2019. Exclusion criteria included the following: patients readmitted for a missed injury, 18 years or younger, patients not initially admitted to the ICU, those who died or were discharged before floor transfer, those who underwent a tracheostomy prior to initial floor transfer, and those who had prolonged floor stays (>100 days) before an ICU readmission (Fig. 1).

Data on patient demographics, comorbidities, injury characteristics, procedures, and outcomes were obtained from the trauma registry. Specific injury characteristics were identified using Abbreviated Injury Scale (AIS) codes. Surgical procedures were identified using International Classification of Diseases Procedure Coding System codes version 9 and 10 as appropriate. All codes used are listed in the supplemental digital content (SDC 1 and 2, http://links.lww.com/TA/C120). Massive transfusion was defined as receiving 10 units or more of packed red blood cells in the first 24 hours after presentation for patients whose initial blood transfusion was within 4 hours of hospital arrival. Additional time-stamped data characterizing the type of oxygen support (e.g., nasal cannula, ventilator, room air, etc.) for all patients throughout their hospital stay were obtained from an institutional data warehouse of electronic health records (EHR). This study was reviewed by the institutional review board at the University of Washington and was considered exempt.

## Outcome Definition

The primary outcome was the occurrence of a respiratory event after transfer to the acute care floor. A respiratory event was defined as any escalation in oxygen therapy beyond simple nasal cannula (e.g., nonrebreather mask, high-flow nasal cannula, intubation) that lasted for at least three continuous hours. The specific etiology of these events is unspecified and is not used in the definition of the primary outcome. The first significant respiratory event was assessed as the primary outcome. A secondary outcome was unplanned intubation for a primary pulmonary cause after transfer to the floor. If intubation occurred as a result of the first respiratory event, then the case was coded as meeting both the primary and secondary endpoints. For patients with a primary respiratory event and delayed intubation, these outcomes were coded based on the time each event occurred.

To categorize intubation events, all patients receiving ventilator support after the date of their initial floor transfer were identified using EHR and trauma registry data. Chart review was conducted by one author (J.E.R.) to identify intubations that were unplanned and due to a pulmonary cause. Intubations were classified as a pulmonary cause if clinical documentation indicated that the reason for reintubation was pneumonia, presumed/witnessed aspiration, uncontrolled pain, pleural effusion/empyema, retained/reaccumulated hemothorax, pneumothorax, or hypoxemic arrest. We excluded cases of reintubation that were clearly nonpulmonary in origin, such as planned operating room procedures, endoscopic or radiologic procedures, altered mental status/seizures in the setting of intracranial pathology (e.g., expanding subdural hematoma), sepsis from a confirmed nonpulmonary source (e.g., intraabdominal), and code/arrest that was clearly nonhypoxemic in origin (e.g., myocardial infarction). In situations that were ambiguous, adjudication was performed by all three authors (J.E.R., E.M.B., J.C.). If the cause was not clearly nonpulmonary in origin, the intubation was classified as a pulmonary etiology.

## Statistical Analysis

We summarized continuous covariates using means with standard deviations (SDs) for normally distributed continuous covariates and medians with interquartile ranges (IQRs) for nonnormally distributed covariates. *t* Tests were used to compare the means of normally distributed covariates and Wilcoxon rank-sum tests were used for nonnormally distributed covariates. Distributions of categorical covariates were compared with Pearson's $\chi^2$ test. Logistic regression models were specified a priori based on literature review of prior studies, clinical experience, and inspection of bivariate data analyses. Model discrimination was assessed using the area under the receiver operating curve and calibration was assessed using a Hosmer-Lemeshow goodness of fit test. Levels of missing covariate data were low (highest being 3.6% for racial identity), thus missing data were

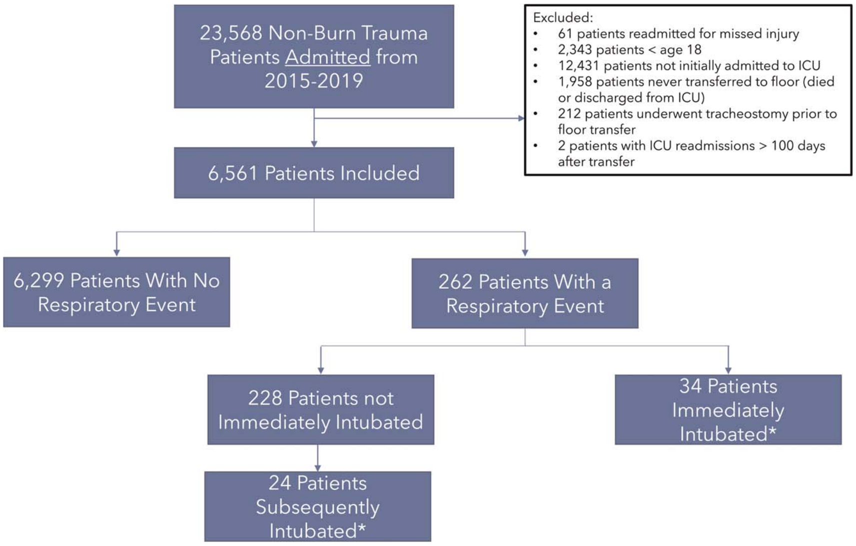


**Figure 1.** Patient selection flow diagram. *Intubated for primary pulmonary causes.

treated as a separate covariate level for analyses (i.e., missing was coded as a separate level for categorical covariates). An α level of 0.05 was chosen for significance. All analyses were performed in Stata version 16.1 (Stata Corp, College Station, TX).

## RESULTS

During the study period, a total of 23,568 trauma patients were admitted, of whom 11,137 were initially admitted to the ICU, with 6,561 patients meeting inclusion criteria (Fig. 1). The mean age was 52.3 years (SD = 21.3 years), the majority were male (69.1%), with a median Injury Severity Score (ISS) of 18 (IQR, 13–26). Overall, 262 patients (4.0%) experienced a respiratory event after transfer from the ICU, and this rate was relatively stable over the study period (3.6%–4.3% per year, $p = 0.88$; SDC 3, http://links.lww.com/TA/C120). There was a total of 167 intubation events, of which 58 were unplanned and for a primary pulmonary cause. Among these intubations, 34 were immediate, and 24 occurred during an escalation of support (Fig. 1). Respiratory events generally occurred early after transfer (median, 2 days; IQR, 1–5 days; Fig. 2).

Table 1 shows the characteristics of the study cohort, those who experienced a respiratory event, and those who were intubated, and additional information is presented in SDC 3, http://links.lww.com/TA/C120. Overall, patients who experienced respiratory events were older, more likely to be men, were more severely injured (median ISS, 24.5 vs. 18.0, $p < 0.001$), had more severe chest injury (median AIS chest score, 3.0 vs. 2.0), were more likely to be intubated at the time of admission, and if intubated had a longer duration of intubation during their initial ICU stay (median, 48 vs. 25 hours). Patients who experienced a respiratory event were more likely to have comorbid alcohol use disorder, chronic obstructive pulmonary disease, diabetes, congestive heart failure, hypertension, or a diagnosed personality disorder and were more likely to have undergone either craniotomy or thoracic surgery during their hospital course.

Respiratory events were associated with high in-hospital mortality (16.0% vs. 1.8%, $p < 0.001$) as well as a longer total length of stay (LOS) (median, 19.0 vs. 8.0 days; $p < 0.001$), and longer total ICU LOS (median, 7.0 vs. 2.0 days; $p < 0.001$). Patients who experienced respiratory events had higher rates of ICU readmission (52.6% vs. 4.7; $p < 0.001$). Full outcome data are shown in Table 2.

In a multivariate logistic regression model for the outcome of any respiratory event (Table 3), older age, male sex, comorbid alcohol use disorder, congestive heart failure, chronic obstructive pulmonary disease, diabetes, increasing injury severity, massive transfusion in the first 24 hours, and more severe chest injury (intubation at the time of admission, ≥3 rib fractures or flail chest) were significantly associated with increased odds of respiratory complications. The model had an area under the receiver operating curve of 0.72 (95% confidence interval, 0.69–0.75) and a Hosmer-Lemeshow goodness of fit test yielded a $p$ value of 0.23.

Fifty-eight patients experienced an unplanned intubation for a primary pulmonary cause. Causes of reintubation are listed in the supplemental digital content (SDC 4, http://links.lww.com/TA/C120). These patients typically were older, had more severe chest injury, and had higher rates of preexisting cardiopulmonary disease (Table 1). Patients reintubated for a pulmonary cause had very high mortality rate (39.7%) and prolonged hospital and ICU LOS (Table 2).

## DISCUSSION

This study examined a large cohort of diverse trauma patients who survived their initial ICU admission and were transferred to the acute care ward in a Level I trauma center. Overall, respiratory

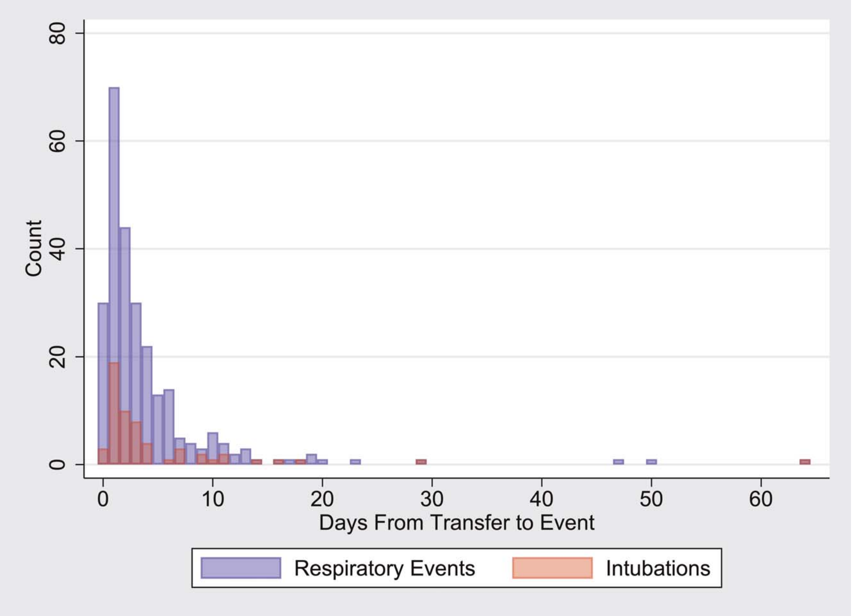


**Figure 2.** Number of days from ICU transfer until first occurrence of a respiratory event and unplanned intubation for a pulmonary cause.

**TABLE 1.** Characteristics of the Study Cohort, as Well as Those Experiencing and Not Experiencing a Respiratory event and Intubation for a Primary Pulmonary Cause

| | | Total | No Respiratory Event After Floor Transfer | Respiratory Event After Floor Transfer | | No Unplanned Intubation for Pulmonary Cause | Unplanned Intubation for Pulmonary Cause | |
|---|---|---|---|---|---|---|---|---|
| | | N = 6,561 | n = 6,299 | n = 262 | p | n = 6,503 | n = 58 | p |
| Age | Mean (SD) | 52.3 (21.3) | 52.0 (21.3) | 59.9 (19.1) | <0.001 | 52.2 (21.3) | 63.6 (15.7) | <0.001 |
| Sex | | | | | 0.004 | | | 0.59 |
| | Male | 4,535 (69.1%) | 4,333 (68.8%) | 202 (77.1%) | | 4,493 (69.1%) | 42 (72.4%) | |
| | Female | 2,026 (30.9%) | 1,966 (31.2%) | 60 (22.9%) | | 2,010 (30.9%) | 16 (27.6%) | |
| Race | | | | | 0.82 | | | 0.91 |
| | White | 5,153 (78.5%) | 4,944 (78.5%) | 209 (79.8%) | | 5,104 (78.5%) | 49 (84.5%) | |
| | Black | 501 (7.6%) | 486 (7.7%) | 15 (5.7%) | | 497 (7.6%) | 4 (6.9%) | |
| | Asian | 394 (6.0%) | 380 (6.0%) | 14 (5.3%) | | 392 (6.0%) | 2 (3.4%) | |
| | Native American | 207 (3.2%) | 197 (3.1%) | 10 (3.8%) | | 205 (3.2%) | 2 (3.4%) | |
| | Pacific Islander | 62 (0.9%) | 60 (1.0%) | 2 (0.8%) | | 62 (1.0%) | 0 (0.0%) | |
| | Other | 5 (0.1%) | 5 (0.1%) | 0 (0.0%) | | 5 (0.1%) | 0 (0.0%) | |
| | Unknown | 239 (3.6%) | 227 (3.6%) | 12 (4.6%) | | 238 (3.7%) | 1 (1.7%) | |
| Ethnicity | | | | | 0.45 | | | 0.37 |
| | Non-Hispanic | 5,856 (89.3%) | 5,616 (89.2%) | 240 (91.6%) | | 5,801 (89.2%) | 55 (94.8%) | |
| | Hispanic | 550 (8.4%) | 533 (8.5%) | 17 (6.5%) | | 548 (8.4%) | 2 (3.4%) | |
| | Unknown | 155 (2.4%) | 150 (2.4%) | 5 (1.9%) | | 154 (2.4%) | 1 (1.7%) | |
| Penetrating trauma | | 627 (9.6%) | 603 (9.6%) | 24 (9.2%) | 0.82 | 623 (9.6%) | 4 (6.9%) | 0.49 |
| Injury mechanism | | | | | 0.30 | | | 0.84 |
| | Bicycle crash | 250 (3.8%) | 238 (3.8%) | 12 (4.6%) | | 248 (3.8%) | 2 (3.4%) | |
| | Stab or laceration | 224 (3.4%) | 213 (3.4%) | 11 (4.2%) | | 223 (3.4%) | 1 (1.7%) | |
| | Fall | 2,355 (35.9%) | 2,246 (35.7%) | 109 (41.6%) | | 2,330 (35.8%) | 25 (43.1%) | |
| | Firearm injury | 375 (5.7%) | 362 (5.7%) | 13 (5.0%) | | 372 (5.7%) | 3 (5.2%) | |
| | Motor vehicle crash | 2,175 (33.2%) | 2,093 (33.2%) | 82 (31.3%) | | 2,155 (33.1%) | 20 (34.5%) | |
| | Pedestrian struck by vehicle | 566 (8.6%) | 549 (8.7%) | 17 (6.5%) | | 562 (8.6%) | 4 (6.9%) | |
| | Other | 616 (9.4%) | 598 (9.5%) | 18 (6.9%) | | 613 (9.4%) | 3 (5.2%) | |
| Injury and clinical characteristics | | | | | | | | |
| Intubated at time of admission | | 2,033 (31.0%) | 1,929 (30.6%) | 104 (39.7%) | 0.002 | 2,004 (30.8%) | 29 (50.0%) | 0.002 |
| Massive transfusion in first 24 h | | 117 (1.8%) | 106 (1.7%) | 11 (4.2%) | 0.003 | 115 (1.8%) | 2 (3.4%) | 0.34 |
| Total length of intubation during ICU admission (among those intubated), h | Median (IQR) | 26.25 (12.9–66.6) | 25.0 (12.6–64.9) | 48.4 (21.0–102.9) | <0.001 | 25.6 (66.0–12.8) | 66.4 (216.5–35.7) | <0.001 |
| > = 3 Rib Fx or flail chest | | 2,111 (32.2%) | 1,987 (31.5%) | 124 (47.3%) | <0.001 | 2,082 (32.0%) | 29 (50.0%) | 0.004 |
| Pneumothorax or hemothorax | | 1,967 (30.0%) | 1,851 (29.4%) | 116 (44.3%) | <0.001 | 1,944 (29.9%) | 23 (39.7%) | 0.11 |
| Pulmonary contusion or laceration | | 1,296 (19.8%) | 1,222 (19.4%) | 74 (28.2%) | <0.001 | 1,277 (19.6%) | 19 (32.8%) | 0.012 |
| ISS | | | | | <0.001 | | | 0.010 |
| | 0–9 | 872 (13.3%) | 857 (13.6%) | 15 (5.7%) | | 869 (13.4%) | 3 (5.2%) | |

Continued next page

TABLE 1. (Continued)

| | | Total | No Respiratory Event After Floor Transfer | Respiratory Event After Floor Transfer | | No Unplanned Intubation for Pulmonary Cause | Unplanned Intubation for Pulmonary Cause | |
|---|---|---|---|---|---|---|---|---|
| | | N = 6,561 | n = 6,299 | n = 262 | p | n = 6,503 | n = 58 | p |
| | 10–16 | 1,491 (22.7%) | 1,447 (23.0%) | 44 (16.8%) | | 1,484 (22.8%) | 7 (12.1%) | |
| | >16 | 4,183 (63.8%) | 3,980 (63.2%) | 203 (77.5%) | | 4,135 (63.6%) | 48 (82.8%) | |
| | Missing | 15 (0.2%) | 15 (0.2%) | 0 (0.0%) | | 15 (0.2%) | 0 (0.0%) | |
| AIS head score | Median (IQR) | 2.0 (0.0–3.0) | 2.0 (0.0–3.0) | 2.0 (0.0–4.0) | 0.023 | 2.0 (0.0–3.0) | 3.0 (0.0–4.0) | 0.020 |
| AIS chest score | Median (IQR) | 2.0 (0.0–3.0) | 2.0 (0.0–3.0) | 3.0 (0.0–3.0) | <0.001 | 2.0 (0.0–3.0) | 3.0 (1.0–4.0) | <0.001 |
| AIS abdomen score | Median (IQR) | 0.0 (0.0–2.0) | 0.0 (0.0–2.0) | 0.0 (0.0–2.0) | 0.12 | 0.0 (0.0–2.0) | 0.0 (0.0–2.0) | 0.90 |
| Surgical procedures during hospital stay | | | | | | | | |
| Exploratory laparotomy | | 538 (8.2%) | 510 (8.1%) | 28 (10.7%) | 0.13 | 533 (8.2%) | 5 (8.6%) | 0.91 |
| Thoracotomy | | 88 (1.3%) | 80 (1.3%) | 8 (3.1%) | 0.014 | 86 (1.3%) | 2 (3.4%) | 0.16 |
| VATS | | 73 (1.1%) | 62 (1.0%) | 11 (4.2%) | <0.001 | 69 (1.1%) | 4 (6.9%) | <0.001 |
| Craniotomy | | 376 (5.7%) | 341 (5.4%) | 35 (13.4%) | <0.001 | 368 (5.7%) | 8 (13.8%) | 0.008 |
| Comorbidities | | | | | | | | |
| Smoker | | 1,520 (23.2%) | 1,450 (23.0%) | 70 (26.7%) | 0.16 | 1,509 (23.2%) | 11 (19.0%) | 0.45 |
| Alcohol use | | 932 (14.2%) | 881 (14.0%) | 51 (19.5%) | 0.013 | 917 (14.1%) | 15 (25.9%) | 0.011 |
| Substance use disorder | | 599 (9.1%) | 575 (9.1%) | 24 (9.2%) | 0.99 | 593 (9.1%) | 6 (10.3%) | 0.75 |
| Anticoagulation use | | 353 (5.4%) | 334 (5.3%) | 19 (7.3%) | 0.17 | 347 (5.3%) | 6 (10.3%) | 0.092 |
| Cirrhosis | | 120 (1.8%) | 114 (1.8%) | 6 (2.3%) | 0.57 | 118 (1.8%) | 2 (3.4%) | 0.36 |
| Chronic obstructive pulmonary disease | | 358 (5.5%) | 328 (5.2%) | 30 (11.5%) | <0.001 | 349 (5.4%) | 9 (15.5%) | <0.001 |
| Dementia | | 271 (4.1%) | 255 (4.0%) | 16 (6.1%) | 0.10 | 270 (4.2%) | 1 (1.7%) | 0.35 |
| Diabetes | | 682 (10.4%) | 636 (10.1%) | 46 (17.6%) | <0.001 | 672 (10.3%) | 10 (17.2%) | 0.086 |
| Congestive heart failure | | 283 (4.3%) | 255 (4.0%) | 28 (10.7%) | <0.001 | 276 (4.2%) | 7 (12.1%) | 0.003 |
| Hypertension | | 1,889 (28.8%) | 1,792 (28.4%) | 97 (37.0%) | 0.003 | 1,863 (28.6%) | 26 (44.8%) | 0.007 |
| Peripheral vascular disease | | 36 (0.5%) | 32 (0.5%) | 4 (1.5%) | 0.029 | 36 (0.6%) | 0 (0.0%) | 0.57 |
| History of myocardial infarction | | 11 (0.2%) | 11 (0.2%) | 0 (0.0%) | 0.50 | 11 (0.2%) | 0 (0.0%) | 0.75 |
| Chronic kidney disease | | 37 (0.6%) | 34 (0.5%) | 3 (1.1%) | 0.20 | 35 (0.5%) | 2 (3.4%) | 0.003 |
| Steroid use | | 101 (1.5%) | 94 (1.5%) | 7 (2.7%) | 0.13 | 97 (1.5%) | 4 (6.9%) | <0.001 |
| Personality disorder | | 463 (7.1%) | 434 (6.9%) | 29 (11.1%) | 0.010 | 454 (7.0%) | 9 (15.5%) | 0.012 |
| Bleeding disorder | | 313 (4.8%) | 292 (4.6%) | 21 (8.0%) | 0.012 | 310 (4.8%) | 3 (5.2%) | 0.89 |
| Cancer | | 32 (0.5%) | 28 (0.4%) | 4 (1.5%) | 0.014 | 31 (0.5%) | 1 (1.7%) | 0.17 |
| Functionally dependent status | | 509 (7.8%) | 478 (7.6%) | 31 (11.8%) | 0.012 | 500 (7.7%) | 9 (15.5%) | 0.026 |

VATS, video-assisted thoracoscopic surgery.

**TABLE 2.** In-Hospital Outcomes of Patients Who Experienced a Respiratory Event or Unplanned Intubation for a Primary Pulmonary Cause Compared With Those Who Did Not

| | | Total | No Respiratory Event After Floor Transfer | Respiratory Event After Floor Transfer | | No Unplanned Intubation for Pulmonary Cause | Unplanned Intubation for Pulmonary Cause | |
|---|---|---|---|---|---|---|---|---|
| | | N = 6,561 | n = 6,299 | n = 262 | *p* | n = 6,503 | n = 58 | *p* |
| Mortality | | 153 (2.3%) | 111 (1.8%) | 42 (16.0%) | <0.001 | 130 (2.0%) | 23 (39.7%) | <0.001 |
| Hospital disposition (for those surviving to discharge) | | | | | 0.015 | | | <0.001 |
| | Home | 3466 (54.1%) | 3384 (54.5%) | 82 (41.4%) | | 3460 (54.3%) | 6 (17.1%) | |
| | Home with home health | 226 (3.5%) | 220 (3.5%) | 6 (3.0%) | | 224 (3.5%) | 2 (5.7%) | |
| | Skilled nursing facility | 1639 (25.6%) | 1573 (25.3%) | 66 (33.3%) | | 1626 (25.5%) | 13 (37.1%) | |
| | LTAC/acute care | 672 (10.5%) | 646 (10.4%) | 26 (13.1%) | | 660 (10.4%) | 12 (34.3%) | |
| | Hospice | 20 (0.3%) | 19 (0.3%) | 1 (0.5%) | | 20 (0.3%) | 0 (0.0%) | |
| | Other | 376 (5.9%) | 359 (5.8%) | 17 (8.6%) | | 374 (5.9%) | 2 (5.7%) | |
| | Unknown | 9 (0.1%) | 9 (0.1%) | 0 (0.0%) | | 9 (0.1%) | 0 (0.0%) | |
| Total LOS, d | Median (IQR) | 8.0 (4.0–15.0) | 8.0 (4.0–15.0) | 19.0 (11.0–35.0) | <0.001 | 8.0 (4.0–15.0) | 30.0 (16.0–46.0) | <0.001 |
| Total ICU LOS, d | Median (IQR) | 2.0 (1.0–4.0) | 2.0 (1.0–4.0) | 7.0 (3.0–14.0) | <0.001 | 2.0 (1.0–4.0) | 16.0 (9.0–23.0) | <0.001 |
| Any ICU readmission | | 420 (6.4%) | 300 (4.7%) | 120 (52.6%) | <0.001 | 367 (5.6%) | 58 (100%) | <0.001 |

LTAC, long-term acute care.

events occurred in 4% of patients and were associated with significant in-hospital mortality (16%) and increased total ICU and hospital LOS. These data are further confirmation of the importance and severity of respiratory events in trauma patients throughout their hospital course. In a 2016 National Trauma Databank study, Prin and Li[14] found a 16.9% mortality across all trauma patients who required ICU admission and suffered an in-hospital complication. Chung et al.[23] examined failure-to-rescue in trauma patients at a single trauma center and found an 11.6% mortality rate in ICU patient's after a defined major complication. The fact that the mortality rate in the present study was comparable at 16% is notable, given that the patients in this study had survived their initial ICU admission, and were likely considered stable enough to merit transfer to the acute care floor. However, exact transfer criteria and moderating factors for individual patients are not available in our data set (see SDC 4, http://links.lww.com/TA/C120 for typical ward transfer criteria).

We used a highly sensitive and objective definition for a respiratory event as the main outcome measure in this study. Like the use of ventilator-associated events versus ventilator-associated pneumonia, this definition has the advantage of increased sensitivity and objectivity by not relying on inconsistent clinical documentation and abstractor review for identification.[15,24] While this increased sensitivity will naturally come at the expense of specificity for clinical pulmonary diagnoses (e.g., pneumonia), the high mortality rate associated with these events (16% in this study) reflects their importance, similar to what has been found for ventilator-associated events.[15] In a similar study, Chung et al.[23] used complication definitions from the Pennsylvania Trauma Systems Foundation and found a 1.4% mortality rate among patients experiencing any complication on the ward and a 9.1% mortality rate for those with a defined pulmonary complication using the Trauma Quality Improvement Program (TQIP) definitions. This is lower than the 16% mortality rate we found and may reflect our broader capture of events with this sensitive and objective definition.

To complement our sensitive measure of respiratory events, our approach to identifying intubation events allowed for both high sensitivity and specificity by combining EHR data with manual chart review. Of the 167 intubation events after floor transfer identified by EHR data, 70 of these were categorized as "unplanned intubations" based on TQIP criteria and 58 of them were ultimately determined to be from a pulmonary etiology by chart review. The majority of the 167 patients that were not captured in the trauma registry were appropriate because they did not meet criteria for an unplanned intubation (e.g., intubation for a planned operating room procedure). Notably, of the 58 intubations for a pulmonary cause that we identified, 13 were not captured in the trauma registry based on TQIP criteria. The reasons for this are likely varied, including inadequate or confusing provider documentation, or because of the sequencing of events leading abstractors to feel it was not "unplanned," or simply because of the errors associated with the high volume of clinical documentation that abstractors must parse through. Overall, these results highlight the utility of pairing sensitive (oxygenation data) and specific (targeted chart review) measures to understand the true incidence of pulmonary complications to guide research and quality improvement activities and are already informing efforts at our institution to improve the capture of etiology-specific data in our trauma registry.

In line with prior work, we found increasing age, more severe chest injury, and preexisting cardiopulmonary disease to be significant risk factors for respiratory events.[17,25] Notably, much of this prior work has focused on high-risk subpopulations of trauma patients (e.g., elderly, blunt chest injury), has not used a broad definition of respiratory events, and has not focused on the timing of events relative to specific care transitions.[7,17] Our data extend this work to a more generalized population of trauma patients, using a highly sensitive measure of respiratory events and emphasizes that these risk factors continue to be important throughout the hospital stay. For example, 129 of the 262 patients who experienced respiratory events (46%) had no

**TABLE 3.** Logistic Regression Model for Outcome of Respiratory Event After Transfer From the ICU

| Covariates | | Odds Ratio | 95% Confidence Interval | p |
|---|---|---|---|---|
| Age >65 y | | 1.68 | 1.20–2.36 | 0.003 |
| Male sex | | 1.55 | 1.14–2.11 | 0.005 |
| Injury mechanism | | | | |
| | Bicycle crash | Reference | | |
| | Stab or laceration | 1.35 | 0.56–3.28 | 0.506 |
| | Fall | 0.75 | 0.39–1.43 | 0.381 |
| | Firearm injury | 0.71 | 0.31–1.67 | 0.438 |
| | Motor vehicle crash | 0.63 | 0.33–1.19 | 0.157 |
| | Pedestrian struck by vehicle | 0.49 | 0.22–1.06 | 0.07 |
| | Other | 0.64 | 0.30–1.37 | 0.252 |
| Functionally dependent | | 1.46 | 0.92–2.32 | 0.105 |
| Smoker | | 1.33 | 0.98–1.81 | 0.063 |
| Alcohol use | | 1.60 | 1.14–2.26 | 0.007 |
| Substance use disorder | | 1.03 | 0.66–1.61 | 0.9 |
| Anticoagulation use | | 0.87 | 0.51–1.49 | 0.616 |
| Cirrhosis | | 0.94 | 0.39–2.22 | 0.88 |
| Chronic obstructive pulmonary disease | | 1.72 | 1.11–2.65 | 0.015 |
| Dementia | | 1.31 | 0.73–2.34 | 0.367 |
| Congestive heart failure | | 2.16 | 1.34–3.49 | 0.002 |
| Diabetes | | 1.78 | 1.24–2.55 | 0.002 |
| Chronic kidney disease | | 1.70 | 0.48–5.94 | 0.409 |
| Steroid use | | 1.21 | 0.53–2.75 | 0.657 |
| ISS | | | | |
| | 0–9 | Reference | | |
| | 10–16 | 1.51 | 0.82–2.77 | 0.184 |
| | >16 | 2.47 | 1.39–4.40 | 0.002 |
| | Missing | 0.00 | 0.00–0.00 | 0.991 |
| AIS head score | | 1.04 | 0.96–1.13 | 0.324 |
| Intubated at time of admission | | 1.68 | 1.25–2.25 | 0.001 |
| ≥ 3 Rib fractures or flail chest present | | 1.90 | 1.40–2.57 | <0.001 |
| Pulmonary contusion or laceration present | | 1.38 | 1.00–1.89 | 0.051 |
| Massive transfusion in first 24 h | | 2.50 | 1.28–4.91 | 0.008 |

rib fractures, which would have excluded them from many studies focusing exclusively on blunt chest trauma.

Most respiratory events occurred within 5 days of transfer to the acute care ward (median, 2 days). This may indicate that current protocols for evaluating suitability for floor transfer are inadequate for identifying this small but consequential population. There are multiple possible strategies to address posttransfer respiratory events, including (1) revising criteria for floor transfer, (2) increased noninvasive continuous monitoring of patients following floor transfer, (3) protocols for respiratory therapy interventions aimed at decreasing respiratory events, (4) dedicated teams composed of either ICU or specified non-ICU personnel to monitor and evaluate recently transferred patients, (5) clustering at risk patients in a common physical location (e.g., step-down unit[26]), or on a common hospital service to promote increased monitoring and prevent, (6) a combination of the above.

Criteria used for transfer to the acute care ward must balance patient safety and the utilization of limited hospital resources, such as ICU beds. For example, our institutional protocol[9] for patients with rib fractures supports primary ICU admission for patients older than 65 years with three or more rib fractures and involves a functional assessment (incentive spirometry, cough strength, pain control) in addition to standard ICU transfer criteria (SDC 5, http://links.lww.com/TA/C120). While the rate of respiratory events was overall not large (4%), the associated morbidity and mortality was high even with these stringent criteria. Floor transfer criteria could be modified either by applying existing criteria to a broader group of patients, or by using better risk stratification models. For instance, of the 262 patients who experienced respiratory events, 138 of them (53%) did not meet criteria to be included in our initial rib fracture management pathway for high-risk patients. However, expanding the use of these criteria to all trauma patients would require significant investment of resources and personnel, which are not currently justified based on the lack of empirical evidence for their effectiveness in a broader trauma population. Furthermore, changes to ICU transfer criteria must be considered in the context of a specific institutions bed-capacity and patient flow needs. A second approach would involve developing additional criteria for floor transfer, or further refining risk prediction methods. Significant effort has been devoted to developing prediction algorithms and risk scores to identify patients at high risk of pulmonary complications.[8,9,20,27–30] However, many of these algorithms rely only on patient characteristics at the time of admission, retrospectively look at the entire hospital course (not just the time of floor transfer), use defined pulmonary complications as an outcome (as opposed to respiratory events), have not been extensively validated in other cohorts, and have been limited to patients with chest wall injury. The applicability and utility of these scoring systems at the time of ward transfer is not currently established. Notably, the prediction task involved in identifying a small number of events across a heterogeneous population in a way that optimizes resource utilization is not trivial and may not be possible with current approaches and data sources, but ideally, targeted therapy to individual patients at greatest risk should be the goal. Specifically, newer approaches using machine learning techniques for event prediction from large data sets may be beneficial in this area.[26]

An alternate strategic approach is to accept the limits of our ability to refine predictions currently and deploy interventions for increased monitoring and support of patients outside of the ICU setting. Given that most respiratory events occurred early after transfer, it is possible that interventions such as frequent respiratory therapy sessions and nursing checks, continuous oxygen saturation monitoring, and provider adjustments targeted in this high-risk window could be an effective way to reduce respiratory events. Many of the interventions currently used for the prevention of pulmonary complications (respiratory hygiene, multimodal analgesia, catheter-based analgesia, frequent monitoring)[9] could theoretically be delivered on an acute care ward if sufficient resources were available. Although targeted therapy would be optimal, such an approach may allow for the reduction of respiratory events while still preserving limited ICU resources for patients requiring interventions such as mechanical ventilation and vasopressor support that cannot be delivered in other settings. A 2016 study by Nyland and colleagues[10] evaluated a standardized preventative protocol for high-risk trauma patients on the acute care floor. In a pre-post analysis, they demonstrated a reduction in unplanned ICU admissions in the intervention period. While the outcome of ICU readmissions is a surrogate marker for respiratory events and may represent appropriate care escalation rather than a negative outcome in itself, this study and others[31] demonstrate the feasibility of implementing an intensive respiratory hygiene protocol outside of the ICU setting. The major limitation of such an approach is the cost in terms of manpower and resources needed to implement these protocols, which merits further exploration.

Strengths of this study are the inclusion of a diverse group of trauma patients, the use of detailed EHR data to implement a highly sensitive and objective definition of a respiratory event, the use of manual adjudication for intubation events to isolate those related to pulmonary causes, and the use of timing data to study respiratory events relative to important transitions of care, which can inform the development and implementation of interventions to address them. The main limitations include focusing on the experience of a single high-volume Level I trauma center, which may not reflect patterns of care in other settings, and lack of detailed information about specific medical interventions performed, functional covariates, and service staffing information (e.g., medications, pulmonary function, fluid balance, diet status, service transferred to) in the peritransfer period to examine additional clinical risk factors. Furthermore, while our institution has generally acceptable criteria for transfer suitability (SDC 5, http://links.lww.com/TA/C120), some of these can be modified at the attending's discretion, and we are not able to capture the specific factors that led to the decision to transfer a patient a given time (e.g., bed flow concerns to accommodate higher acuity patients). Finally, for this study, we chose to exclude patients who underwent tracheostomy placement during their initial ICU stay. This was done to create a more homogeneous sample population for study, as the risk factors and care patterns of tracheostomy patients on the floor are likely to be different than patients without a tracheostomy. This is an important group of patients that merits separate study.

In conclusion, respiratory events tend to occur early after transfer to the acute care ward and are associated with significant morbidity and mortality.

## AUTHORSHIP

J.E.R. participated in the literature search, study design, data collection, data analysis, data interpretation, writing, critical revisions. E.M.B. participated in the study design, data interpretation, writing, critical revisions. J.C. participated in the study design, data interpretation, writing, critical revisions.

## ACKNOWLEDGMENTS

We would like to thank Shauna Carlson and Ellen Robinson for their assistance with data abstraction for this study. J.E.R. is supported by a training grant from the National Institute of Diabetes and Digestive and Kidney Diseases of the National Institutes of Health under Award Number T32DK070555.

## DISCLOSURE

The authors declare no conflicts of interest.

## REFERENCES

1. Mangram AJ, Sohn J, Zhou N, Hollingworth AK, Ali-Osman FR, Sucher JF, Moyer M, Dzandu JK. Trauma-associated pneumonia: time to redefine ventilator-associated pneumonia in trauma patients. *Am J Surg*. 2015;210(6):1056–1062.
2. Hoyt DB, Simons RK, Winchell RJ, Cushman J, Hollingsworth-Fridlund P, Holbrook T, Fortlage D. A risk analysis of pulmonary complications following major trauma. *J Trauma*. 1993;35(4):524–531.
3. Christmas AB, Freeman E, Chisolm A, Fischer PE, Sachdev G, Jacobs DG, Sing RF. Trauma intensive care unit 'bouncebacks': identifying risk factors for unexpected return admission to the intensive care unit. *Am Surg*. 2014;80(8):778–782.
4. Bradburn EH, Jammula S, Horst MA, et al. An analysis of outcomes and predictors of intensive care unit bouncebacks in a mature trauma system. *J Trauma Acute Care Surg*. 2020;88(4):486–490.
5. Rubano JA, Vosswinkel JA, McCormack JE, Huang EC, Shapiro MJ, Jawa RS. Unplanned intensive care unit admission following trauma. *J Crit Care*. 2016;33:174–179.
6. Fakhry SM, Leon S, Derderian C, Al-Harakeh H, Ferguson PL. Intensive care unit bounce back in trauma patients: an analysis of unplanned returns to the intensive care unit. *J Trauma Acute Care Surg*. 2013;74(6):1528–1533.
7. Bulger EM, Arneson MA, Mock CN, Jurkovich GJ. Rib fractures in the elderly. *J Trauma*. 2000;48(6):1040–1047.
8. Seok J, Cho HM, Kim HH, Kim JH, Huh U, Kim HB, Leem JH, Wang IJ. Chest trauma scoring systems for predicting respiratory complications in isolated rib fracture. *J Surg Res*. 2019;244:84–90.
9. Witt CE, Bulger EM. Comprehensive approach to the management of the patient with multiple rib fractures: a review and introduction of a bundled rib fracture management protocol. *Trauma Surg Acute Care Open*. 2017;2(1):e000064.
10. Nyland BA, Spilman SK, Halub ME, Lamb KD, Jackson JA, Oetting TW, Sahr SM. A preventative respiratory protocol to identify trauma subjects at risk for respiratory compromise on a general in-patient ward. *Respir Care*. 2016;61(12):1580–1587.
11. Galvagno SM Jr., Smith CE, Varon AJ, et al. Pain management for blunt thoracic trauma: a joint practice management guideline from the Eastern Association for the Surgery of Trauma and Trauma Anesthesiology Society. *J Trauma Acute Care Surg*. 2016;81(5):936–951.

12. Robinson BRH, Cohen MJ, Holcomb JB, et al. Risk factors for the development of acute respiratory distress syndrome following hemorrhage. *Shock*. 2018;50(3):258–264.
13. Mulvey HE, Haslam RD, Laytin AD, Diamond CA, Sims CA. Unplanned ICU admission is associated with worse clinical outcomes in geriatric trauma patients. *J Surg Res*. 2020;245:13–21.
14. Prin M, Li G. Complications and in-hospital mortality in trauma patients treated in intensive care units in the United States, 2013. *Inj Epidemiol*. 2016;3(1):18.
15. Meagher AD, Lind M, Senekjian L, Iwuchukwu C, Lynch JB, Cuschieri J, Robinson BRH. Ventilator-associated events, not ventilator-associated pneumonia, is associated with higher mortality in trauma patients. *J Trauma Acute Care Surg*. 2019;87(2):307–314.
16. Lee K, Rincon F. Pulmonary Complications in Patients with Severe Brain Injury. *Crit Care Res Pract*. 2012;2012:207247.
17. Brasel KJ, Guse CE, Layde P, Weigelt JA. Rib fractures: relationship with pneumonia and mortality. *Crit Care Med*. 2006;34(6):1642–1646.
18. Carver TW, Milia DJ, Somberg C, Brasel K, Paul J. Vital capacity helps predict pulmonary complications after rib fractures. *J Trauma Acute Care Surg*. 2015;79(3):413–416.
19. Chapman BC, Herbert B, Rodil M, et al. RibScore: a novel radiographic score based on fracture pattern that predicts pneumonia, respiratory failure, and tracheostomy. *J Trauma Acute Care*. 2016;80(1):95–101.
20. Chen J, Jeremitsky E, Philp F, Fry W, Smith RS. A chest trauma scoring system to predict outcomes. *Surgery*. 2014;156(4):988–994.
21. Hardin KS, Leasia KN, Haenel J, Moore EE, Burlew CC, Pieracci FM. The Sequential Clinical Assessment of Respiratory Function (SCARF) score: a dynamic pulmonary physiologic score that predicts adverse outcomes in critically ill rib fracture patients. *J Trauma Acute Care Surg*. 2019;87(6):1260–1268.
22. Wutzler S, Wafaisade A, Maegele M, Laurer H, Geiger EV, Walcher F, Barker J, Lefering R, Marzi I, Trauma Registry of DGU. Lung Organ Failure Score (LOFS): probability of severe pulmonary organ failure after multiple injuries including chest trauma. *Injury*. 2012;43(9):1507–1512.
23. Chung JJ, Earl-Royal EC, Delgado MK, Pascual JL, Reilly PM, Wiebe DJ, Holena DN. Where we fail: location and timing of failure to rescue in trauma. *Am Surg*. 2017;83(3):250–256.
24. Younan D, Griffin R, Zaky A, Pittet J-F, Camins B. A comparison of outcomes of trauma patients with ventilator- associated events by diagnostic criteria set. *Shock*. 2019;51(5):599–604.
25. Battle CE, Hutchings H, Evans PA. Risk factors that predict mortality in patients with blunt chest wall trauma: a systematic review and meta-analysis. *Injury*. 2012;43(1):8–17.
26. Chen L, Ogundele O, Clermont G, Hravnak M, Pinsky MR, Dubrawski AW. Dynamic and personalized risk forecast in step-down units. Implications for monitoring paradigms. *Ann Am Thorac Soc*. 2017;14(3):384–391.
27. Pape H-C, Remmers D, Rice J, Ebisch M, Krettek C, Tscherne H. Appraisal of early evaluation of blunt chest trauma: development of a standardized scoring system for initial clinical decision making. *J Trauma*. 2000;49(3): 496–504.
28. Pressley CM, Fry WR, Philp AS, Berry SD, Smith RS. Predicting outcome of patients with chest wall injury. *Am J Surg*. 2012;204(6):910–914.
29. Shulzhenko NO, Zens TJ, Beems MV, Jung HS, O'Rourke AP, Liepert AE, Scarborough JE, Agarwal SK. Number of rib fractures thresholds independently predict worse outcomes in older patients with blunt trauma. *Surgery*. 2017;161(4):1083–1089.
30. Bakhos C, O'Connor J, Kyriakides T, Abou-Nukta F, Bonadies J. Vital capacity as a predictor of outcome in elderly patients with rib fractures. *J Trauma*. 2006;61(1):131–134.
31. Naar L, El Hechi MW, van Erp IA, et al. Isolated rib cage fractures in the elderly: do all patients belong to the intensive care unit? A retrospective nationwide analysis. *J Trauma Acute Care Surg*. 2020;89(6):1039–1045.

## DISCUSSION

**PAULA FERRADA, M.D. (Glen Allen, Virginia):** Thank you, Dr. Michetti for the introduction. I want to thank the AAST for the privilege of the podium and the opportunity to discuss this interesting paper. I also, want to thank the authors for providing me with their manuscript in a timely manner.

Let me start by saying that I believe this manuscript will be a great addition to our literature and congratulate Dr. Rosen for having the insight to write about these important issues that affect our patients and our entire health care system, especially since early in this career as a future trauma surgeon.

This study, as he eloquently spoke about, described the transition of patients from the ICU to the ward and their respiratory complications following ICU liberation.

During this time period, there were 23,000 patients that were admitted and more than 11,000 submitted to the ICU and over 6,000 that met inclusion criteria. Four percent of them had respiratory complications that led to ICU readmission.

And for the patients that got intubated secondary to a primary respiratory complication, there was an increased mortality of over 40%. The majority of these respiratory complications occurred within two days of ICU liberation.

As it was very clearly pointed out by the authors in the manuscript, these results mirror previous publications and possibly the experience in the majority of our trauma centers.

My question is how do we prevent this? How do we protect our most vulnerable patients?

In several health care systems there is a push to decrease costs by decreasing length of stay and liberating beds, especially ICU beds.

Throughput, as described in the English dictionary, is "the amount of stuff or material that pass through a system or a process." But our patients are not "stuff." Our patients are people.

Intensive care beds are expensive and throughput has become a priority and a hot term for some in the hospital leadership. But are we emphasizing throughput at the expense of patient safety? Are we discharging patients out of the ICU prematurely? And is this a major factor contributing to early readmissions?

How do we get stakeholders to listen to this data? Moreover, how do we get experienced clinicians to be part of the stakeholders that takes these decisions?

At the end, an increased mortality and morbidity increases, also, length of stay and costs. Furthermore, the cost of these mortalities and complications goes above and beyond what we can measure in dollars.

It's a cost to the team members, to the hospital staff, and to the patient's families. It's a cost that we pay in blood, tears and sweat. It comes at a cost of losing the trust that our patients place in our teams and our institutions.

How do we get clinicians involved in higher level decisions that drive priorities for health care systems? I truly believe these types of manuscripts are tools that can help us advocate for our patients.

My only question to the authors is what are you doing to address this locally? Have you implemented changes in the ICU liberation protocols since you discovered this data?

And my question to all the listeners today in this room, is what can we do as leaders to advocate for our patients and support more surgeons to be included among the hospital stakeholders that takes the decisions and impact here?

Thank you so much, again, for the opportunity to discuss this paper and the privilege of the podium.

**ANNA M. LEDGERWOOD, M.D. (Detroit, Michigan):** I'm surprised that you did not look at the effect of sedatives and/or narcotics prior to this event's taking place.

**AJAI K. MALHOTRA, M.D. (Burlington, Vermont):** Really enjoyed that presentation. We recently looked at ICU bounce-backs and what we found was that the commonest cause of ICU bounce-back was respiratory deterioration. We saw it in two-thirds of the patients.

But sort of what Dr. Ferrada mentioned, we looked at patients who were delayed in the ICU just because of lack of bed availability. And that delay, just 24-hour delay, decreased the rate of bounce-back, decreased in the older patients even mortality and even with regression analysis it was an independent protector of mortality.

So based on all that I would encourage some float level stuff in the first 24-hours after ICU discharge. You can call it "step-down" but the data on step-down is very mixed.

And because it's a respiratory event, maybe focusing on aggressive respiratory care just in the first 24-hours after ICU discharge.

Very nice paper.

**JOSHUA E. ROSEN, M.D., M.H.S. (Seattle, Washington):** Well, thank you, Dr. Ferrada and for the rest of the questions – and I apologize for the error in the audio synchronization with the video.

I think the question that you raised, Dr. Ferrada, about what are we doing about this is super important. And I would frame it in the context that these events, as we pointed out, are actually less common than we suspected they would be when we set out to start this study, but have a really high associated consequence with them.

So I think when you are in that space you have to apply interventions carefully to avoid overutilization of resources.

And I think the first thing that we've tried to do with this data is look at the highest "bang for our buck" in terms of the most severe events and what we think are the causes behind them.

So I mentioned that of the intubation events – the highest cause behind that was aspiration that we could identify from the medical records.

So the first thing we've done now are we're working with our trauma registry colleagues and with the providers and our respiratory therapy teams in the ICUs to improve the way we capture aspiration events and the way we can monitor and surveille for these so that we can get better data and hopefully implement some interventions to decrease them, because when we started to look into this further there was a real deficit in the amount of data that we had even about what we think is one of the primary drivers behind these outcomes.

So I think the first thing we're doing is even though it's not super exciting, it's not an immediate intervention that we're doing, is looking at saying how can we figure out what the core cause is behind a lot of these events are and implement programs to address those.

I think the point that was raised about sedatives or narcotics is a great one. That was a variable that I'm really hoping to look at along with other clinical variables like fluid balance, and mental status evaluations at the time of discharge.

For this first study there was a limit to the amount that we could pull from our medical records, given that our hospital is undergoing a change in our medical record system right now. So those are all definitely future directions we would like to consider.

And I think when we start to talk about prediction modeling, about better risk profiling, all those variables like medication dosage within the 24 hours prior to transfer, volume status, are super important to look at and will help give us insight beyond just patient characteristics, comorbidities and injuries that we have been able to look at in this study.

And then, finally, the comment about ICU bounce-backs and looking at, you know, what can we be doing in that first early period after transfer, I think that's a big take-away for me from this study is that a lot of these events happen early.

And many of the interventions that we do for patients for pulmonary complications, like frequent respiratory hygiene, or frequent monitoring, don't necessarily need to be delivered in an ICU setting.

So I think that the idea of dedicated floor teams, dedicated surveillance teams, or a dedicated respiratory therapy team that can, focus on these patients in this vulnerable window right after discharge is a great one and something that I hope to explore with future work.