Assessment of Hospital Readmission Rates, Risk Factors, and Causes After Cardiac Arrest
Analysis of the US Nationwide Readmissions Database

Ilhwan Yeo, MD, MS; Jim W. Cheung, MD; Dmitriy N. Feldman, MD; Nivee Amin, MD; John Chae, BA; S. Chiu Wong, MD; Luke K. Kim, MD

Introduction

Cardiac arrest (CA) remains a global health challenge with high rates of mortality and morbidity.\textsuperscript{1,2} Furthermore, recovery from CA without residual neurologic deficit is limited. Consequently, the burden of CA on the US health care system is increasing.\textsuperscript{3} However, there is a paucity of data regarding the readmission characteristics of CA, and previous studies have mostly focused on older populations.\textsuperscript{4} Therefore, further understanding of readmission after CA is needed to allow institutions to focus already limited resources and prevent unnecessary readmissions. We aimed to investigate contemporary rate, timing, causes, and risk factors associated with 30-day readmissions after CA.

Methods

This cohort study used data from the Nationwide Readmissions Database (NRD) from 2010 to 2014. Data analysis was performed from January 1, 2010, to November 30, 2014. The NRD collects annual discharge data and enables nationally representative readmission analyses.\textsuperscript{5} All hospitalizations associated with either out-of-hospital CA or in-hospital CA were selected based on the International Classification of Diseases, Ninth Revision, Clinical Modification code 427.5. Among those with CA, ventricular tachycardia and ventricular fibrillation were identified by codes 427.1 and 427.4, respectively. Pulseless electrical activity or asystole arrests were defined as CA without concomitant ventricular arrhythmia. The primary outcome of interest was 30-day all-cause readmission. To identify independent risk factors associated with 30-day readmission following discharge after CA, we created a multivariable Cox proportional hazards regression model. The Weill Cornell Medicine institutional review board deemed this study exempt because the NRD is a publicly available database containing deidentified patient information. All analyses were performed using SAS statistical software version 9.4 (SAS Institute). All tests were 2-sided, with \( P < .05 \) indicating statistical significance. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.

Results

There were 251,346 patients who survived the CA-related index hospitalization. Median (interquartile range) age was 64.8 (53.7-75.8) years, and 106,831 participants (42.5\%) were women (Table 1). Among CA survivors, 49,305 (19.6\%) were readmitted within 30 days after discharge. While 30-day readmission rate was higher in the cohort with pulseless electrical activity or asystole than in the cohort with ventricular tachycardia or ventricular fibrillation (20.3\% vs 18.3\%; difference, 2.0\%; 95\% CI, 1.7\%-2.4\%; \( P < .001 \)), the median (interquartile range) time to readmission was 9 (4-18) days for both cohorts.
Overall, approximately three-quarters (72.1%) of the 30-day readmissions were due to noncardiac causes, which were more common among patients with pulseless electrical activity or asystole than those with ventricular tachycardia or ventricular fibrillation (77.2% vs 61.4%; difference, 15.7%; 95% CI, 14.9%-16.6%; \( P < .001 \)). Among noncardiac causes, infectious etiology (pneumonia and sepsis) was most prevalent (18.9%), followed by chronic obstructive pulmonary

Table 1. Baseline Individual- and Hospital-Level Characteristics for Cardiac Arrest Survivors Stratified by Causative Rhythm

| Characteristic                        | Overall | 30-Day Readmission | 30-Day Readmission | PEA or Asystole (n = 166 492) | PEA or Asystole (n = 166 492) |
|--------------------------------------|---------|--------------------|--------------------|-------------------------------|-------------------------------|
|                                      | No. (%) | No | Yes | P Value | No | Yes | P Value |
| No. of patients                      | 251 346 | 69 358 (81.7)     | 15 496 (18.3)     | .001                           | 132 683 (79.7)             | 33 809 (20.3)             |
| Age, median (IQR), y                 | 64.8 (53.7-75.8) | 62.6 (52.8-72.8) | 65.2 (55.2-74.9) | .001 | 66.1 (54.3-77.2) | 66.4 (55.6-76.8) | .42 |
| Female                               | 106 831 (42.5) | 23 152 (33.4) | 5682 (36.7) | .001 | 61 572 (46.4) | 16 425 (48.6) | .001 |
| ST-elevation myocardial infarction   | 32 584 (13.0) | 19 125 (27.6) | 3368 (21.7) | .001 | 8295 (6.3) | 1796 (5.3) | .001 |
| Pulmonary embolism                   | 8563 (3.4) | 1403 (2.0) | 393 (2.5) | .07 | 5423 (4.1) | 1344 (4.0) | .62 |
| Coma                                 | 9790 (3.9) | 2942 (4.2) | 486 (3.1) | .01 | 5328 (4.0) | 1034 (3.1) | .10 |
| Hypertension                         | 153 419 (61.0) | 41 415 (59.7) | 9613 (62.0) | .004 | 80 500 (60.7) | 14 026 (41.5) | .001 |
| Diabetes                             | 83 635 (33.3) | 19 518 (28.1) | 502 (35.5) | .01 | 44 589 (33.6) | 10 792 (30.7) | .001 |
| Coronary artery disease              | 104 277 (41.5) | 40 067 (57.8) | 8812 (56.9) | .01 | 43 323 (32.7) | 12 075 (35.7) | .001 |
| Myocardial infarction                | 19 831 (7.9) | 7326 (10.6) | 1631 (10.5) | .01 | 8424 (6.3) | 2450 (7.2) | .001 |
| Pericardial tamponade                | 17 686 (7.0) | 6350 (9.0) | 1390 (9.0) | .01 | 7794 (5.9) | 2153 (6.4) | .08 |
| Coronary artery bypass graft         | 16 437 (6.5) | 4908 (7.1) | 1204 (7.8) | .11 | 8090 (6.1) | 2234 (6.6) | .07 |
| Congestive heart failure             | 100 016 (39.8) | 30 327 (43.7) | 8760 (56.5) | .001 | 45 980 (34.7) | 14947 (44.2) | .001 |
| Cardiac arrest                       | 5523 (2.2) | 2378 (3.4) | 379 (2.4) | .01 | 2315 (1.7) | 451 (1.3) | .001 |
| Peripheral vascular disease          | 20 980 (8.3) | 4977 (7.2) | 1608 (10.4) | .01 | 10 792 (8.1) | 3603 (10.7) | .001 |
| Pulmonary hypertension               | 18 339 (7.3) | 4446 (6.4) | 1384 (8.9) | .01 | 9562 (7.2) | 2947 (8.7) | .001 |
| Chronic pulmonary disease            | 49 776 (19.8) | 11 565 (16.7) | 3778 (24.1) | .01 | 26 517 (20.0) | 8318 (24.6) | .001 |
| Chronic kidney disease               | 49 755 (19.8) | 11 057 (16.7) | 3377 (21.8) | .01 | 26 303 (19.8) | 8737 (25.8) | .001 |
| Hemodialysis                         | 26 341 (10.5) | 4509 (6.5) | 2160 (13.9) | .01 | 13 720 (10.3) | 5951 (17.6) | .001 |
| Anemia                               | 71 400 (28.4) | 16 135 (23.3) | 4696 (30.3) | .01 | 38 499 (29.0) | 12 070 (35.7) | .001 |
| Atrial fibrillation                  | 65 876 (26.2) | 18 934 (27.3) | 4792 (30.9) | .01 | 32 881 (24.8) | 9269 (27.4) | .001 |
| Coagulopathy                         | 36 886 (14.7) | 9171 (13.2) | 2506 (16.2) | .01 | 19 516 (14.7) | 5694 (16.8) | .001 |
| Obesity                              | 37 946 (15.1) | 10 306 (14.9) | 2425 (15.7) | .18 | 19 677 (14.8) | 5537 (16.4) | .001 |
| Pulmonary circulation disorders      | 15 909 (6.3) | 2343 (3.4) | 887 (5.7) | .01 | 9676 (7.3) | 3003 (8.9) | .001 |
| Vascular heart disease               | 15 116 (6.0) | 2862 (4.1) | 960 (6.2) | .01 | 8781 (6.6) | 2513 (7.4) | .005 |
| Elixhauser Comorbidity index score   | 141 903 (56.5) | 33 711 (48.6) | 9739 (62.8) | .01 | 75 425 (56.8) | 23 028 (68.1) | .001 |

Abbreviations: IQR, interquartile range; PEA, pulseless electrical activity; VF, ventricular fibrillation or flutter; VT, ventricular tachycardia.

a Nonteaching hospital as reference.

b Rural hospital location as reference.

c Length of stay days exceeding the 75th percentile (\( \geq 20 \) days) of the entire stay days.
disease or respiratory failure (13.3%). Heart failure and arrhythmia accounted for more than 50% of all cardiac causes of readmission. After adjusting for baseline characteristics, several comorbidities were independently associated with a higher risk of 30-day readmission across the rhythm cohorts (Table 2).

**Discussion**

Given the high readmission rates and substantial economic burden associated with CA, nationwide efforts are necessary to develop strategies designed explicitly for CA survivors to reduce preventable readmissions. Of those readmitted within 30 days, more than half were readmitted within 9 days, especially for noncardiac causes. Close outpatient follow-up during the first 10 days after hospitalization may be an opportunity for clinicians to preemptively intervene on any evolving medical conditions and consequently prevent readmissions for CA survivors.6 Furthermore, patients with limited access to health care owing to their socioeconomic status have been shown to use the emergency department more as a primary source of care, which may lead to more readmissions. Therefore, multidisciplinary efforts to support the transition from inpatient to outpatient care with a readily available support system, including proper patient education, follow-up telephone calls, use of remote telemonitoring, clinician home visits, and postdischarge hotlines are potential strategies to

### Table 2. Risk Factors Associated With 30-Day Readmission After Cardiac Arrest–Related Index Hospitalization

| Covariate                          | VT or VF |          |          |          | PEA or Asystole |          |          |
|------------------------------------|----------|----------|----------|----------|----------------|----------|----------|
|                                    | Univariatea | Multivariableb | Univariatea | Multivariableb |
|                                    | Unadjusted HR (95% CI) | P Value | Adjusted HR (95% CI) | P Value | Unadjusted HR (95% CI) | P Value | Adjusted HR (95% CI) | P Value |
| Female                             | 1.14 (1.07-1.21) | <.001 | 1.05 (0.99-1.12) | .13 | 1.08 (1.04-1.12) | <.001 | 1.06 (1.02-1.11) | .002 |
| Chronic kidney disease receiving hemodialysis | 2.07 (1.92-2.24) | <.001 | 1.56 (1.43-1.70) | <.001 | 1.70 (1.62-1.78) | <.001 | 1.44 (1.36-1.52) | <.001 |
| Prolonged hospital staya          | 1.71 (1.61-1.81) | <.001 | 1.38 (1.30-1.48) | <.001 | 1.46 (1.40-1.52) | <.001 | 1.35 (1.29-1.41) | <.001 |
| History of congestive heart failure | 1.58 (1.49-1.68) | <.001 | 1.27 (1.20-1.36) | <.001 | 1.42 (1.37-1.48) | <.001 | 1.19 (1.14-1.24) | <.001 |
| Chronic kidney disease          | 1.53 (1.43-1.64) | <.001 | 1.21 (1.12-1.30) | <.001 | 1.35 (1.29-1.41) | <.001 | 1.17 (1.12-1.23) | <.001 |
| Chronic pulmonary disease       | 1.34 (1.25-1.43) | <.001 | 1.16 (1.08-1.25) | <.001 | 1.27 (1.21-1.33) | <.001 | 1.18 (1.12-1.24) | <.001 |
| Intra-aortic balloon pump        | 1.04 (0.94-1.16) | .41 | NCc | NC | 1.13 (1.00-1.27) | .048 | 1.18 (1.04-1.34) | .01 |
| Peripheral vascular disease      | 1.43 (1.30-1.56) | <.001 | 1.16 (1.06-1.27) | .002 | 1.29 (1.21-1.38) | <.001 | 1.11 (1.03-1.19) | .005 |
| Percutaneous coronary intervention | 0.78 (0.73-0.83) | <.001 | 1.13 (1.03-1.24) | .007 | 0.88 (0.81-0.95) | .002 | 0.97 (0.87-1.08) | .57 |
| Diabetes                          | 1.35 (1.27-1.43) | <.001 | 1.08 (1.01-1.15) | .02 | 1.34 (1.29-1.40) | <.001 | 1.12 (1.07-1.17) | <.001 |
| Anemia                             | 1.37 (1.29-1.46) | <.001 | 1.07 (1.00-1.14) | .06 | 1.31 (1.26-1.37) | <.001 | 1.06 (1.02-1.11) | .007 |
| Urban hospital locationa         | 1.14 (1.07-1.21) | <.001 | 1.08 (1.01-1.15) | .02 | 1.15 (1.10-1.20) | <.001 | 1.06 (1.01-1.10) | .009 |
| Elixhauser Comorbidity Index score >4 | 1.68 (1.58-1.79) | <.001 | 1.06 (0.97-1.15) | .24 | 1.54 (1.48-1.60) | <.001 | 1.06 (1.00-1.13) | .04 |
| Atrial fibrillation               | 1.17 (1.10-1.24) | <.001 | 1.01 (0.95-1.07) | .79 | 1.13 (1.08-1.18) | <.001 | 1.05 (1.01-1.10) | .03 |
| Hypertension                      | 1.09 (1.03-1.16) | .003 | 0.93 (0.87-0.99) | .02 | 1.17 (1.12-1.22) | <.001 | 0.99 (0.94-1.03) | .50 |
| Coronary angiography              | 0.71 (0.67-0.75) | <.001 | 0.89 (0.83-0.95) | <.001 | 0.95 (0.90-1.00) | .04 | 0.98 (0.92-1.05) | .61 |
| History of cardiac arrest         | 0.72 (0.61-0.85) | <.001 | 0.81 (0.69-0.96) | .01 | 0.78 (0.67-0.92) | .003 | 0.77 (0.65-0.90) | .001 |
| Targeted temperature management   | 0.66 (0.57-0.77) | <.001 | 0.76 (0.66-0.89) | <.001 | 0.90 (0.76-1.07) | .22 | NC | NC |
| Coma                               | 0.76 (0.65-0.89) | <.001 | 0.73 (0.62-0.84) | <.001 | 0.78 (0.70-0.86) | <.001 | 0.75 (0.67-0.82) | <.001 |

Abbreviations: HR, hazard ratio; NC, not calculated; PEA, pulseless electrical activity; VF, ventricular fibrillation or flutter; VT, ventricular tachycardia.

*a* Univariate Cox proportional hazards regression model was created with an outcome of 30-day readmission for each covariate from Table 1.

*b* Multivariable Cox proportional hazards regression model was created with an outcome of 30-day readmission including all covariates with *P* < .10 in the univariate analysis, and the covariates with *P* < .05 for either rhythm cohort are listed.

*c* Length of stay days exceeding the 75th percentile (>20 days) of the entire stay days.

*d* Covariate with *P* > .10 in the univariate analysis was not included in the multivariable analysis.

*e* Rural hospital location as reference.
consider. A limitation of our study is that we were unable to validate the codes for comorbidities from the International Classification of Diseases, Ninth Revision, Clinical Modification.

Conclusions

This cohort study found increased rates of readmission among patients who survived CA. Early follow-up with health care professionals may enable timely management of both cardiac and general medical conditions and reduce preventable readmissions of CA survivors.

ARTICLE INFORMATION

Accepted for Publication: August 9, 2019.

Published: September 27, 2019. doi:10.1001/jamanetworkopen.2019.12208

Open Access: This is an open access article distributed under the terms of the CC-BY License. © 2019 Yeo I et al. JAMA Network Open.

Corresponding Author: Ilhwan Yeo, MD, MS, Icahn School of Medicine at Mount Sinai, One Gustave L. Levy Place, PO Box 1086, New York, NY 10029-6574 (ilhwan.yeo@mountsinai.org).

Author Affiliations: Division of Hospital Medicine, Department of Medicine, Icahn School of Medicine at Mount Sinai, The Mount Sinai Hospital, New York, New York (Yeo); Weill Cornell Cardiovascular Outcomes Research Group, Division of Cardiology, Department of Medicine, Weill Cornell Medicine, New York Presbyterian Hospital, New York (Cheung, Feldman, Amin, Wong, Kim); Weill Cornell Medicine, New York Presbyterian Hospital, New York (Chae).

Author Contributions: Drs Yeo and Kim had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: Yeo, Feldman, Kim.

Acquisition, analysis, or interpretation of data: Yeo, Cheung, Amin, Chae, Wong, Kim.

Drafting of the manuscript: Yeo, Chae, Kim.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Yeo, Kim.

Obtained funding: Kim.

Administrative, technical, or material support: Yeo, Wong, Kim.

Supervision: Yeo, Cheung, Feldman, Kim.

Conflict of Interest Disclosures: Dr Cheung reported receiving consulting fees from Biosense Webster and fellowship grant support from Biosense Webster and Abbott. No other disclosures were reported.

Funding/Support: This work was supported by grants from the Michael Wolk Heart Foundation, the New York Cardiac Center, Inc, and New York Weill Cornell Medical Center Alumni Council.

Role of the Funder/Sponsor: The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

REFERENCES

1. Benjamin EJ, Virani SS, Callaway CW, et al; American Heart Association Council on Epidemiology and Prevention Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics—2018 update: a report from the American Heart Association. Circulation. 2018;137(12):e67-e492. doi:10.1161/CIR.0000000000000558

2. Girotra S, Nallamothu BK, Spertus JA, Li Y, Krumholz HM, Chan PS; American Heart Association Get With the Guidelines-Resuscitation Investigators. Trends in survival after in-hospital cardiac arrest. N Engl J Med. 2012;367(20):1912-1920. doi:10.1056/NEJMoa1109148

3. Zuckerman RB, Sheingold SH, Orav EJ, Rueter J, Epstein AM. Readmissions, observation, and the hospital readmissions reduction program. N Engl J Med. 2016;374(16):1543-1551. doi:10.1056/NEJMoa1513024

4. Chan PS, McNally B, Nallamothu BK, et al. Long-term outcomes among elderly survivors of out-of-hospital cardiac arrest. J Am Heart Assoc. 2016;5(3):e002924. doi:10.1161/JAHA.115.002924
5. Agency for Healthcare Research and Quality. Introduction to the HCUP Nationwide Readmissions Database (NRD). [https://www.hcup-us.ahrq.gov/db/nation/nrd/Introduction_NRD_2010-2014.pdf](https://www.hcup-us.ahrq.gov/db/nation/nrd/Introduction_NRD_2010-2014.pdf). Accessed August 8, 2019.

6. Hernandez AF, Greiner MA, Fonarow GC, et al. Relationship between early physician follow-up and 30-day readmission among Medicare beneficiaries hospitalized for heart failure. *JAMA*. 2010;303(17):1716-1722. doi:10.1001/jama.2010.533