Early Cardiac Arrest in Patients Hospitalized With Pneumonia

A Report From the American Heart Association's Get With the Guidelines-Resuscitation Program

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Background: Pneumonia is the leading infectious cause of death. Early deterioration and death commonly result from progressive sepsis, shock, respiratory failure, and cardiac complications. Recent data suggest that cardiac arrest may also be common, yet few previous studies have addressed this. Accordingly, we sought to characterize early cardiac arrest in patients who are hospitalized with coexisting pneumonia.

Methods: We performed a retrospective analysis of a multicenter cardiac arrest database, with data from >500 North American hospitals. We included in-hospital cardiac arrest events that occurred in community-dwelling adults with pneumonia within the first 72 h after hospital admission. We compared patient and event characteristics for patients with and without pneumonia. For patients with pneumonia, we also compared events according to event location.

Results: We identified 4,453 episodes of early cardiac arrest in patients who were hospitalized with pneumonia. Among patients with preexisting pneumonia, only 36.5% were receiving mechanical ventilation and only 33.3% were receiving infusions of vasoactive drugs prior to cardiac arrest. Only 52.3% of patients on the ward were receiving ECG monitoring prior to cardiac arrest. Shockable rhythms were uncommon in all patients with pneumonia (ventricular tachycardia or fibrillation, 14.8%). Patients on the ward were significantly older than patients in the ICU.

Conclusions: In patients with preexisting pneumonia, cardiac arrest may occur in the absence of preceding shock or respiratory failure. Physicians should be alert to the possibility of abrupt cardiopulmonary collapse, and future studies should address this possibility. The mechanism may involve myocardial ischemia, a maladaptive response to hypoxia, sepsis-related cardiomyopathy, or other phenomena.

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Abbreviations: GWTR = Get With the Guidelines-Resuscitation; IHCA = in-hospital cardiac arrest; PEA = pulseless electrical activity

In the United States, pneumonia causes >1 million hospitalizations annually, with hospital mortality approaching 18%.^{1–4} Early complications are common, and most deaths occur in the initial days after admission.⁵ Twenty percent of patients hospitalized for pneumonia require intensive care on admission.^{3,6} Of those patients initially admitted to the routine ward, a similar fraction deteriorates within 72 h.^{7–11} Death commonly results from progressive sepsis, shock, and respiratory failure,^{8–10,12} but the importance of heart failure, myocardial ische-

mia/infarction, and arrhythmia are increasingly recognized.^{8,13}

Through these complications or others, pneumonia may also cause cardiac arrest. In the trial of early goal-directed therapy for sepsis by Rivers et al,¹⁴ sudden cardiovascular collapse occurred in ≤21% of patients. Another prospective study found that cardiac arrest occurred in ≤12% of patients admitted with pneumonia.¹⁵ Beyond these, few studies have investigated the relationship between pneumonia and cardiac arrest.

Optimizing outcomes from pneumonia will require an improved understanding of its association with cardiac arrest. Accordingly, we sought to assess the characteristics of early in-hospital cardiac arrests (IHCAs) in patients with preexisting pneumonia.

MATERIALS AND METHODS

Study Design and Patients

We performed a retrospective analysis using a database of IHCA events (the Get With the Guidelines-Resuscitation [GWTG-R] database, formerly known as the National Registry of Cardiopulmonary Resuscitation). The GWTG-R is a voluntary database sponsored by the American Heart Association and includes data for > 160,000 IHCAs at > 550 North American hospitals. Data were available from January 1, 2000, to October 21, 2009. The institutional review board at the University of Chicago deemed the study exempt from further review under 45CFR46.101(b)(4).

Data Collection and Integrity

The GWTG-R database has been described elsewhere.¹⁶ Data collection follows the Utstein guidelines for standardized reporting of IHCA data.¹⁷ Cases of IHCA are identified prospectively. Certified personnel at each study hospital then abstract data from the medical record using a standardized template and explicit operational definitions (Table 1). GWTG-R personnel periodically perform a detailed re-abstraction process to ensure data validity, and the mean error rate has been estimated to be $2.5\% \pm 2.7\%$.¹⁸

Inclusion and Exclusion Criteria

We included IHCA events that occurred among adult inpatients during the initial 72 h following hospital admission. If a patient had more than one event, we only included the first. We chose 72 h a priori because we were interested in studying cardiac

arrest as an early complication of community-acquired pneumonia; after that time point, many complications may be unrelated to pneumonia, and pneumonia is more likely to be nosocomial.^{9,10,19} We included events that occurred in an ICU or on an inpatient ward. We excluded patients admitted from other acute care hospitals or long-term-care settings (eg, nursing homes, long-term acute care hospitals, or rehabilitation facilities) and patients for whom preexisting conditions or duration of hospitalization were unknown.

Data Analysis

We investigated patient- and event-related characteristics in patients with IHCAs and preexisting pneumonia, including baseline demographic data, comorbid illnesses, clinical interventions prior to an IHCA, possible causes of IHCAs, initial pulseless rhythms, and survival. For context, we compared events in patients with preexisting pneumonia to events in all patients without pneumonia. For patients with preexisting pneumonia, we also compared characteristics according to event location (ICU vs hospital ward, including telemetry and step-down units). Our study design and data source precluded the assembly of a true control group, so our main objective was to measure and report the magnitude of relevant clinical variables in patients with pneumonia in the context of the GWTG-R population.

"Preexisting pneumonia" was defined as a clinical diagnosis of active pneumonia in the medical record prior to an IHCA. Primary admitting diagnoses were not differentiated, and patients with pneumonia may have had other active diagnoses at the time of cardiac arrest. Possible causes of cardiac arrest were determined based on information available to the trained chart reviewers and are neither mutually exclusive nor exhaustive.

Analyses were performed using a statistics software application (Stata, version 11.0; Statacorp). Patient and event characteristics were reported and compared using two-sided Student *t* tests, χ^2 tests, or Wilcoxon rank-sum tests, as appropriate. Using the Bonferroni correction to account for multiple comparisons and assuming an α of 0.05, we set the level of statistical significance for univariate analysis at $P < .002$. For outcomes, we performed a multivariate logistic regression analysis that included baseline clinical and event characteristics to adjust for potential confounders, using $P < .05$.

RESULTS

Figure 1 shows the flow diagram for the derivation of the study population. There were 112,540 index cardiac arrest events among adults who were hospital inpatients. We identified 55,276 events that occurred within 72 h of admission. Before these events, 40,441 patients had resided at home prior to admission. Pneumonia preceded cardiac arrest in 4,453 patients. Of these early IHCA events in patients with pneumonia, 2,748 (61.7%) occurred in an ICU, and 1,705 (38.3%) occurred in a general inpatient ward. This distribution was similar for patients without pneumonia (61.2% in an ICU, 38.8% on the ward, $P = .53$).

Table 2 shows baseline demographic and clinical characteristics for patients with early IHCAs, including patients with and without pneumonia. Patients with pneumonia are further grouped according to event location.

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*A complete list of Get With the Guidelines-Resuscitation Investigators is available in e-Appendix 1.

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Table 1—Definitions

Term	Definition
Acute respiratory insufficiency	Any of the following conditions: required emergency-assisted ventilation within 1 h up to the time of cardiac arrest; $\text{PaO}_2/\text{FiO}_2$ ratio < 300 ; $\text{PaO}_2 < 60$ mm Hg; $\text{SaO}_2 < 90\%$; $\text{PaCO}_2 > 50$ mm Hg; or spontaneous respiratory rate $> 40/\text{min}$ or $< 5/\text{min}$.
Arrhythmia	Any documented rhythm disturbance, excluding sinus tachycardia, including the first dysrhythmia documented for the event.
Congestive heart failure	A documented diagnosis of congestive heart failure.
Hepatic insufficiency	Either of the following within 24 h up to the time of the event: cirrhosis, or total bilirubin $> 2\text{mg/dL}$ and AST > 2 times normal.
Hypotension	Systolic BP < 90 mm Hg or MAP < 60 mm Hg with or without pharmacologic or IABP support.
Immediate causes	Conditions present at the time of the event documented anywhere in the medical record, including autopsy report, that directly contributed to and/or caused cardiopulmonary arrest.
IHCA	Cardiopulmonary arrest event characterized by either pulselessness or a pulse with inadequate perfusion, requiring chest compressions and/or defibrillation and eliciting a hospital-wide emergency response by acute care facility personnel.
Invasive airway	Endotracheal tube, tracheostomy, laryngeal mask airway, or other invasive airway. Does not include nasopharyngeal or oropharyngeal airway.
Metabolic/electrolyte abnormality	Any of the following levels: sodium < 125 or > 150 mEq/L, potassium < 2.5 or > 6 mEq/L, arterial pH < 7.3 or > 7.5 , lactate > 2.5 mmol/L, or blood glucose < 60 mg/dL. For immediate cause, also included magnesium > 4 mEq/L.
Myocardial ischemia/infarction	A documented diagnosis of myocardial ischemia/infarction and acute coronary syndromes.
Pneumonia	A documented diagnosis of active pneumonia, where antibiotics have not yet been started or the pneumonia is still being treated with antibiotics.
Preexisting conditions	Conditions that existed prior to the event.
Renal insufficiency	Either requiring ongoing dialysis or extracorporeal filtration therapies, or creatinine > 2 mg/dL within 24 h up to the time of the event.

AST = aspartate aminotransferase; IABP = intraaortic balloon pump; IHCA = in-hospital cardiac arrest; MAP = mean arterial pressure; SaO_2 = arterial oxygen saturation.

Compared with patients without pneumonia, patients with pneumonia and IHCA were more likely to be black and to have a medical admitting diagnosis. They were also more likely to have a coexisting malignancy,

hepatic insufficiency, renal insufficiency, active congestive heart failure, and baseline neurologic deficits. Myocardial ischemia/infarction was more common in patients without pneumonia (19.5% vs 13.4% in the pneumonia group, $P < .001$), but was nevertheless present in approximately one in seven patients with pneumonia and cardiac arrest.

Comparing patients with pneumonia by arrest location, patients on the ward were significantly older. Active myocardial ischemia/infarction, neurologic deficits, bacteremia, and hepatic or renal insufficiency were more common in the ICU group. Congestive heart failure was common in both groups (22.1% in the ICU vs 25.1% on the ward, $P = .02$).

Table 3 shows arrest characteristics for patients with early IHCA, including patients with or without pneumonia. Patients with preexisting pneumonia are further grouped according to event location. Compared with patients without pneumonia, patients with preexisting pneumonia were only marginally more likely to be receiving assisted or mechanical ventilation prior to the event. The use of vasoactive medications was similar (33.3% of patients with pneumonia vs 31.4% of patients without pneumonia, $P = .01$). Interestingly, only 51.9% of patients in the ICU with pneumonia and cardiac arrest were receiving vasoactive drugs, and only 56.3% were receiving mechanical ventilation prior to cardiac arrest. Continuous ECG monitoring was common in patients in the ICU with pneumonia (97.5%), but preceded only 52.3% of arrests in patients on the ward ($P < .001$).

Arrhythmia, respiratory distress, and hypotension were commonly suspected as causes of cardiac arrest in patients with and without preexisting pneumonia. While respiratory distress and hypotension were more common in patients with pneumonia, they only precipitated cardiac arrest in roughly one-half of the patients with preexisting pneumonia. Arrhythmia was equally common in patients with and without preexisting pneumonia. Notably, though, in patients with pneumonia, arrhythmia occurred more frequently than either hypotension or respiratory distress; 31% had arrhythmia in the absence of concurrent hypotension or respiratory distress. This was particularly apparent among patients in the ICU, where monitoring intervals were presumably shorter and where 95.1% of arrests were witnessed. Metabolic and electrolyte abnormalities were also frequently noted as possible causes of IHCA in patients with preexisting pneumonia.

Compared with initial arrest rhythms in patients without pneumonia, shockable rhythms were uncommon among patients with preexisting pneumonia (ventricular fibrillation or tachycardia occurred in 14.8% vs 22.1% of patients without pneumonia, $P < .001$). To account for the possibility that some cases of

FIGURE 1. Flow diagram of study population.

pulseless electrical activity (PEA) or asystole may have represented late detection of pulselessness, we also assessed the initial arrest rhythms in the subgroup of patients with pneumonia who were receiving ECG monitoring prior to arrest. In this group, shockable rhythms were still uncommon (15.5% vs 24.0% in patients without pneumonia, $P < .001$). Shockable rhythms were equally uncommon in monitored patients with pneumonia regardless of location (15.1% in the ICU group, 16.7% in the ward group, $P = .09$).

Figure 2 shows the proportions of cardiac arrests occurring in patients with preexisting pneumonia during successive 6-h intervals following admission, stratified by event location. The median time from admission to cardiac arrest was significantly longer for patients on the ward than for patients in the ICU (28.4 h; interquartile range, 11.9-49.3 vs 18.9 h; interquartile range, 8.0-39.6 h; $P < .001$).

In order to assess whether our results were specific to pneumonia or reflective of infection more generally, we performed a subgroup analysis to compare patients with pneumonia to patients with bacteremia, the only other subgroup of patients with an infection in the GWTC-R database. Patients with

overlapping diagnoses were excluded. At the time of cardiac arrest, 53.8% of patients with pneumonia were located in an ICU, compared with 75.0% of patients with bacteremia ($P < .001$). Prior to cardiac arrest, assisted ventilation was less common in patients with pneumonia compared with patients with bacteremia (28.9% vs 43.2%, $P < .001$). Similarly, the use of vasoactive drugs prior to cardiac arrest was twice as common among patients with bacteremia (23.9% vs 48.3%, $P < .001$). Respiratory distress was noted more frequently as a cause of cardiac arrest in patients with pneumonia (51.4% vs 40.3% in patients with bacteremia, $P < .001$), while hypotension was more commonly noted as a cause of cardiac arrest in patients with bacteremia (58.3% vs 36.9% in patients with pneumonia, $P < .001$).

Outcomes

Table 4 shows outcomes data. After adjusting for baseline and event characteristics, event survival was similar in all groups. Pneumonia was not independently associated with survival to discharge. However, among patients with preexisting pneumonia, there was a trend toward higher discharge survival in patients

Table 2—Baseline Patient Characteristics

Characteristic	Patients Without Pneumonia (n = 32,645)	Patients With Pneumonia (n = 4,453)	P Value	Patients With Pneumonia, ICU (n = 2,748)	Patients With Pneumonia, Ward (n = 1,705)	P Value
Age, median (IQR), y	68 (55-78)	68 (55-78)	.86	64 (52-76)	73 (60-82)	< .001
Male sex	18,889 (57.9)	2,625 (59.0)	.17	1,637 (59.6)	988 (58.0)	.28
Race			< .001			.55
White	23,424 (71.8)	3,119 (70.0)		1,912 (69.6)	1,207 (70.8)	
Black	5,951 (18.2)	950 (21.3)		590 (21.5)	360 (21.1)	
Other/unknown	3,270 (10.0)	384 (8.6)		246 (9.0)	138 (8.1)	
Illness category			< .001			.05
Medical	26,190 (80.2)	4,277 (96.1)		2,625 (95.5)	1,652 (96.9)	
Surgical	5,361 (16.4)	156 (3.5)		107 (3.9)	49 (2.9)	
Other/unknown ^a	1,094 (3.4)	20 (0.5)		16 (0.6)	4 (0.2)	
Preexisting conditions ^b						
Myocardial ischemia/infarction	6,375 (19.5)	596 (13.4)	< .001	435 (15.8)	161 (9.4)	< .001
Congestive heart failure	5,508 (16.9)	1,035 (23.2)	< .001	607 (22.1)	428 (25.1)	.02
Diabetes mellitus	9,277 (28.4)	1,292 (29.0)	.41	751 (27.3)	541 (31.7)	.002
Malignancy	3,995 (12.2)	695 (15.6)	< .001	413 (15.0)	282 (16.5)	.177
Baseline CNS deficit	3,468 (10.6)	648 (14.6)	< .001	447 (16.3)	201 (11.8)	< .001
Acute stroke	1,146 (3.5)	113 (2.5)	.001	80 (2.9)	33 (1.9)	.04
Acute mental status change	2,609 (8.0)	350 (7.9)	.76	246 (9.0)	104 (6.1)	.001
Hepatic insufficiency	2,551 (7.8)	418 (9.4)	< .001	314 (11.4)	104 (6.1)	< .001
Renal insufficiency	9,937 (30.4)	1,714 (38.5)	< .001	1,187 (43.2)	527 (30.9)	< .001
Bacteremia	3,757 (11.5)	1,273 (28.6)	< .001	1,037 (37.7)	236 (13.8)	< .001

Data are shown as No. (%) unless otherwise indicated. IQR = interquartile range.

^aIncludes trauma, obstetric, and other categories.

^bMultiple preexisting conditions could be present.

on the ward (18.4% vs 12.7% in the ICU, $P = .05$). Nevertheless, the fraction of patients with intact neurologic functions (ie, cerebral performance category 1 or 2) was equally poor in both locations (9.4% in the ICU group vs 12.4% in the ward group, $P = .74$) (Table 4).

DISCUSSION

To our knowledge, this is the first large study to report the characteristics of early IHCA in patients with preexisting pneumonia. Our main finding is that overt shock and respiratory failure (as indicated by the need for vasoactive medications and assisted ventilation) are infrequent before cardiac arrest.

Multiple phenomena may explain this finding. Some patients may have had mild pneumonia, so some episodes of cardiac arrest may have been related to other problems. Latent respiratory failure or circulatory collapse may have gone unrecognized or undocumented prior to the IHCAs, causing us to underestimate their frequency. Alternatively, though, our results suggest that some patients with pneumonia may develop abrupt cardiac arrest without a premonitory period of shock or respiratory failure.

In patients with pneumonia, abrupt cardiac arrest may develop because of the effects of sepsis. Sepsis results from the host's systemic inflammatory response to infection, and cardiovascular deterioration is a key

factor in mortality from this syndrome.^{20,21} In many patients, septic shock develops after progression through the stages of infection, sepsis, and severe sepsis. However, some patients with life-threatening infections may skip one or more stages and develop more precipitous cardiovascular compromise.^{14,21}

Several mechanisms may explain such deterioration in patients with sepsis. In some patients with sepsis, tissue hypoxia and hypoperfusion may be profound in spite of relatively normal global parameters of respiratory status and hemodynamic function.^{22,23} These patients may be difficult to identify at the time of presentation.²⁴ Patients with such "cryptic shock" may be at high risk for occult myocardial ischemia/infarction. Sepsis can also cause abrupt cardiac arrest through effects independent of coronary ischemia, either through direct arrhythmogenic effects or through nonischemic myocardial injury and circulatory dysfunction.²⁵⁻²⁹

While we were not able to investigate these mechanisms directly, we found myocardial ischemia/infarction as a possible cause in 6.3% of arrests in patients with pneumonia, and it was an active diagnosis in 13.4%. These are likely underestimates, as some cases of myocardial ischemia/infarction could have been undetected prior to an IHCA. This finding adds to prior studies that have shown epidemiologic and pathophysiologic links between pneumonia and myocardial ischemia/infarction.³⁰⁻³²

Table 3—Arrest Characteristics

Characteristic	Patients Without Pneumonia (n = 32,645)	Patients With Pneumonia (n = 4,453)	P Value	Patients With Pneumonia, ICU (n = 2,748)	Patients With Pneumonia, Ward (n = 1,705)	P Value
Daytime arrests ^a	20,968 (64.2)	2,882 (64.7)	.52	1,829 (66.6)	1,053 (61.8)	.004
Witnessed arrests ^b	26,498 (81.0)	3,639 (82.0)	.35	2,613 (95.1)	1,026 (60.2)	<.001
Interventions in place before IHCA						
Assisted ventilation	9,807 (30.0)	1,625 (36.5)	<.001	1,547 (56.3)	78 (4.6)	<.001
Invasive airway	9,396 (28.8)	1,507 (33.8)	<.001	1,454 (52.9)	53 (3.1)	<.001
Vasoactive drugs	10,205 (31.4)	1,471 (33.3)	.01	1,415 (51.9)	56 (3.3)	<.001
Continuous ECG monitoring	26,309 (80.6)	3,572 (80.2)	.55	2,680 (97.5)	892 (52.3)	<.001
Immediate causes of IHCA ^c						
Arrhythmia	19,610 (60.1)	2,600 (58.4)	.03	1,758 (64.0)	842 (49.4)	<.001
Myocardial ischemia/infarction	3,329 (10.2)	279 (6.3)	<.001	199 (7.2)	80 (4.7)	.001
Respiratory distress ^d	11,522 (35.3)	2,240 (50.3)	<.001	1,312 (47.7)	928 (54.4)	<.001
Hypotension	13,427 (41.1)	1,979 (44.4)	<.001	1,587 (57.8)	392 (23.0)	<.001
Metabolic or electrolyte abnormality	4,262 (13.1)	813 (18.3)	<.001	660 (24.0)	153 (9.0)	<.001
Unknown	3,428 (10.5)	412 (9.3)	.01	137 (5.0)	275 (16.1)	<.001
Initial pulseless rhythm			<.001			<.001
Ventricular fibrillation/tachycardia	7,204 (22.1)	659 (14.8)		409 (14.9)	250 (14.7)	
Pulseless electrical activity	12,753 (39.1)	1,926 (43.3)		1,277 (46.5)	649 (38.1)	
Asystole	10,909 (33.4)	1,598 (35.9)		938 (34.1)	660 (38.7)	
Unknown	1,779 (5.5)	270 (6.1)		124 (4.5)	146 (8.6)	

Data are shown as No. (%) unless otherwise indicated. See Table 1 legend for expansion of the abbreviation.

^aDaytime includes 6:01 AM to 10:59 PM.

^bMissing data for two patients without pneumonia and one patient with pneumonia on the ward.

^cMultiple conditions could be present.

^dIncludes respiratory insufficiency and pulmonary edema.

PEA and asystole were the most common initial arrest rhythms in patients with preexisting pneumonia. We would expect these rhythms to have been common when arrests were preceded by shock, respiratory failure, and metabolic disarray. However, where such phenomena did not precede cardiac arrest, PEA or asystole may have resulted from ischemia or nonischemic

myocardial injury or circulatory dysfunction.³³ Alternatively, some episodes of PEA or asystole may represent late detection of pulselessness, and shockable arrest rhythms may degenerate to PEA or asystole if cardiac arrest remains undetected.³⁴

In our study, most patients with IHCA on the ward in the setting of preexisting pneumonia had been

FIGURE 2. Time to cardiac arrest. For patients with an in-hospital cardiac arrest and preexisting pneumonia, each bar shows the percentage of patients with cardiac arrests occurring during successive 6-h intervals. Patients are divided according to event location (ICU vs ward). Median times from admission to cardiac arrest are identified by arrows.

Table 4—Outcomes

Outcome	Patients Without Pneumonia (n = 32,645)	Patients With Pneumonia (n = 4,453)	Adjusted P Value	Patients With Pneumonia, ICU (n = 2,748)	Patients With Pneumonia, Ward (n = 1,705)	Adjusted P Value
Survived event	17,182 (52.6)	2,332 (52.4)	.03	1,441 (52.4)	891 (52.3)	.007
Survived to discharge ^a	6,407 (19.7)	664 (14.9)	.41	350 (12.7)	314 (18.4)	.05
Neurologically intact ^b	4,926 (15.5)	462 (10.6)	.59	255 (9.4)	207 (12.4)	.74

Data are shown as No. (%) unless otherwise indicated.

^aMissing data for 34 patients without pneumonia and one patient with pneumonia in the ICU.

^bMissing data for 762 patients without pneumonia and 78 patients with pneumonia (40 ICU, 38 ward).

treated there for > 1 day before the event. Previous studies have shown that early admission to the ICU may confer a survival advantage.³⁵⁻³⁷ Similarly, morbidity and mortality appear to be increased when septic shock develops on the ward as opposed to in the ICU.³⁸⁻⁴⁰ The long interval between admission and cardiac arrest may represent a window of missed opportunity to provide time-sensitive interventions, which suggests that current methods of identifying and treating patients with pneumonia who are at high risk may be suboptimal in design or implementation.

Patients with preexisting pneumonia and cardiac arrest on the ward were older than such patients in the ICU. This may be due to age-associated variability in the manifestations of life-threatening illness. For example, patients who are elderly and have pneumonia may be less likely to develop ARDS, indicating that age may affect the host's response to infection.⁴¹ Consistent with this report, our findings suggest that the possibility that patients who are elderly more frequently develop cardiac arrest without a preceding period of overt critical illness deserves further study.

Many patients on the ward did not have ECG monitoring in place prior to an IHCA. This suggests that physicians may have underestimated the risk of arrhythmia in some patients with pneumonia. Since cardiac events are important early complications of pneumonia and because myocardial injury is associated with mortality in patients with sepsis, future studies should address the role of routine, continuous ECG monitoring or other assessments of cardiac risk in the treatment of pneumonia.^{9,13,27,42}

This study has important limitations. Since we relied on retrospective cardiac arrest registry data, we were not able to determine the incidence of IHCA in patients with pneumonia. The GWTG-R database does not include sufficient data for us to measure antibiotic appropriateness, guideline compliance, or severity-of-illness scores. Similarly, we could not reliably exclude all patients with possible nosocomial or health-care-associated pneumonia, so our results should be generalized to patients with community-acquired pneumonia with caution. Given the retrospective nature of this study, we were not able to fully

elucidate causation. Finally, since we relied on clinical diagnoses obtained from retrospective chart review, we may have misclassified certain conditions, including pneumonia. We were not able to independently corroborate this clinical diagnosis, and our definition may diverge from those used in other studies. However, the GWTG-R does use explicit operational definitions. Furthermore, the chart reviews are performed by certified personnel and are audited for quality assurance. Other retrospective methods used to identify pneumonia may also misclassify patients, and we believe that the clinical diagnosis of pneumonia employed in our study likely reflects widespread, current clinical practice.⁴³⁻⁴⁵

CONCLUSIONS

Among patients with preexisting pneumonia, cardiac arrest may frequently occur in patients who are not receiving vasoactive medications or mechanical ventilation. Physicians should be alert to the possibility of abrupt cardiovascular collapse, and future studies should address the incidence and causes of this phenomenon and strategies to prevent it.

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Author contributions: Dr Carr had access to all data and is responsible for its integrity.

Dr Carr: contributed to the design and conception of the study, data analysis, and manuscript preparation.

Mr Yuen: contributed to data analysis and manuscript preparation.

Dr McConville: contributed to the design and conception of the study, data analysis, and manuscript preparation.

Dr Kress: contributed to the design and conception of the study, data analysis, and critical review of the manuscript.

Dr VandenHoek: contributed to the design and conception of the study and critical review of the manuscript.

Dr Hall: contributed to the design and conception of the study, data analysis, and critical review of the manuscript.

Dr Edelson: contributed to the design and conception of the study, data analysis, and manuscript preparation.

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Additional information: The e-Appendix can be found in the "Supplemental Materials" area of the online article.

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