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Clinical paper

Impact of right ventricular dysfunction on mortality in adults with cardiac arrest undergoing coronary angiogram

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Abstract

Objective: We sought to identify the impact of echocardiographic right ventricular (RV) systolic dysfunction on mortality in adults with cardiac arrest (CA).

Methods: The study population included 147 adults hospitalized with CA who underwent both echocardiogram and coronary angiogram at an academic tertiary medical center. The primary outcome of interest was all-cause in-hospital mortality.

Results: Of the 147 patients studied, 20 (13.6%) had evidence of RV systolic dysfunction while 127 (86.4%) did not. Patients with RV dysfunction had higher rates of prior surgical and percutaneous coronary revascularization. They also had higher rates of mechanical ventilation, therapeutic hypothermia, vasopressor and inotrope use, and a trend towards higher rates of mechanical support. Coronary angiogram revealed higher rates of multivessel disease, right coronary artery intervention, and glycoprotein IIb–IIIa inhibitor use in those with RV dysfunction, alongside with lower echocardiographic left ventricular ejection fraction. In-hospital mortality rates were higher in adults with RV dysfunction compared to those without (55% vs 11%, $p < 0.001$). In multivariate analysis, RV dysfunction was the strongest independent predictor of higher mortality [odds ratio 4.71, 95% confidence interval 1.27–17.50].

Conclusions: In this observational contemporary study, RV dysfunction was independently associated with higher mortality in adults with CA undergoing coronary angiogram. RV dysfunction may be useful for risk stratification and management in this high-mortality population.

Keywords: Right ventricular dysfunction, Cardiac arrest, Mortality

Introduction

Cardiac arrest (CA) is one of the leading causes of morbidity and mortality in the U.S.[1] Despite increasing use of advanced therapies to achieve targeted temperature management, hemodynamic stability, and optimization of coronary status, rates of survival with favorable neurologic outcomes remain low.[2] Bedside echocardiography can be a useful tool in identifying CA patients at high risk for poor prognosis. Left ventricular (LV) dysfunction has been well documented as a poor prognostic indicator following CA.[3,4] While right ventricular (RV) dysfunction has been known to contribute to morbidity and mortality in a number of specific populations,[5–7] its association with outcomes in adults with CA has not been well studied. Data from the Penn Alliance for Therapeutic Hypothermia registry previously identified post-arrest RV dysfunction as an independent predictor of worse outcomes.[8] However, the impact of RV dysfunction on coronary findings and clinical management in association with mortality remains unclear.

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Accordingly, we sought to assess the association between RV dysfunction and obstructive coronary artery disease (CAD), clinical management, and mortality in adults with CA undergoing coronary angiogram.

Methods

We conducted a retrospective cohort study examining the association between RV dysfunction, obstructive CAD, clinical management and mortality following CA in a single academic tertiary medical center. All adults (age >18 years) with a cardiac arrest (CA) requiring a resuscitation attempt, and undergoing coronary angiogram at Stony Brook University Medical Center from February 2010 to December 2014. CA was defined as absent heartbeat and respirations requiring CPR.

The demographic and baseline medical history data extracted included age, gender, body mass index (BMI), prior coronary artery bypass graft surgery (CABG) or percutaneous coronary intervention (PCI), diabetes mellitus, peripheral arterial disease, chronic obstructive pulmonary disease, chronic kidney disease, and smoking status. Clinical presentation data extracted included electrocardiogram at time of arrest, initial rhythm [e.g. ventricular fibrillation (VF), ventricular tachycardia (VT), pulseless electrical activity (PEA), asystole], location of CA (e.g. out-of-hospital (OHCA), in-hospital (IHCA), mechanical ventilation, therapeutic hypothermia, use of vasopressors and/or inotropes, use of mechanical support [e.g. intra-aortic balloon pump (IABP), Impella left ventricular device, or veno-arterial extracorporeal membrane oxygenation (ECMO)], and admission laboratory data [e.g. serum potassium, blood urea nitrogen (BUN), serum creatinine, hemoglobin, hematocrit, platelet count, white blood cell count. Invasive data collected included extent and severity of CAD including coronary vessel affected, percutaneous coronary intervention including vessel intervened, use of aspiration thrombectomy, and medications, including fibrinolytics and glycoprotein IIb–IIIa inhibitor.

Echocardiographic data collected during index hospitalization included left ventricular ejection fraction (LVEF), LV diameter in diastole, interventricular septal width, LV posterior width, left atrial size, left atrial volume, RV systolic dysfunction, RV enlargement, RV systolic pressure, presence of aortic stenosis, aortic insufficiency, mitral regurgitation, tricuspid regurgitation, and pericardial effusion. All echocardiographic measurements were performed in accordance to American Society of Echocardiography guidelines.[9] Invasive data collected during index hospitalization included extent and severity of CAD including coronary vessel affected, percutaneous coronary intervention including vessel intervened, use of aspiration thrombectomy, and medications, including fibrinolytics and glycoprotein IIb–IIIa inhibitor.

The primary outcome of interest was all-cause in-hospital mortality. This study was approved by the Institutional Review Board. A waiver of consent to use data retrospectively was obtained for all patients.

Categorical variables were presented as percentages and compared with the chi-squared test or Fisher's exact test, if applicable. Continuous variables were presented as means ± standard deviation (SD) and compared using student's t test. Multivariable logistic regression was utilized to determine the association between the presence and absence of RV dysfunction with in-hospital mortality in this population. Predictors for the logistic regression were selected based on statistical significance in the univariate analysis ($p < 0.1$) and previous clinical data and included right ventricular dysfunction, age, gender, left ventricular ejection fraction, use of vasopressors, use of mechanical support, and use of therapeutic hypothermia. SPSS version 23.0 (SPSS, Inc. Chicago, IL) was used for data analysis and a two-tailed p-value of 0.05 was regarded as statistically significant.

Results

We studied 147 adults with CA (both out-of hospital and in-hospital) who underwent ACLS-guided resuscitation and subsequent coronary angiogram and transthoracic echocardiogram with RV assessment at Stony Brook University Medical Center during the index hospitalization of the CA event. Of the 147 patients studied, 20 patients (13.6%) had evidence of RV systolic dysfunction while 127 (86.4%) did not.

Table 1 highlights the demographic and baseline medical history of the study population. Patients with RV dysfunction had higher rates of prior surgical and percutaneous coronary revascularization. Clinical presentation and management are depicted in Table 2. Patients with RV dysfunction had higher rates of mechanical ventilation, therapeutic hypothermia, vasopressor and inotrope use, and a trend towards higher rates of mechanical support. Coronary angiogram and echocardiographic data are described in Tables 3 and 4. Coronary angiogram revealed higher rates of multivessel disease, right coronary artery intervention, and glycoprotein IIb–IIIa inhibitor use in those with RV dysfunction, alongside with lower echocardiographic left ventricular ejection fraction.

In-hospital mortality rates were higher in adults with RV dysfunction compared to those without (55% vs 11%, $p < 0.001$) (Fig. 1A). Rates of discharge to home were also notably lower in the RV dysfunction cohort (Fig. 1B).

Table 1 – Baseline medical history.

	Right ventricular dysfunction		
	No (n = 127)	Yes (n = 20)	p Value
Age (years)	61 + 12	62 + 9	0.665
Weight (kg)	85.4 + 17.1	87.0 + 13.6	0.690
Height (m)	1.74 + 0.09	1.78 + 0.08	0.061
Body mass index (kg/m^2)	28.1 + 4.8	27.4 + 3.7	0.535
Prior coronary artery bypass grafting	4 (3.1%)	5 (26.3%)	0.002
Prior percutaneous coronary intervention	24 (18.9%)	8 (42.1%)	0.023
Hypertension	81 (63.8%)	12 (63.2%)	0.958
Diabetes mellitus	29 (22.8%)	7 (36.8%)	0.186
Peripheral arterial disease	7 (5.5%)	2 (10.5%)	0.331
Chronic obstructive pulmonary disease	10 (7.9%)	0 (0%)	0.360
Chronic kidney disease	13 (10.3%)	3 (15.8%)	0.442
Smoker			0.349
Never	39 (31.7%)	8 (47.1%)	
Former	35 (28.5%)	5 (29.4%)	
Current	49 (39.8%)	4 (23.5%)	

Table 2 – Clinical presentation and management.

	Right ventricular dysfunction		
	No (n = 127)	Yes (n = 20)	p Value
Admission labs			
Serum creatinine (mg/dl)	1.2 + 1.1	1.2 + 0.5	0.874
Blood urea nitrogen (mg/dl)	22 + 12	23 + 5	0.707
Serum potassium (mmol/l)	3.9 + 0.6	4.2 + 1.0	0.183
Hemoglobin (g/dl)	13.3 + 2.2	13.8 + 2.0	0.338
Hematocrit (%)	39 + 7	41 + 6	0.253
White blood cell (K/ul)	13.7 + 6.3	15.9 + 7.6	0.158
Platelets (K/ul)	217 + 72	214 + 83	0.901
Location of cardiac arrest			0.225
Out-of-hospital	76 (59.8%)	15 (75.0%)	
In-hospital	51 (40.2%)	5 (25.0%)	
Initial rhythm			0.574
Ventricular fibrillation/tachycardia	109 (85.8%)	16 (80.0%)	
Asystole/pulseless electrical activity	10 (7.9%)	3 (15.0%)	
Other	8 (6.3%)	1 (5.0%)	
Electrocardiogram at time of arrest			0.653
ST-elevation myocardial infarction	65 (53.3%)	11 (55.0%)	
Non-ST-elevation myocardial infarction	52 (42.6%)	9 (45.0%)	
New left bundle branch block	5 (4.1%)	0 (0%)	
Defibrillation	112 (89.6%)	17 (85.0%)	0.542
Mechanical ventilation	84 (66.1%)	18 (90.0%)	0.036
Therapeutic hypothermia	39 (31.0%)	14 (70.0%)	0.001
Vasopressors	37 (29.1%)	14 (70.0%)	<0.001
Inotropes	3 (2.4%)	3 (15.0%)	0.033
Any mechanical support	36 (28.3%)	10 (50.0%)	0.052
Intra-aortic balloon pump	34 (26.8%)	9 (45.0%)	0.096
Impella	4 (3.1%)	1 (5.0%)	0.524
Extracorporeal membrane oxygenation	1 (0.8%)	1 (5.0%)	0.254

Table 3 – Coronary angiographic and percutaneous coronary intervention data.

	Right ventricular dysfunction		p Value
	No (n = 127)	Yes (n = 20)	
Time from cardiac arrest to coronary angiogram (days)	2.3 + 3.6	2.1 + 2.4	0.804
Fibrinolytic administration	6 (4.7%)	0 (0%)	1.000
Right heart catheterization	28 (22.0%)	6 (30.0%)	0.433
Extent of coronary artery disease			0.054
Normal/nonobstructive	30 (23.6%)	3 (15.0%)	
1-Vessel disease	46 (36.2%)	3 (15.0%)	
2-Vessel disease	29 (22.8%)	6 (30.0%)	
3-Vessel disease	22 (17.3%)	8 (40.0%)	
Coronary artery affected			
Left main	11 (8.7%)	5 (25.0%)	0.045
Left anterior descending	76 (59.8%)	14 (70.0%)	0.386
Left circumflex	42 (33.1%)	9 (45.0%)	0.298
Right	49 (38.6%)	16 (80.0%)	0.001
Percutaneous coronary intervention	74 (58.3%)	12 (60.0%)	0.884
Left main	2 (1.6%)	2 (10.0%)	0.089
Left anterior descending	51 (40.2%)	4 (20.0%)	0.134
Left circumflex	19 (15.0%)	4 (20.0%)	0.520
Right	16 (12.6%)	8 (40.0%)	0.002
Drug-eluting stent	53 (41.7%)	9 (45.0%)	0.783
Number of stents	0.9 + 1.0	1.3 + 1.3	0.092
Aspiration thrombectomy	30 (23.6%)	5 (25.0%)	1.000
Glycoprotein IIb–IIIa inhibitor	7 (5.5%)	5 (25.0%)	0.012

Table 4 – Echocardiographic characteristics.

	Right ventricular dysfunction		
	No (n = 127)	Yes (n = 20)	p Value
Left ventricular systolic function			0.118
Normal	35 (28.5%)	5 (26.3%)	
Mild/moderately reduced	62 (50.4%)	6 (31.6%)	
Severely reduced	26 (21.1%)	8 (23.5%)	
Left ventricular ejection fraction (%)	42 + 15	35 + 18	0.049
Left ventricular enlargement	21 (17.4%)	4 (26.7%)	0.477
Left ventricular internal diameter diastole (cm)	5.0 + 0.8	5.0 + 0.8	0.727
Interventricular septum width (cm)	1.1 + 0.2	1.0 + 0.2	0.570
Left ventricular posterior wall width (cm)	1.0 + 0.2	1.0 + 0.2	0.466
Left atrial diameter (cm)	3.6 + 0.7	3.5 + 0.7	0.691
Left atrial area (cm^2)	19 + 5	18 + 6	0.619
Left atrial volume (ml)	56 + 22	53 + 29	0.663
Left ventricular diastolic dysfunction			0.451
None	18 (17.0%)	2 (13.3%)	
Mild	49 (46.2%)	6 (40.0%)	
Moderate	35 (33.0%)	5 (33.3%)	
Severe	4 (3.8%)	2 (13.3%)	
Mitral valve E wave (m/s)	0.8 + 0.2	0.7 + 0.3	0.055
Mitral valve A wave (m/s)	0.7 + 0.3	0.6 + 0.1	0.013
>2 + mitral regurgitation	6 (4.9%)	1 (5.9%)	1.000
Right atrial diameter (cm)	3.7 + 0.6	3.8 + 0.5	0.859
Right ventricular enlargement	3 (2.5%)	9 (45.0%)	<0.001
Right ventricular systolic pressure (mmHg)	33 + 13	28 + 10	0.175
>2 + tricuspid regurgitation	7 (5.6%)	3 (15.8%)	0.126
Pericardial effusion (>small)	7 (5.6%)	1 (5.0%)	1.000

In multivariate analysis, RV dysfunction was the strongest independent predictor of higher mortality [odds ratio (OR) 4.71, 95% confidence interval (CI) 1.27–17.50]. Other independent predictors of mortality included use of vasopressors (OR 4.47, 95% CI 1.16–17.19) and use of therapeutic hypothermia (OR 3.59, 95%CI 1.00–12.85) (Table 5).

Discussion

Several findings are noteworthy in this contemporary observational study of adults with CA undergoing coronary angiography and echocardiography. First, RV dysfunction was associated with higher rates of hemodynamic instability as evidenced by higher use of vasopressors, inotropes, and mechanical support. Second, RV dysfunction was associated with lower LVEF and higher rates of multivessel CAD. Lastly, RV dysfunction was the strongest independent predictor of higher rates of mortality in this population while controlling for LVEF, use of vasopressors, use of mechanical support, and use of therapeutic hypothermia. Few studies to date have examined the impact of RV dysfunction on both presentation and outcomes in adults with CA, especially in those with post-arrest coronary angiogram performed.

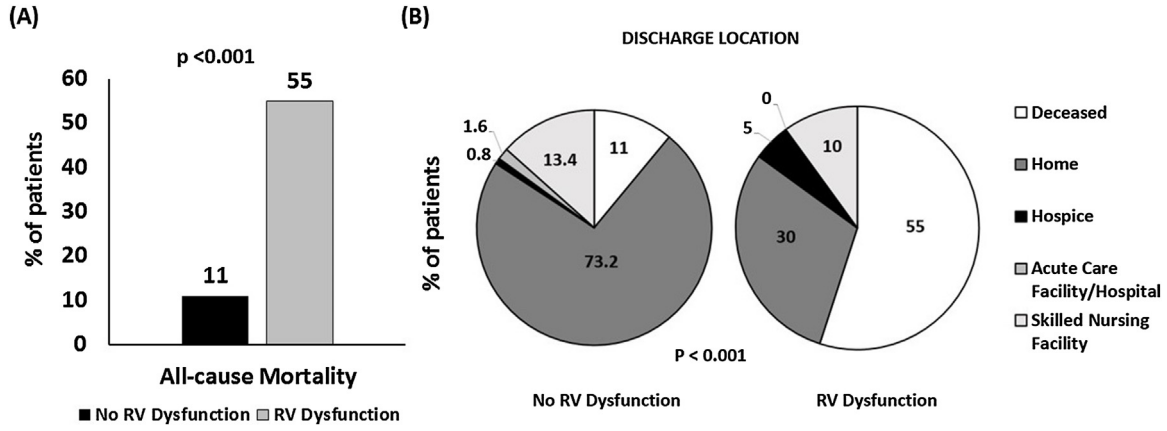

Fig. 1 – (A) In-hospital mortality and (B) discharge location of adults with CA in the presence and absence of RV dysfunction.

Table 5 – Multivariate analysis of predictors of mortality.

Variable	Odds ratio	95% confidence interval	p Value
Right ventricular dysfunction	4.71	1.27–17.50	0.021
Use of vasopressors	4.47	1.16–17.19	0.029
Therapeutic hypothermia	3.59	1.00–12.85	0.050
Age (per year)	1.02	0.96–1.07	0.554
Female sex (versus male sex)	2.28	0.66–7.87	0.191
Left ventricular ejection fraction (per %)	0.99	0.95–1.03	0.533
Requirement for any mechanical support	0.86	0.21–3.55	0.830

Model included age, gender, right ventricular dysfunction, left ventricular ejection fraction, use of vasopressors, requirement for of any mechanical support, and use of therapeutic hypothermia; c-statistic of 0.853.

Earlier animal studies explored the role of the RV in CA.[10–12] In a porcine model of electrically induced ventricular fibrillation, Meyer et al. demonstrated that RV ejection fraction significantly decreased in the post-arrest period, while RV end diastolic pressure and pulmonary artery wedge pressure (PAWP) increased,[10] with peak dysfunction occurring within 30 min of arrest and returned baseline within 5 h. In another porcine model, Aagaard et al. randomized 30 pigs to cardiac arrest via hypovolemia, hyperkalemia, or primary arrhythmia and noted that the RV was dilated in all 3 arms, and that RV size was greatest in the hypovolemia arm.[11]

Echocardiographic evaluation in the CA population has been limited to date, owing to the high level of illness acuity in this patient cohort.[13] The Penn Alliance for Therapeutic Hypothermia registry, a single-center retrospective cohort study at a tertiary care university hospital, studied adults with CA and demonstrated that RV dysfunction was predictive of a 50–80% worse survival independent of LV function.[8] This study was limited by absence of data regarding several confounding variables including type of myocardial infarction, presence of coronary revascularization, need for vasopressors and hemodynamic mechanical support– all factors which have been recorded in the present study. It is also important to note that RV dysfunction may be aggravated by the use of left ventricular mechanical support by means of RV overload. In our study, 29% of patients received an IABP, 3% of patients received percutaneous LV support (i.e. Impella) device, and 1% of patients received venoarterial ECMO. Nevertheless, our findings expand upon the importance of the RV in clinical outcomes in the CA population.

Our study had a number of limitations. First, information regarding RV systolic dysfunction was obtained from echocardiographic reports. All echocardiograms at our institution are read by cardiologists with board certification in echocardiography. RV dysfunction was determined by visual estimation and/or assessment of tricuspid annular plane systolic excursion. Second, all adult patients with CA do not routinely undergo coronary angiography and echocardiography as part of their clinical care. Factors associated with performing emergent or urgent coronary angiography in the CA population have included younger age, male gender, STEMI, VF/VT, use of defibrillation, and history of CAD.[14–16] This study only captures adult patients with CA who were referred for coronary angiography and underwent echocardiography with RV assessment. Finally, follow-up data was not recorded and so data was limited to in-hospital outcomes.

In conclusion, in this observational contemporary study, RV dysfunction was associated with higher mortality in adults with CA undergoing coronary angiogram. RV dysfunction may be useful for risk stratification and management in this high-mortality population.

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Disclosures

None.

Conflict of interest

JKP, RS, AF, HK, PBP: None.

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