Original Article

Incidence and Survival After In-Hospital Cardiopulmonary Resuscitation in Nonelderly Adults

US Experience, 2007 to 2012

Sagar Mallikethi-Reddy, MD; Alexandros Briasoulis, MD, PhD;
Emmanuel Akintoye, MD, MPH; Kavyashri Jagadeesh, MD; Robert D. Brook, MD;
Melvyn Rubenfire, MD; Luis Afonso, MD; Cindy L. Grines, MD

Background**—**Survival trends after in-hospital cardiopulmonary resuscitation (ICPR) for cardiac arrest in nonelderly adults is not well known. Influence of cardiopulmonary resuscitation guidelines on nationwide survival after ICPR is yet to be well elucidated.

Methods and Results**—**We examined survival trends and factors associated with survival after ICPR in nonelderly adults aged 18 to 64 years, using Healthcare Utilization Project Nationwide Inpatient Sample Database from 2007 through 2012 in the United States. Furthermore, we studied the impact of 2010 American Heart Association cardiopulmonary resuscitation guidelines on survival. We identified 235 959 patients who underwent ICPR after cardiac arrest. Overall, 30.4% patients survived to hospital discharge. Survival improved from 27.4% in 2007 to 32.8% in 2012 (P_{trend}<0.001). Shockable arrest rhythms were noted in 23.3% of patients. Incidence of ICPR increased from 1.81 per 1000 hospitalizations in 2007 to 2.37 per 1000 hospitalizations in 2012 (P_{trend}<0.001). There was no statistically significant change in survival trends before and after 2010 cardiopulmonary resuscitation guidelines. Female sex and shockable rhythms were associated with higher adjusted odds of survival, whereas black race, lack of health insurance, age, and weekend admission were associated with lower adjusted odds of survival.

Conclusions**—**Among nonelderly adults, survival after ICPR improved significantly from 2007 through 2012, with an overall survival rate of 30.4%. Incidence of ICPR increased significantly during the study period. There was no statistically significant change in survival before and after 2010 cardiopulmonary resuscitation guidelines. Female sex and black race were associated with higher and lower odds of survival, respectively. **(*Circ Cardiovasc Qual Outcomes*. 2017;10:e003194. DOI: 10.1161/CIRCOUTCOMES.116.003194.)**

Key Words: adult ■ aged ■ American Heart Association ■ atropine ■ cardiopulmonary resuscitation ■ survival

Nearly 209 000 adults undergo in-hospital cardiopulmonary resuscitation (ICPR) for in-hospital cardiac arrest (IHCA) in the United States annually.[1] Considerable effort has been expended during the past decade, with assorted attempts, primarily aimed at improving outcomes after cardiopulmonary resuscitation (CPR) for IHCA and out-of hospital cardiac arrest, even as opportunities for further improvement remain.[2]

The overall incidence of ICPR in a nationally representative study of elderly Medicare patients was 2.73 per 1000 admissions, and overall survival post-ICPR was 18.3%.[3] Of note, no improvement in incidence or survival after IPCR was reported in the elderly from 1992 to 2005.[3] A subsequent large study showed that survival to hospital discharge improved significantly, at hospitals participating in a national quality improvement registry from 2000 through 2009.[4] The above data notwithstanding, comparable data on survival trends and incidence of ICPR in nonelderly adults are lacking.

The overall survival rate for hospitalized adults after ICPR was 19% in 2010.[5] The American Heart Association (AHA) has set a goal for doubling the survival rate to 38%, by the year 2020.[2] During the past 2 decades, the AHA has published CPR guidelines quinquennially (every 5 years) with the most recent one being 2015.[5] There were number of modifications (initiation of chest compressions before rescuer breaths; chest compression rate of at least 100/min; elimination of look, listen, and feel for breathing; chest compression depth of at least 2 inches; use of continuous quantitative wave capnography; abolition of atropine use in nonshockable rhythms; and aggressive use of therapeutic hypothermia) in basic life support and advanced cardiovascular life support algorithms recommended in the 2010 AHA CPR guidelines[6] in an attempt to improve CPR outcomes. However, whether these guidelines have had a significant impact in bettering outcomes after IHCA remains unclear.

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From the Division of Cardiology, Detroit Medical Center, Wayne State University School of Medicine, MI (S.M.-R., A.B., E.A., K.J., L.A., C.L.G.); and Division of Cardiovascular Medicine, University of Michigan Medical School, Ann Arbor (R.D.B., M.R.).

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Correspondence to Sagar Mallikethi-Reddy, MD, Division of Cardiology, Wayne State University School of Medicine, 3990 John R, 4 Hudson, Detroit MI 48201. E-mail smaliket@med.wayne.edu

WHAT IS KNOWN

- Temporal trends in incidence and survival after in-hospital cardiopulmonary resuscitation for cardiac arrest in elderly patient population is well studied.
- However, a similar study on recent temporal trends in nonelderly adults is lacking.
- Furthermore, impact of 2010 AHA CPR guidelines on in-hospital survival outcomes has not been well studied.

WHAT THE STUDY ADDS

- Among nonelderly adults in the United States, survival after ICPR improved significantly from 2007 through 2012, with an overall survival rate of 30.4%, notwithstanding the increasing incidence of ICPR.
- There was no statistically significant change in survival before and after 2010 CPR guidelines; however, we observed a continuous linear trend in survival improvement during the entire study period.

Our study objectives were accordingly 3-fold: (1) to identify the trends in incidence of ICPR and survival after ICPR among nonelderly adult (age 18–64 years) patient population in the United States from year 2007 through 2012; (2) to determine patient- and hospital-level factors associated with survival; and (3) to study whether 2010 AHA CPR guidelines[6] had a significant impact on survival in the United States.

Methods

Source of Data

Our analysis is based on the data of the Nationwide Inpatient Sample (NIS), which is the largest publicly available all-payer inpatient database in the United States. The NIS is a part of the Healthcare Cost and Utilization Project (HCUP) sponsored by the Agency for Healthcare Research and Quality and provides nationally representative data on ≈8 million hospital stays from ≈1000 hospitals that approximates 20% of discharges from nonfederal US community hospitals, representing >95% of hospital discharges nationwide.[7] A unique stratified systematic random-sampling design was used to make the database a more representative sample of nationwide discharges. A stratified random sample of discharges was obtained systematically from a list of all hospital discharges. HCUP NIS databases are built from hospital administrative data (ie, hospital billing records containing all the data elements) and are based on the data collection efforts of various organizations, such as hospital associations, state data organizations, and private data organizations (ie, HCUP partners), through Federal–State–Industry partnership (sponsored by Agency for Healthcare Research and Quality). Professional medical coders at each hospital generate the codes found in the discharge data.[7] The database includes unique identifiers for the hospitalization and clinical information for each hospital stay. To generate national estimates, Agency for Healthcare Research and Quality recommends using discharge trend weights that are provided in the HCUP NIS database.[8]

Study Population

After applying discharge trend weights, we estimated a total of 236 069 nonelderly adults (unweighted n=49 016), aged 18 to 64 years, who underwent CPR for IHCA during the years 2007 to 2012, using *International Classification of Diseases*, *Ninth Revision*, Clinical Modification (ICD-9-CM) procedure codes (99.60 or 99.63). These codes have been used to determine national estimates in previous studies.[3,9] We excluded 110 subjects with missing data on survival. An outline of the patient selection is shown in Figure 1.

Study Outcomes

The primary outcome of interest was survival to hospital discharge. We studied the temporal trends in survival to hospital discharge for both sex and racial categories during 6-year study period. We also analyzed the trends in incidence of CPR per 1000 hospitalizations and disposition in survivors. Patient- and hospital-level characteristics (age, sex, race, baseline comorbidities, median household income, insurance coverage, weekend admission, arrest rhythm, disposition, hospital bed size, location, teaching status, and region) that were associated with survival after ICPR were also identified. Furthermore, we determined whether there is any significant change in survival trends before and after 2010 AHA CPR guidelines.

Shockable cardiac arrest rhythms were identified using ICD-9-CM codes 427.41; 427.42 (ventricular fibrillation or ventricular flutter); and 427.1 (ventricular tachycardia). Patients were considered to have nonshockable cardiac arrest rhythms (pulseless electrical activity or asystole) if discharge records did not contain either of the codes for shockable cardiac arrest rhythms.[9] Acute myocardial infarction (AMI), utilization of coronary angiogram, and revascularization were determined using ICD-9-CM codes (Table I in the Data Supplement). Severity of underlying chronic illness was assessed using Elixhauser comorbidity score,[10] which contains 29 comorbidities defined by Agency for Healthcare Research and Quality, with higher scores indicating higher burden. Elixhauser comorbidity measure is a well-validated index for predicting in-hospital mortality.[11]

Because HCUP NIS is a publicly available database that contains completely deidentified patient data, it is exempt from Institutional Review Board approval.

Statistical Analysis

The statistical analyses were performed using STATA 14 (StataCorp, College Station, TX) and IBM SPSS Statistics 23 (IBM Corp, Armonk, NY). We applied discharge trend weights to unweighted records during the statistical analysis to generate national estimates. We tested all variables for normal data distribution. We used the χ^2 test

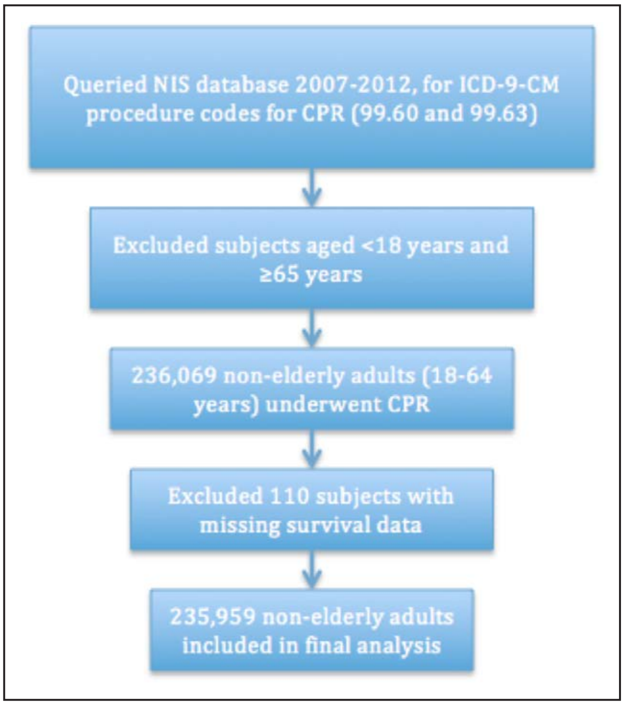

Figure 1. Patient selection.

to compare the distributions of categorical variables for the 2 groups. One-way ANOVA (if normally distributed) or Kruskal–Wallis test (if not normally distributed) was used for comparison of continuous variables. Because of the nested pattern of observations in the NIS database, we used the mixed-effect logistic model to assess temporal trends and evaluation for independent factors associated with survival after CPR for IHCA. This model enabled us to account for the potential correlation of observations within each hospital. As patient factors are nested within hospital-level factors, we build a hierarchical model with unique hospital identification number as random effects in the model. Temporal trends were assessed by modeling year (coded as 2007–2012) as a continuous independent variable. To evaluate for independent factors associated with survival, we included patient- and hospital-level characteristics in a multivariable model. Data were complete for all variables except hospital location (18%), race (11%), insurance (5.6%), median income (3.2%), hospital bed size (0.7%), and teaching status (0.7%). Although 35% of the observations had at least one missing value, we did not recognize any pattern to the missingness among variables. We, therefore, performed multiple imputations using the chained equation procedure in STATA to account for the missing data. Estimates with and without imputation were identical, so we retained the former. All significance tests were 2 tailed and conducted at the 5% significance level.

Results

Baseline Characteristics

We identified a total of 235 959 patients who underwent CPR after IHCA. The Table 1 presents the comparison of patient and hospital characteristics among both groups of patients (in-hospital mortality versus survival to hospital discharge) during the study period. Overall, the mean age of the cohort was 50.9±10.9 years, with no significant difference between groups. The in-hospital mortality cohort had a relatively higher percentage of black patients (27.9% versus 22.6%) and men (59% versus 57%). Mean Elixhauser comorbidity score was slightly higher in the survival group (3.67 versus 3.53). However, compared with the survival cohort, those with in-hospital mortality were noted to have a higher percentage of alcohol abuse, connective tissue disorder, coagulopathy, fluid and electrolyte disturbance, liver disease, neoplasm, and pulmonary circulation disorder. Survival to discharge cohort had higher percentage of patients with highest median household income and private health insurance. AMI was seen more commonly in those who survived than those who died (22.2% versus 15.6%). Shockable arrest rhythms (ventricular tachycardia or ventricular fibrillation) were more frequently found in the survival group than in mortality group (29.9% versus 20.4%). Most common discharge disposition in patients who survived was home (40.3%). Higher proportion of patients in the survival group were from a hospital in Midwest (21.1 versus 18%) and rural location (8.9% versus 7.5%) in comparison to the mortality group. Mean Elixhauser comorbidity score increased significantly during the study period (3.12 in 2007, 3.38 in 2008, 3.46 in 2009, 3.55 in 2010, 3.88 in 2011, and 3.92 in 2012; P_{trend}<0.001).

Most common causes of cardiac arrest were sepsis (16.2%), respiratory failure (14.7%), AMI (8.6%), surgical procedural complications (4.3%), sudden cardiac arrest (3.7%), congestive heart failure (3.7%), trauma (3.1%), pneumonia (2.9%), substance abuse (2.8%), arrhythmias (2.4%), stroke (2.3%), hepatobiliary disorders (1.9%), vascular disorders (1.7%), intestinal disorders (1.6%), acute renal failure (1.5%), diabetic complications (1.5%), coronary artery disease (1.5%), etc (Table II in the Data Supplement).

Outcomes

Among 235 959 patients who underwent CPR after IHCA, 30.4% survived to hospital discharge and 69.6% had in-hospital mortality. We observed a significant improvement in survival rates during the study period, from 27.4% in 2007 to 32.8% in 2012 (P_{trend}<0.001; Figure 2). Overall survival to discharge rate was 33.1% in whites when compared with 26% among blacks. Significant improvement in survival trends were noted across different races after adjustment for age, sex, and Elixhauser comorbidity score (P_{trend}<0.001; Figure 3). Overall survival rate was slightly higher in women than that in men (31.4% versus 29.7%). Survival rate improved significantly during the study period across both sexes after adjustment for age, race, and Elixhauser comorbidity score (P_{trend}<0.001; Figure 4).

Although we observed a steady improvement in rates of survival to hospital discharge from 2007 through 2012, we did not find a statistically significant change in survival trends before and after the publication of 2010 AHA CPR guidelines[6] (Figure 5). Incidence of ICPR increased from 1.81 per 1000 hospitalizations in 2007 to 2.37 per 1000 hospitalizations in 2012 (P_{trend}<0.001). Figure 6 demonstrates the divergent trends in incidence of ICPR and in-hospital mortality after CPR from 2007 through 2012.

Among survivors of IHCA, the percentage of patients who were discharged home, a skilled nursing facility, and short-term hospital were 53.1%, 31.2%, and 13.8%, respectively. Trends in discharge disposition during the 6-year study period are shown in Figure 7.

Overall, shockable arrest rhythms were found in 23.3% of patients. Proportion of patients with shockable rhythms increased from 21.2% in 2007 to 25% in 2012 (P_{trend}<0.001). Shockable arrest rhythms were noted among 21.6% of patients in Northeast, 22.7% in South, 23.9% in West, and 25.3% in the Midwest. Overall survival to discharge was 38.9% in shockable arrest rhythm and 27.7% in nonshockable arrest rhythm. We noted significant improvement in survival trends in patients with shockable arrest rhythm, from 2007 through 2012 (P_{trend}<0.001; Figure 8). Coronary angiography was performed in 11.2% and coronary revascularization (percutaneous coronary intervention [PCI] or coronary bypass surgery) in 6.7% patients after ICPR. Among those who underwent coronary revascularization, 63% survived to discharge as opposed to only 28% in those who did not undergo coronary revascularization.

The multivariate model included age, sex, race, Elixhauser score, median income, type of insurance, weekend admission, AMI, arrest rhythm, hospital bed size, region, location, and teaching status as fixed effect while modeling hospital ID as random effect and showed that female sex (adjusted odds ratio [OR], 1.11; 95% confidence interval [CI], 1.07–1.16) AMI (adjusted OR, 1.42; 95% CI, 1.34–1.49), shockable rhythms (adjusted OR, 1.56; 95% CI, 1.49–1.64), and use of private health insurance (adjusted OR, 1.10; 95% CI, 1.04–1.16) were associated with significantly higher survival rates, whereas black race (adjusted OR, 0.77; 95% CI, 0.73–0.81),

Table 1. Baseline Characteristics

Variables	In-Hospital Mortality	Survival to Hospital Discharge	Overall	*P* Value
Total number of CPR, n	164 320	71 639	235 959	<0.001
Age, y (mean±SD)	50.9±10.9	50.8±10.9	50.9±10.9	0.09
18–34 y	10.6	11.0	10.7	
35–49 y	24.5	24.9	24.6	
50–64 y	64.9	64.1	64.6	
Female sex, %	41.0	43.0	41.6	<0.001
Race, %				<0.001
White	53.2	60.5	55.4	
Black	27.9	22.6	26.3	
Others	18.9	27.9	18.3	
Elixhauser comorbidity score (mean±SD)	3.53±2.08	3.67±2.18	3.57±2.11	<0.001
0	5.7	5.7	5.7	
1	11.4	11.1	11.3	
2	17.0	16.2	16.8	
≥3	65.9	67.0	66.2	
Comorbidities, %				
Dyslipidemia	15.4	23.2	17.8	<0.001
AIDS	0.8	0.7	0.8	<0.06
Alcohol abuse	10.7	9.9	10.5	<0.004
Connective tissue diseases	2.9	2.3	2.7	0.001
Chronic pulmonary disease	20.5	23.7	21.5	<0.001
Anemia	23.1	27.6	24.5	<0.001
Coagulopathy	20.7	14.6	18.9	<0.001
Diabetes mellitus	29.7	31.8	30.4	<0.001
Depression	7.3	9.3	7.9	<0.001
Drug abuse	7.2	7.9	7.4	<0.01
Hypertension	44.9	51.4	46.9	<0.001
Hypothyroidism	6.3	7.4	6.6	<0.001
Fluid and electrolyte disturbance	56.7	52.6	55.4	<0.001
Liver disease	9.4	5.5	8.2	<0.001
Lymphoma	1.5	0.7	1.2	<0.001
Solid tumor	2.9	1.5	2.5	<0.001
Metastatic cancer	5.3	2.2	4.4	<0.001
Neurological disorder	11.6	14.5	12.5	<0.001
Paralysis	3.9	4.9	4.2	<0.001
Obesity	14.6	16.9	15.3	<0.001
Peripheral vascular disease	7.8	8.0	7.8	0.39
Psychoses	5.0	6.7	5.5	<0.001
Pulmonary circulation disorder	7.4	6.0	7.0	<0.001
Valvular disease	3.7	4.5	4.0	<0.001
Weight loss	10.4	13.0	11.2	<0.001
Renal failure	22.9	23.7	23.1	<0.05

(*Continued*)

Table 1. Continued

Variables	In-Hospital Mortality	Survival to Hospital Discharge	Overall	*P* Value
Median household income national quartile for patient ZIP code				<0.001
0–25th percentile	35.9	33.0	35.0	
26th–50th percentile	25.6	25.3	25.5	
51st–75th percentile	22.8	23.3	23.0	
76th–100th percentile	15.7	18.4	16.5	
Expected primary payer, %				<0.001
Medicare	27.8	27.8	27.8	
Medicaid	23.0	21.9	22.7	
Private insurance	31.1	36.8	32.8	
Weekend admission, %	25.5	23.3	24.8	<0.001
AMI, %	15.6	22.2	17.6	<0.001
Heart failure, %	22.6	29.4	24.7	<0.001
Arrest rhythm				<0.001
Nonshockable rhythm	79.6	70.1	76.7	
Shockable rhythm	20.4	29.9	23.3	
Disposition, %				<0.001
Home	…	40.3	12.2	
Short-term hospital	…	13.8	4.2	
Skilled nursing facility	…	31.2	9.5	
Home healthcare	…	12.8	3.9	
Hospital characteristics				
Hospital bed size, %				0.05
Small	8.2	8.8	8.4	
Medium	24.2	24.5	24.3	
Large	67.6	66.7	67.3	
Hospital location, %				<0.001
Rural	7.5	8.9	7.9	
Urban	92.5	91.1	92.1	
Teaching status, %				<0.001
Nonteaching	48.0	50.5	48.7	
Teaching	52.0	49.5	51.3	
Hospital region, %				<0.001
Northeast	17.2	14.5	16.4	
Midwest	18.0	21.1	19.0	
South	40.2	39.4	39.9	
West	24.6	25.0	24.7	

AMI indicates acute myocardial infarction; and CPR, cardiopulmonary resuscitation.

lack of health insurance (adjusted OR, 0.63; 95% CI, 0.58–0.68), and age (adjusted OR, 0.99; 95% CI, 0.99–0.99) were associated with significantly lower survival rates compared with the reference categories (*P* for all <0.001) as shown in Table 2. Weekend admission (adjusted OR, 0.89; 95% CI, 0.85–0.93; *P*<0.001), urban hospital (adjusted OR, 0.82; 95% CI, 0.75–0.90; *P*<0.001), and large hospital size (adjusted OR, 0.90; 95% CI, 0.83–0.98; *P*=0.02) were associated with lower survival rates. Geographically, Midwest hospitals were associated with significantly higher survival compared with Northeast hospital locations (adjusted OR, 1.38; 95% CI, 1.26–1.50; *P*<0.001).

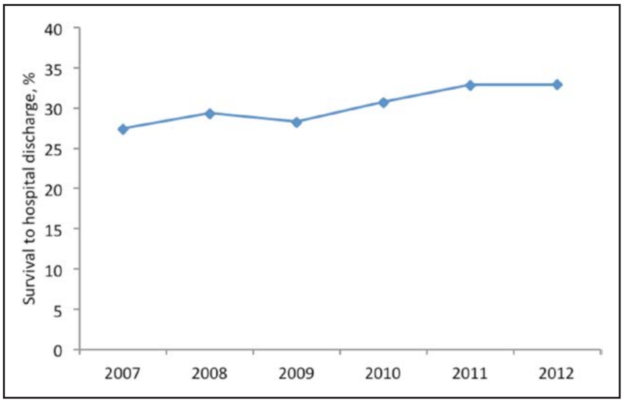

Figure 2. Trends in survival to hospital discharge among US patients undergoing cardiopulmonary resuscitation for in-hospital cardiac arrest between 2007 and 2012. P_{trend}<0.001 (odds ratios, 1.05 [95% confidence interval, 1.03–1.07] after adjusting for age, sex, race, and Elixhauser score).

Discussion

In our study of a large nationwide inpatient database comprising 235 959 hospitalized nonelderly adults (aged 18–64 years) who underwent ICPR after cardiac arrest, we found that the rate of survival to discharge improved from 27.4% in 2007 to 32.9% in 2012 (overall survival rate of 30.4%) in the United States, notwithstanding the increasing incidence of CPR during this time period. However, no significant change in survival trend before and after the 2010 AHA CPR guidelines was observed. Female sex, private health insurance, AMI as a cause of cardiac arrest, shockable arrest rhythm, and higher income were each associated with better survival.

Overall survival to hospital discharge after ICPR has been reported to vary from 17% to 24.7% in previous nationwide studies.[3,4,9] However, we found a significantly better survival rate of 30.4%. There are many potential explanations for this discrepancy in survival. Unlike our study population of nonelderly adults, Ehlenbach et al[3] analyzed a large cohort of elderly Medicare beneficiaries aged ≥65 years from 1992 through 2005 and found overall survival to discharge rate of 18.3%, without

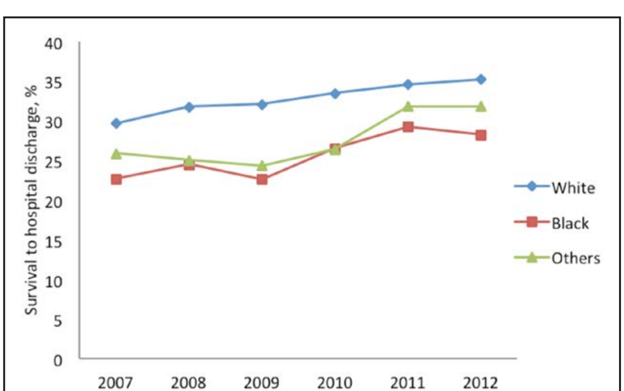

Figure 3. Trends in survival to hospital discharge among US patients undergoing cardiopulmonary resuscitation for in-hospital cardiac arrest between 2007 and 2012, stratified by race. P_{trend}<0.001 for each racial category (odds ratios, 1.05 [95% confidence interval {CI}, 1.03–1.07], 1.06 [95% CI, 1.03–1.09], and 1.07 [95% CI, 1.03–1.10] among white, black, and others, respectively, after adjusting for age, sex, and Elixhauser score).

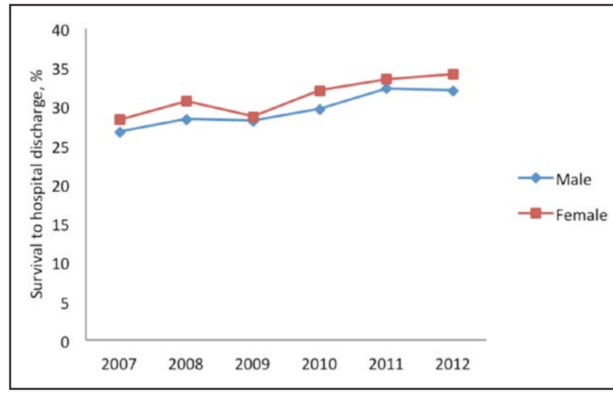

Figure 4. Trends in survival to hospital discharge among US patients undergoing cardiopulmonary resuscitation for in-hospital cardiac arrest between 2007 and 2012, stratified by sex. P_{trend}<0.001 for each sex (odds ratios, 1.05 [95% confidence interval {CI}, 1.03–1.07] and 1.05 [95% CI, 1.03–1.07] among male and female patients, respectively, after adjusting for age, race, and Elixhauser score).

any improving trends. Advanced age is a known poor predictor of success after ICPR.[12] A recent study on 838 465 hospitalized adult patients aged ≥18 years (mean age of 67 years) in the same NIS database (from 2003 through 2011) showed that the overall survival was 24.7%.[9] The fact that we restricted our analyses to the age group 18 to 64 years (mean age of 51 years) during years 2007 to 2012 may partly explain the difference in survival to discharge. Much lower survival rate of 17% was observed in a study of patients at hospitals participating in the AHA Get with the Guidelines Resuscitation Registry, but these results may not be generalizable nationwide.[4] In contrast, our study represents a real-world inpatient population. Similar to our study, improving survival trends after ICPR have been observed during the past 10 to 15 years.[4,9]

We noted ≈31% increase in incidence of ICPR from 2007 to 2012. Severity of comorbid illnesses also worsened significantly during the study period as reflected by increasing

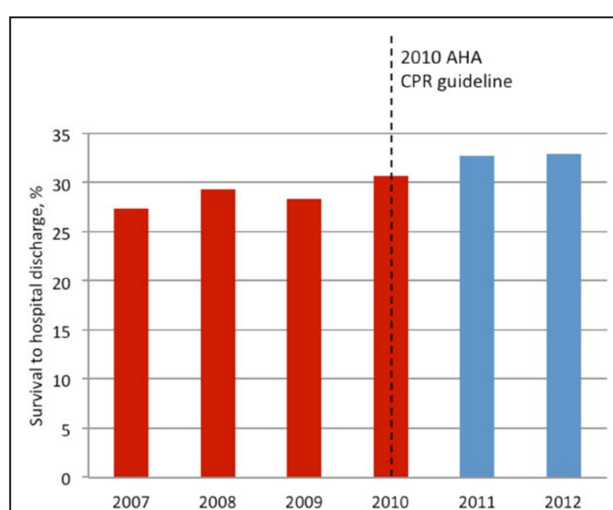

Figure 5. Survival to hospital discharge among US patients undergoing cardiopulmonary resuscitation for in-hospital cardiac arrest before (in red) and after (in blue) the 2010 American Heart Association guidelines for cardiopulmonary resuscitation (CPR). P_{trend}<0.001 from 2007 to 2012.

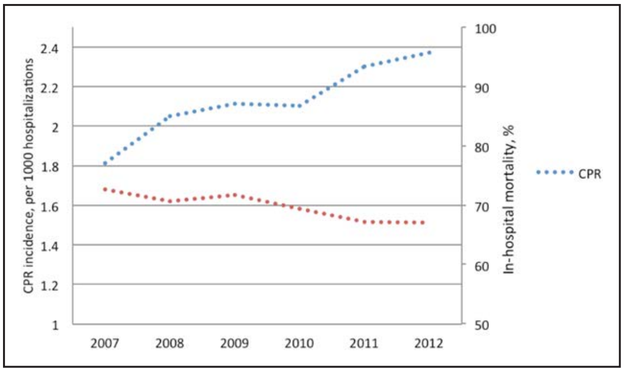

Figure 6. Trends in the incidence of in-hospital cardiopulmonary resuscitation (CPR) compared with trends in mortality post-CPR for in-hospital cardiac arrest in US patients between 2007 and 2012. P_{trend}<0.001 for both trends.

Elixhauser comorbidity scores from 2007 through 2012 in our study. The overall incidence of ICPR was 2.12 per 1000 hospitalizations in this study, which is lower than previously reported incidence of 2.73 to 2.85 per 1000 hospitalizations from earlier studies that studied predominant elderly cohorts.[3,9] In aggregate, the increase in incident ICPR possibly relates to more aggressive strategies used by hospitals in treating critically ill patients,[1,9] variability in approach to end-of-life care,[1] and worsening severity of comorbid illness, as observed in our study. Early recognition of deranged vital signs, prompt availability of rapid response teams, and timely transfer to intensive care units have all been shown to be effective in reducing not only the ICPR incidence but also the in-hospital mortality.[2] Significant regional and state-wide variation in incidence of ICPR has been reported in a previous study by Kolte et al.[9] The lowest incidence was observed in the Midwest (2.33 per 1000 admissions), whereas the highest incidence was in the West (3.73 per 1000 admissions). These investigators also reported an inverse correlation between the survival after IHCA and ICPR incidence at the state level. Racial variation in ICPR incidence has also been reported with blacks and whites having the highest and lowest incidence, respectively.[3] The higher incidence in blacks has, in turn, been attributed to a higher burden of acute and chronic comorbidities prevalent in this subset.[3]

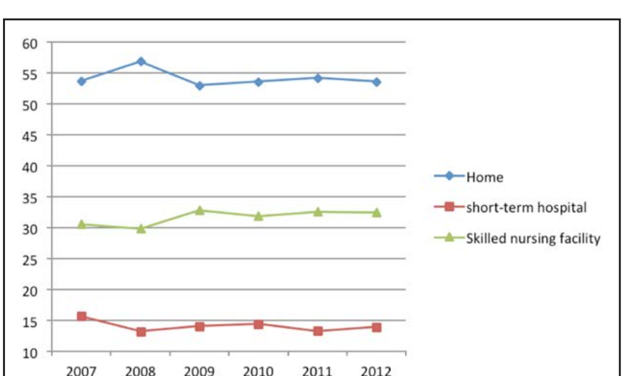

Figure 7. Trends in disposition among survivors of in-hospital cardiopulmonary resuscitation (CPR). P_{trend}=0.58, P_{trend}=0.02, and P_{trend}<0.001 for home, short-term hospital, and skilled nursing facility, respectively.

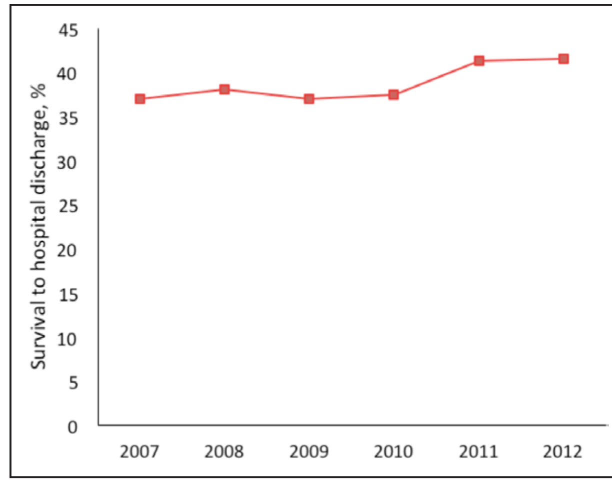

Figure 8. Trends in survival to hospital discharge among US patients undergoing cardiopulmonary resuscitation for in-hospital cardiac arrest between 2007 and 2012, stratified by shockable vs nonshockable rhythm. Odds ratio for trend=1.05 (95% confidence interval [CI], 1.02–1.07; *P*=0.001) for shockable rhythm after adjusting for age, race, and Elixhauser score.

After rigorous adjustments for confounding variables, several patient- and hospital-level characteristics (Table 2) were independently associated with survival after ICPR in our study. We found female sex to be significantly associated with better survival than men, a finding consistent with previous studies[3,9] but at odds with a Canadian study that found no difference in either sex.[13] Similar to other studies,[3,14] we found black race to be independently associated with poor survival post-ICPR than whites, which partially is thought to be because of care received at poorly performing hospitals.[3,14] Older age was modestly associated with lower odds of survival in this analysis, unlike previous studies with inconsistent results.[3,4,9,13] Higher median household income was associated with improved survival to hospital discharge, which is not surprising as socioeconomic status and cardiovascular disease burden are inversely proportional.[15] In agreement with a previous study,[16] lack of health insurance was found to be associated with lowest odds of survival, whereas private insurance was associated with higher survival after ICPR as compared with Medicare insurance. Urban location and larger size of the hospital were associated with lower survival to discharge rates. Hospitals in Midwest had higher odds of survival in comparison to Northeast, and the results were congruent with a recent study on regional variation in ICPR in the United States.[9] The percentage of patients with shockable cardiac arrest rhythm was significantly higher in the Midwest in comparison to the Northeast region in our study, which probably explains better survival outcomes in Midwest. Interestingly, weekend admissions were associated with lower odds of survival after ICPR, highlighting the possibility of inefficient care over the weekends.[17] Proportion of survivors being discharged home declined significantly from 1992 through 2005 in elderly patients[3]; however, we found no significant change trend in the younger cohort.

Shockable cardiac arrest rhythms are associated with better survival than nonshockable rhythms.[3,4] We found shockable

Table 2. Factors Associated With Survival to Hospital Discharge Among US Patients Undergoing Cardiopulmonary Resuscitation for In-Hospital Cardiac Arrest

Factors	Adjusted Odds Ratio (95% CI)*	*P* Value
Age, y	0.99 (0.99–0.99)	<0.001
Female sex	1.11 (1.07–1.16)	<0.001
Race		
White	Reference	
Black	0.77 (0.73–0.81)	<0.001
Others	0.84 (0.79–0.90)	<0.001
Median household income†	1.04 (1.01–1.06)	0.001
Weekend admission	0.89 (0.85–0.93)	<0.001
Insurance		
Medicare	Reference	
Medicaid	0.98 (0.92–1.04)	0.45
Private	1.10 (1.04–1.16)	<0.001
Self-pay	0.63 (0.58–0.68)	<0.001
Acute myocardial infarction	1.42 (1.34–1.49)	<0.001
Arrest rhythm		
Nonshockable rhythm	Reference	
Shockable rhythm	1.56 (1.49–1.64)	<0.001
Hospital bed size		
Small	Reference	
Medium	0.95 (0.87–1.04)	0.28
Large	0.90 (0.83–0.98)	0.02
Hospital location		
Rural	Reference	
Urban	0.82 (0.75–0.90)	<0.001
Hospital region		
Northeast	Reference	
Midwest	1.38 (1.26–1.50)	<0.001
South	1.18 (1.10–1.28)	<0.001
West	1.19 (1.09–1.30)	<0.001

CI indicates confidence interval.

*The multivariate model included age, sex, race, Elixhauser score, median income, type of insurance, weekend admission, acute myocardial infarction, arrest rhythm, hospital bed size, hospital region, hospital location, and teaching vs nonteaching status as fixed-effect while modeling hospital ID as random effect.

†Represent the increase in the odds of survival across quartile of household income (eg, 2nd vs 1st quartile; 3rd vs 2nd quartile, etc).

rhythms in ≈23% of our study population, which is slightly higher than previous studies,[4,9] which partially explains our better survival rates after ICPR. Furthermore, patients with shockable rhythms and AMI were noted to have 56% and 46% higher odds of survival, respectively, than those who did not. We hypothesize that our study cohort might have had earlier access to coronary revascularization, considering younger age probably contributing to better outcomes.

In comparison to the 2005 AHA CPR guidelines,[18] the 2010 CPR guidelines had a few notable modifications in basic life support and advanced cardiovascular life support algorithms[6] directed at potentially improving CPR outcomes. Although we observed an improving linear trend in survival from 2007 through 2012, we did not find a statistically significant improvement in survival when we compared trends before and after the 2010 CPR guidelines.[6] Possible explanations for this observation include the effect of guidelines might have been better appreciated if we had included elderly patients, who constitute a major proportion of cardiac arrests nationally. It is also possible that the linear improvement in survival trends from 2007 to 2010 might be because of 2005 AHA CPR guidelines[18] and the improvement from 2010 to 2012 might be because of 2010 guidelines.[6] Certainly, complying with guidelines and being part of national quality improvement registries have shown better outcomes after ICPR.[4]

In our study, only 6.7% of patients underwent coronary revascularization, which is consistent with a previous study.[19] Among those who underwent revascularization, 63% of patients survived to hospital discharge. Timely coronary angiography with potential PCI improves survival after cardiac arrest.[20,21] Yet, only 11.2% of patients underwent coronary angiography after IHCA in our study. The underutilization of coronary angiography and PCI after cardiac arrest is probably because of current public reporting standards that consider mortality after PCI as a procedural complication although in most instances PCI is an innocent bystander.[22] AHA's goal for doubling survival rates to 38% by 2020[2] is probably achievable in nonelderly adults especially if coronary angiography with potential PCI is performed more frequently. We are of the opinion that goals should be age group specific, with much higher goals set for nonelderly adults.

We would like to acknowledge several important limitations. We identified CPR procedures using ICD-9 codes, but CPR codes are not well validated and hence are subject to coding limitations.[3,9] Because the NIS database contains deidentified data, validation of ICD-9 codes is difficult to perform.[9] Nonshockable arrest rhythms do not have a specific ICD-9 codes; however, proportion of IHCA patients with nonshockable rhythms is similar to previous reports.[4,9] NIS database lacks accurate information on postresuscitation ECG finding, time-to-CPR, time-to-defibrillation, time-to-death, time-to-discharge, do-not-resuscitate policies, and important neurological outcome determinants such as cerebral performance category and the use of hypothermia protocol because they potentially influence ICPR incidence or survival outcomes. However, home discharge likely indicates good cerebral performance category. The timing of coronary revascularization after IHCA is not well defined in NIS database, although it is known to influence outcomes. Information on the site of IHCA such as medical floors, surgical floors, or intensive care units was not available. Although we did not observe significant change in survival trends before and after 2010 AHA CPR guidelines, we think that survival improvement from 2007 through 2012 is probably because of overall better resuscitation care nationally and periodic updates in CPR guidelines.[5] The nature of the NIS database does not allow us to study compliance with AHA CPR guidelines. The dissemination and implementation of guidelines into practice requires time; in this context, a study by Berdowski et al[23] noted that it took ≈1.5 years to implement CPR guidelines in emergency medical systems in the Netherlands. We only had 2 years of data (2011–2012) post 2010 guidelines, which might explain the lack of statistically significant survival improvement during this time frame. Despite these limitations, a major strength of our study on NIS is that it comprises real-world patients with national estimates representing >95% of the US inpatient population, unlike previous studies that focused only on elderly medicare cohort[3] or hospitals participating in quality improvement registries.[4]

Conclusions

We found that survival to hospital discharge after ICPR in nonelderly adults aged 18 to 64 years improved from 2007 through 2012 in the United States. Incidence of ICPR also increased significantly during the study period. Black race, advancing age, weekend admission, and lack of health insurance were associated with poor survival, and hence, such patients may need more intense postresuscitation monitoring. In contrast, female sex, higher median household income, private health insurance, AMI, and shockable cardiac arrest rhythms were associated with better survival. Although we observed no statistically significant change in survival trends before and after the 2010 AHA CPR guidelines were released, further studies analyzing more recent years of data in adults of all age groups may provide more definitive insight into the impact of the guidelines on survival.

Disclosures

None.

References

1. Merchant RM, Yang L, Becker LB, Berg RA, Nadkarni V, Nichol G, Carr BG, Mitra N, Bradley SM, Abella BS, Groeneveld PW; American Heart Association Get With The Guidelines-Resuscitation Investigators. Incidence of treated cardiac arrest in hospitalized patients in the United States. *Crit Care Med*. 2011;39:2401–2406. doi: 10.1097/CCM.0b013e3182257459.
2. Kronick SL, Kurz MC, Lin S, Edelson DP, Berg RA, Billi JE, Cabanas JG, Cone DC, Diercks DB, Foster JJ, Meeks RA, Travers AH, Welsford M. Part 4: systems of care and continuous quality improvement: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2015;132(18 suppl 2):S397–S413. doi: 10.1161/CIR.0000000000000258.
3. Ehlenbach WJ, Barnato AE, Curtis JR, Kreuter W, Koepsell TD, Deyo RA, Stapleton RD. Epidemiologic study of in-hospital cardiopulmonary resuscitation in the elderly. *N Engl J Med*. 2009;361:22–31. doi: 10.1056/NEJMoa0810245.
4. 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;367:1912–1920. doi: 10.1056/NEJMoa1109148.
5. Neumar RW, Shuster M, Callaway CW, Gent LM, Atkins DL, Bhanji F, Brooks SC, de Caen AR, Donnino MW, Ferrer JM, Kleinman ME, Kronick SL, Lavonas EJ, Link MS, Mancini ME, Morrison LJ, O'Connor RE, Samson RA, Schexnayder SM, Singletary EM, Sinz EH, Travers AH, Wyckoff MH, Hazinski MF. Part 1: executive summary: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2015;132(18 suppl 2):S315–S367. doi: 10.1161/CIR.0000000000000252.
6. Field JM, Hazinski MF, Sayre MR, Chameides L, Schexnayder SM, Hemphill R, Samson RA, Kattwinkel J, Berg RA, Bhanji F, Cave DM, Jauch EC, Kudenchuk PJ, Neumar RW, Peberdy MA, Perlman JM, Sinz E, Travers AH, Berg MD, Billi JE, Eigel B, Hickey RW, Kleinman ME, Link MS, Morrison LJ, O'Connor RE, Shuster M, Callaway CW, Cucchiara B, Ferguson JD, Rea TD, Vanden Hoek TL. Part 1: executive summary: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2010;122(18 suppl 3):S640–S656. doi: 10.1161/CIRCULATIONAHA.110.970889.
7. Overview of the National (Nationwide) Inpatient Sample (NIS). http://www.hcup-us.ahrq.gov/nisoverview.jsp. Accessed February 15, 2016.
8. Trend Weights for HCUP NIS Data. http://www.hcup-us.ahrq.gov/db/nation/nis/trendwghts.jsp. Accessed February 15, 2016.
9. Kolte D, Khera S, Aronow WS, Palaniswamy C, Mujib M, Ahn C, Iwai S, Jain D, Sule S, Ahmed A, Cooper HA, Frishman WH, Bhatt DL, Panza JA, Fonarow GC. Regional variation in the incidence and outcomes of in-hospital cardiac arrest in the United States. *Circulation*. 2015;131:1415–1425. doi: 10.1161/CIRCULATIONAHA.114.014542.
10. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care*. 1998;36:8–27.
11. Southern DA, Quan H, Ghali WA. Comparison of the Elixhauser and Charlson/Deyo methods of comorbidity measurement in administrative data. *Med Care*. 2004;42:355–360.
12. Schneider AP 2nd, Nelson DJ, Brown DD. In-hospital cardiopulmonary resuscitation: a 30-year review. *J Am Board Fam Pract*. 1993;6:91–101.
13. Brindley PG, Markland DM, Mayers I, Kutsogiannis DJ. Predictors of survival following in-hospital adult cardiopulmonary resuscitation. *CMAJ*. 2002;167:343–348.
14. Chan PS, Nichol G, Krumholz HM, Spertus JA, Jones PG, Peterson ED, Rathore SS, Nallamothu BK; American Heart Association National Registry of Cardiopulmonary Resuscitation (NRCPR) Investigators. Racial differences in survival after in-hospital cardiac arrest. *JAMA*. 2009;302:1195–1201.
15. Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, Cushman M, Das SR, de Ferranti S, Després JP, Fullerton HJ, Howard VJ, Huffman MD, Isasi CR, Jiménez MC, Judd SE, Kissela BM, Lichtman JH, Lisabeth LD, Liu S, Mackey RH, Magid DJ, McGuire DK, Mohler ER 3rd, Moy CS, Muntner P, Mussolino ME, Nasir K, Neumar RW, Nichol G, Palaniappan L, Pandey DK, Reeves MJ, Rodriguez CJ, Rosamond W, Sorlie PD, Stein J, Towfighi A, Turan TN, Virani SS, Woo D, Yeh RW, Turner MB; American Heart Association Statistics Committee; Stroke Statistics Subcommittee. Heart disease and stroke statistics-2016 update: a report from the American Heart Association. *Circulation*. 2016;133:e38–e360.
16. Wilper AP, Woolhandler S, Lasser KE, McCormick D, Bor DH, Himmelstein DU. Health insurance and mortality in US adults. *Am J Public Health*. 2009;99:2289–2295. doi: 10.2105/AJPH.2008.157685.
17. Bell CM, Redelmeier DA. Mortality among patients admitted to hospitals on weekends as compared with weekdays. *N Engl J Med*. 2001;345:663–668. doi: 10.1056/NEJMsa003376.
18. Ecc Committee Subcommittees, and Task Forces of the American Heart Association. 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation.* 2005;112:IV1–IV203.
19. Fugate JE, Brinjikji W, Mandrekar JN, Cloft HJ, White RD, Wijdicks EF, Rabinstein AA. Post-cardiac arrest mortality is declining: a study of the US National Inpatient Sample 2001 to 2009. *Circulation*. 2012;126:546–550. doi: 10.1161/CIRCULATIONAHA.111.088807.
20. Callaway CW, Donnino MW, Fink EL, Geocadin RG, Golan E, Kern KB, Leary M, Meurer WJ, Peberdy MA, Thompson TM, Zimmerman JL. Part 8: post-cardiac arrest care: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2015;132(18 suppl 2):S465–S482. doi: 10.1161/CIR.0000000000000262.
21. Spaite DW, Bobrow BJ, Stolz U, Berg RA, Sanders AB, Kern KB, Chikani V, Humble W, Mullins T, Stapczynski JS, Ewy GA; Arizona Cardiac Receiving Center Consortium. Statewide regionalization of postarrest care for out-of-hospital cardiac arrest: association with survival and neurologic outcome. *Ann Emerg Med*. 2014;64:496–506.e1. doi: 10.1016/j.annemergmed.2014.05.028.
22. Rab T, Wilson H; Interventional Council; Board of Governors. Public reporting of mortality after PCI in cardiac arrest and cardiogenic shock: an opinion from the Interventional Council and the Board of Governors of the American College of Cardiology. *JACC Cardiovasc Interv*. 2016;9:496–498. doi: 10.1016/j.jcin.2015.12.006.
23. Berdowski J, Schmohl A, Tijssen JG, Koster RW. Time needed for a regional emergency medical system to implement resuscitation Guidelines 2005–The Netherlands experience. *Resuscitation*. 2009;80:1336–1341. doi: 10.1016/j.resuscitation.2009.08.011.

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Incidence and Survival After In-Hospital Cardiopulmonary Resuscitation in Nonelderly Adults: US Experience, 2007 to 2012

Sagar Mallikethi-Reddy, Alexandros Briasoulis, Emmanuel Akintoye, Kavyashri Jagadeesh, Robert D. Brook, Melvyn Rubenfire, Luis Afonso and Cindy L. Grines

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SUPPLEMENTAL MATERIAL

Online Supplement Table 1: International Classification of Diseases, Ninth Revision, Clinical Modification codes used to identify comorbidities and procedures

Comorbidities and Procedures	ICD-9-CM Codes
Ventricular fibrillation or Ventricular flutter	427.41; 427.42
Ventricular tachycardia	427.1
Acute myocardial infarction	410.0 to 410.92
Cardiopulmonary resuscitation	99.60; 99.63
Heart failure	428.0 to 428.43
Dyslipidemia	272.0 to 272.4
Cardiac catheterization	3721 to 3723; 8852 to 8857
Percutaneous coronary intervention	0066; 1755; 3601; 3602; 3603; 3604; 3605; 3606; 3607
Coronary bypass surgery	36.10 to 36.17; 36.19; 36.2; 36.3; 36.31 to 36.34; 36.39

Online Supplement Table 2: Principal diagnosis associated with cardiac arrest

1. Sepsis: 16.2%
2. Respiratory failure (with or without chronic obstructive pulmonary disease, asthma, pulmonary embolism, aspiration pneumonitis, etc): 14.7%
3. Acute myocardial infarction: 8.6%
4. Surgical procedural complications: 4.3%
5. Sudden cardiac arrest: 3.7%
6. Congestive heart failure: 3.7%
7. Trauma with or without head injury: 3.1%
8. Pneumonia: 2.9%
9. Drug abuse/ alcohol abuse/ drug overdose/ poisoning: 2.8%
10. Arrhythmias: 2.4%
11. Stroke: 2.3 %
12. Hepatobiliary disorders: 1.9%
13. Vascular disorders (Aneurysms, peripheral vascular disease, etc): 1.7%
14. Intestinal obstruction, diverticular disease and other gastrointestinal illness: 1.6%
15. Acute renal failure: 1.5%
16. Diabetes related complications: 1.5%
17. Coronary artery disease: 1.5%
18. Gastrointestinal bleeding: 1.3%
19. Human Immunodeficiency Virus: 1.2%
20. Drug overdose/Poisoning: 1%
21. Fluid and electrolyte imbalance: 1%
22. Secondary malignancy: 1%
23. Psychiatric illness: 0.9%
24. Myocarditis/Pericarditis: 0.9%
25. Pancreatic illness: 0.8%
26. Hypertension: 0.8%
27. Fracture: 0.8%
28. Lung cancer: 0.7%
29. Coma/ Brain damage: 0.6%
30. Syncope: 0.6%
31. Anemia (Sickle cell or other types): 0.6%
32. Seizures: 0.5%
33. Valvular heart disease: 0.5%
34. Other nervous system disorders 0.5%
35. Dematologic infection 0.4%
36. Leukemias 0.4%
37. Disorders of spine 0.4%
38. Nutrition related illness 0.3%
39. Abdominal hernia: 0.3%
40. Osteoarthritis: 0.2%
41. Non-Hodgkins lymphoma: 0.2%
42. Urinary tract infection 0.2%
43. Complicated delivery 0.2%
44. Others- 10%