Use of Noninvasive Versus Invasive Ventilation and Risk of 30-Day Readmission in Acute Decompensated Heart Failure

RCOP NRD A14

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## Preamble:

* **Reference Studies:**
  + [Lange et al., 2025](https://doi.org/10.4037/ajcc2025261)
  + [Mahmood et al., 2020](https://www.ahajournals.org/doi/10.1161/CIRCULATIONAHA.119.044642)
* **Study Objective:**
* To evaluate the association between ventilation modality, specifically noninvasive ventilation (NIV) versus invasive mechanical ventilation (IMV), and 30-day all-cause readmission risk among adult patients hospitalized with acute decompensated heart failure (ADHF). Secondary objectives include characterizing clinical outcomes during index admission and identifying predictors of readmission in this high-risk population.
* **Data Source:**
* This retrospective cohort study used data from the 2016–2017 Nationwide Readmissions Database (NRD), developed by the Healthcare Cost and Utilization Project (HCUP). The NRD is a nationally representative, all-payer database of U.S. hospitalizations that allows linkage of patients across hospital stays within a calendar year. Survey weights, stratification, and clustering variables support complex sampling design for national estimates.
* **Cohort Definition:**
* Index admissions were selected based on the following inclusion criteria:
  + Adults aged ≥18 years
  + Principal diagnosis of ADHF, defined by ICD-10-CM codes indicating acute or acute-on-chronic systolic, diastolic, or combined heart failure, and acute right heart failure:
    - I5021, I5023, I5031, I5033, I5041, I5043, I50811, I50813
  + Evidence of ventilation support during index stay, categorized into:
    - Noninvasive ventilation (NIV): codes 5A09357, 5A09358, 5A09457, 5A09458, 5A09557, 5A09558
    - Invasive mechanical ventilation (IMV): codes 5A1935Z, 5A1945Z, 5A1955Z
  + Non-elective admission
  + Index discharge by the end of November to allow for a complete 30-day follow-up period
  + Complete data on LOS and NRD\_DAYSTOEVENT, required to compute discharge dates
* **Outcomes of Interest:**
  + Primary Outcome:
    - 30-day all-cause readmission (Yes/No), flagged using NRD linkage variables
  + Secondary Outcomes (index admission):
    - In-hospital mortality (DIED)
    - Length of stay (LOS, continuous in days and also categorized as ≤4 vs >4 days)
    - Total hospitalization charges (TOTCHG), inflation-adjusted to 2017 USD
    - Non-home discharge
  + Outcomes during readmission:
    - In-hospital mortality
    - Length of stay (LOS, in days)
    - Total hospitalization charges (inflation-adjusted to 2017 USD)
* **Outcome Definitions:**
  + Readmission:
    - Defined using HCUP NRD’s methodology. Readmissions were identified only among patients with qualifying index events.
    - Trauma-related hospitalizations were excluded only from the readmission pool to avoid unrelated admissions.
  + Mortality:
    - In-hospital death recorded during index or readmission (DIED = 1)
  + LOS:
    - Reported in days; modeled as count outcome
  + Charge:
    - Derived from HCUP’s TOTCHG variable and adjusted to 2017 dollars using Consumer Price Index (CPI) data
* **Covariates and Variable Construction:**
  + Demographic & Socioeconomic Factors:
    - Age (continuous)
    - Sex (FEMALE; ref = Male)
    - Primary expected payer (Insurance; Medicare, Medicaid, Private, Other)
    - ZIP-based median income quartile (ZIPINC\_QRTL)
    - Weekend admission (AWEEKEND)
  + Comorbidities:
    - Elixhauser comorbidity variables:
      * Diabetes
      * Chronic pulmonary disease
      * Renal failure
      * Hypertension
      * Obesity
      * Cardiac arrhythmia
      * Valvular disease
    - Acute complications during index stay (from secondary diagnosis fields):
      * Acute respiratory failure (ARF): e.g., J9600, J9601, J9620
      * Cardiogenic shock: R570
      * Sepsis: A41*, A40*, R6520, R6521
  + Hospital Characteristics:
    - Hospital bed size (Small, Medium, Large)
    - Urban/rural teaching status (Metropolitan, teaching vs non-teaching, etc.)
  + Disposition and Severity:
    - Non-home discharge (e.g., SNF, hospice, other facilities, or death)
    - Length of stay (categorized as above)
* **Statistical Methods:**
  + Survey Design and Weighting:
    - All analyses accounted for NRD’s complex survey design using weights (DISCWT), strata (NRD\_STRATUM), and clustering (HOSP\_NRD). Survey-adjusted methods were implemented via survey and srvyr packages.
  + Descriptive Analyses:
    - Baseline characteristics were summarized by ventilation type (NIV vs IMV) among index admissions.
    - P-values from design-based statistical tests (Rao–Scott adjusted chi-square for categorical variables; design-based Kruskal–Wallis test for continuous variables).
  + Multivariable Regression:
    - A survey-weighted logistic regression modeled predictors of 30-day readmission.
    - The model included demographic, clinical, hospital-level, and index-stay factors.
    - Results were exponentiated to yield odds ratios (ORs) with 95% confidence intervals.
  + Readmission Characteristics:
    - A sub-analysis among patients with 30-day readmissions summarized readmission hospitalization characteristics descriptively using weighted survey statistics.
* **Software:** All analyses were conducted in R Statistical Language (Version 4.5.0; R Foundation for Statistical Computing, Vienna, Austria).

## Descriptive Analyses:

### Baseline Characteristics of Patients Hospitalized With Acute Decompensated Heart Failure, Stratified by Ventilation Type:

| **Characteristic** | **Overall** N = 74,431*1* | **Noninvasive Ventilation** N = 60,002*1* | **Invasive Mechanical Ventilation** N = 14,429*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| Age (years) | 70 (14) | 71 (14) | 66 (14) | <0.001 |
| Sex |  |  |  | <0.001 |
| Male | 37,512 (50%) | 29,137 (49%) | 8,376 (58%) |  |
| Female | 36,919 (50%) | 30,865 (51%) | 6,053 (42%) |  |
| Primary Expected Payer |  |  |  | <0.001 |
| Private | 7,935 (11%) | 5,795 (9.7%) | 2,140 (15%) |  |
| Medicaid | 8,321 (11%) | 6,225 (10%) | 2,095 (15%) |  |
| Medicare | 55,157 (74%) | 45,788 (76%) | 9,369 (65%) |  |
| Other | 2,939 (4.0%) | 2,137 (3.6%) | 801 (5.6%) |  |
| Median Income Quartile (by ZIP Code) |  |  |  | <0.001 |
| 0-25th percentile | 23,500 (32%) | 18,313 (31%) | 5,187 (37%) |  |
| 26th to 50th percentile | 19,370 (26%) | 15,640 (26%) | 3,730 (26%) |  |
| 51st to 75th percentile | 17,169 (23%) | 14,085 (24%) | 3,084 (22%) |  |
| 76th to 100th percentile | 13,400 (18%) | 11,210 (19%) | 2,190 (15%) |  |
| Admission Day |  |  |  | 0.4 |
| Monday-Friday | 55,273 (74%) | 44,498 (74%) | 10,775 (75%) |  |
| Saturday-Sunday | 19,158 (26%) | 15,504 (26%) | 3,654 (25%) |  |
| Hospital Bed Size |  |  |  | <0.001 |
| Small | 10,535 (14%) | 8,986 (15%) | 1,549 (11%) |  |
| Large | 42,942 (58%) | 33,638 (56%) | 9,305 (64%) |  |
| Medium | 20,954 (28%) | 17,378 (29%) | 3,576 (25%) |  |
| Hospital Location and Teaching Status |  |  |  | <0.001 |
| Metropolitan, non-teaching | 19,509 (26%) | 16,437 (27%) | 3,072 (21%) |  |
| Metropolitan, teaching | 48,637 (65%) | 37,971 (63%) | 10,666 (74%) |  |
| Non-metropolitan | 6,285 (8.4%) | 5,594 (9.3%) | 691 (4.8%) |  |
| Diabetes | 37,167 (50%) | 30,740 (51%) | 6,426 (45%) | <0.001 |
| Chronic Pulmonary Disease | 40,400 (54%) | 34,318 (57%) | 6,082 (42%) | <0.001 |
| Renal Failure | 35,604 (48%) | 28,652 (48%) | 6,952 (48%) | 0.6 |
| Obesity | 24,830 (33%) | 21,211 (35%) | 3,619 (25%) | <0.001 |
| Cardiac Arrhythmias | 43,442 (58%) | 33,883 (56%) | 9,559 (66%) | <0.001 |
| Valvular Heart Disease | 21,880 (29%) | 17,266 (29%) | 4,615 (32%) | <0.001 |
| Hypertension | 57,821 (78%) | 47,725 (80%) | 10,096 (70%) | <0.001 |
| Acute Respiratory Failure | 56,935 (76%) | 43,952 (73%) | 12,983 (90%) | <0.001 |
| Cardiogenic Shock | 5,921 (8.0%) | 1,778 (3.0%) | 4,143 (29%) | <0.001 |
| Sepsis | 4,323 (5.8%) | 1,547 (2.6%) | 2,776 (19%) | <0.001 |
| *1*Mean (SD); n (%) | | | | |
| *2*Design-based KruskalWallis test; Pearson's X^2: Rao & Scott adjustment | | | | |

### Outcomes of Index Hospitalizations by Ventilation Type

| **Characteristic** | **Overall** N = 74,431*1* | **Noninvasive Ventilation** N = 60,002*1* | **Invasive Mechanical Ventilation** N = 14,429*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| 30-Day Readmission | 13,594 (18%) | 11,644 (19%) | 1,949 (14%) | <0.001 |
| In-Hospital Mortality | 8,648 (12%) | 3,945 (6.6%) | 4,703 (33%) | <0.001 |
| Length of Stay (days) | 6 (3, 10) | 5 (3, 9) | 10 (6, 19) | <0.001 |
| Length of Stay Category |  |  |  | <0.001 |
| ≤4 days | 27,675 (37%) | 24,962 (42%) | 2,713 (19%) |  |
| >4 days | 46,756 (63%) | 35,040 (58%) | 11,716 (81%) |  |
| Inflation-Adjusted Total Charges ($) | 51,066 (27,767, 100,298) | 43,298 (24,933, 77,858) | 124,832 (62,263, 268,126) | <0.001 |
| Discharged to Non-Home Setting | 29,566 (40%) | 20,635 (34%) | 8,931 (62%) | <0.001 |
| *1*n (%); Median (Q1, Q3) | | | | |
| *2*Pearson's X^2: Rao & Scott adjustment; Design-based KruskalWallis test | | | | |

## Multivariable Analyses

### Multivariable Predictors of 30-Day Readmission Among Patients Receiving Ventilation During Index Hospitalization:

| **Characteristic** | **OR** | **95% CI** | **p-value** |
| --- | --- | --- | --- |
| Ventilation Type |  |  |  |
| Noninvasive Ventilation | — | — |  |
| Invasive Mechanical Ventilation | 0.75 | 0.69, 0.82 | <0.001 |
| Age (years) | 0.99 | 0.99, 0.99 | <0.001 |
| Sex |  |  |  |
| Male | — | — |  |
| Female | 1.09 | 1.03, 1.15 | 0.002 |
| Primary Expected Payer |  |  |  |
| Private | — | — |  |
| Medicaid | 1.52 | 1.35, 1.71 | <0.001 |
| Medicare | 1.41 | 1.27, 1.57 | <0.001 |
| Other | 1.04 | 0.87, 1.23 | 0.7 |
| Median Income Quartile (by ZIP Code) |  |  |  |
| 0-25th percentile | — | — |  |
| 26th to 50th percentile | 0.93 | 0.86, 1.00 | 0.054 |
| 51st to 75th percentile | 0.88 | 0.82, 0.95 | 0.002 |
| 76th to 100th percentile | 0.87 | 0.79, 0.94 | 0.001 |
| Admission Day |  |  |  |
| Monday-Friday | — | — |  |
| Saturday-Sunday | 1.03 | 0.97, 1.10 | 0.3 |
| Hospital Bed Size |  |  |  |
| Small | — | — |  |
| Large | 0.99 | 0.91, 1.08 | 0.8 |
| Medium | 1.04 | 0.95, 1.14 | 0.4 |
| Hospital Location and Teaching Status |  |  |  |
| Metropolitan, non-teaching | — | — |  |
| Metropolitan, teaching | 1.05 | 0.98, 1.13 | 0.2 |
| Non-metropolitan | 1.04 | 0.92, 1.18 | 0.5 |
| Diabetes |  |  |  |
| No | — | — |  |
| Yes | 1.16 | 1.09, 1.23 | <0.001 |
| Chronic Pulmonary Disease |  |  |  |
| No | — | — |  |
| Yes | 1.29 | 1.22, 1.37 | <0.001 |
| Renal Failure |  |  |  |
| No | — | — |  |
| Yes | 1.30 | 1.23, 1.38 | <0.001 |
| Obesity |  |  |  |
| No | — | — |  |
| Yes | 0.85 | 0.80, 0.91 | <0.001 |
| Cardiac Arrhythmias |  |  |  |
| No | — | — |  |
| Yes | 1.04 | 0.98, 1.10 | 0.2 |
| Valvular Heart Disease |  |  |  |
| No | — | — |  |
| Yes | 1.00 | 0.94, 1.06 | >0.9 |
| Hypertension |  |  |  |
| No | — | — |  |
| Yes | 0.99 | 0.92, 1.06 | 0.8 |
| Acute Respiratory Failure |  |  |  |
| No | — | — |  |
| Yes | 0.90 | 0.85, 0.96 | <0.001 |
| Cardiogenic Shock |  |  |  |
| No | — | — |  |
| Yes | 0.74 | 0.65, 0.84 | <0.001 |
| Sepsis |  |  |  |
| No | — | — |  |
| Yes | 0.63 | 0.54, 0.73 | <0.001 |
| Length of Stay Category |  |  |  |
| ≤4 days | — | — |  |
| >4 days | 1.20 | 1.13, 1.27 | <0.001 |
| Discharged to Non-Home Setting |  |  |  |
| No | — | — |  |
| Yes | 0.84 | 0.79, 0.89 | <0.001 |
| Abbreviations: CI = Confidence Interval, OR = Odds Ratio | | | |

## Readmission Hospitalization Characteristics

### Outcomes of 30-Day Readmission Hospitalizations (Among Patients Ventilated at Index Admission)

| **Characteristic** | **N = 13,597***1* |
| --- | --- |
| In-Hospital Mortality | 1,056 (7.8%) |
| Length of Stay | 5.0 (3.0, 8.0) |
| Inflation-Adjusted Total Charges ($) | 38,286 (20,747, 75,701) |
| *1*n (%); Median (Q1, Q3) | |