Send Orders for Reprints to reprints@benthamscience.ae

Current Cardiology Reviews, **2018,** *14,* **85-91**

REVIEW ARTICLE

Role of Cardiac Catheterization Lab Post Resuscitation in Patients with ST Elevation Myocardial Infarction

Sridhar Reddy and Kwan S. Lee*

Sarver Heart Center, University of Arizona, Tucson, AZ, USA

ARTICLE HISTORY

Received: February 02, 2018
Revised: March 02, 2018
Accepted: April 25, 2018

DOI:
10.2174/1573403X14666180517080828

Abstract: ***Background*:** Cardiac arrest remains a common and lethal condition associated with high morbidity and mortality. Even with improving survival rates, the successfully resuscitated post cardiac arrest patient is also at risk for poor neurological outcomes, functional status and long- term survival if not managed appropriately. Given that acute coronary occlusion has been found to be the leading cause of cardiac arrest, long-term prognosis is good in selected patients after successful out-of-hospital resuscitation and ST elevation myocardial infarction who are taken for immediate coronary angiography, treated with primary percutaneous coronary intervention and hypothermia when indicated.

***Conclusion*:** A priority should therefore be placed in diagnosing as quickly as possible patients who have an acute coronary occlusion (*i.e*. ST elevation myocardial infarction) and implementing the appropriate and timely therapeutic strategy, which will require close chain of survival co- ordination and the services of the cardiac catheterization lab. Here we review previous and current guidelines as well as associated evidence.

Keywords: Cardiac arrest, ST elevation myocardial infarction, cardiac catheterization lab, morbidity, mortality, hypothermia.

1. INTRODUCTION

Cardiac arrest accounts for nearly 500 000 deaths annually in the United States and Europe [1-3]. Out-of-hospital Cardiac Arrest (OHCA) patient survival is <15% [4], while in-hospital cardiac arrest survival is about 22% [1]. Due to better pre-hospital "chain of survival" protocols, OHCA survival rates are improving and increasing number of patients who are successfully resuscitated are being admitted [5]. When the Return of Spontaneous Circulation (ROSC) is achieved, finding and treating the primary etiology of the arrest can improve morbidity and mortality as well as chances of recurrence. Extensive atherosclerotic Coronary Artery Disease (CAD) has been by far the most common pathological finding in patients with sudden cardiac death and acute coronary occlusion has been found to be the leading cause of cardiac arrest [6].

Acute Coronary Syndromes (ACS) are a common cause for OHCA in adults with no clear extra-cardiac etiologies of arrest and also can cause some in-hospital cardiac arrests. Long-term prognosis is good in selected patients following successful out-of-hospital resuscitation and ST Elevation Myocardial Infarction (STEMI) who are taken for immediate coronary angiography, treated with primary Percutaneous Coronary Intervention (PCI) and hypothermia when indicated [7, 8]. Therefore, it is imperative that a clear and decisive plan for patients who present with OHCA and STEMI is in place.

The 2015 American Heart Association (AHA) Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care incorporates available data to help physicians make the complicated set of therapeutic decisions that these patients require [9]. The main tenets of post-arrest STEMI care are to identify and treat the precipitating cause of the cardiac arrest, to minimize ischemia-reperfusion injury, prevent secondary organ injury, determine prognosis to direct the clinical team and to incorporate family decision making when determining goals of care [9]. A priority should, therefore, be placed in diagnosing as quickly as possible patients who have an acute coronary occlusion (*i.e.* STEMI) and implementing the appropriate and timely therapeutic strategy. Here we review previous and current guidelines as well as the evidence behind them to better understand the currently recommended treatment strategy for this high-risk patient group.

2. TIMING AND LIMITATIONS OF POST ARREST ECG

The post cardiac arrest ECG is vital to help determine etiology and management of the successfully resuscitated patient. The 2010 and subsequent updated 2015 AHA guidelines recommend obtaining a 12-lead Electrocardiogram (ECG) as soon as possible (ideally within 10 minutes of

*Address correspondence to this author at the 3950 S Country Club Road; Suite 200, Tucson AZ 85714, USA; Tel: +1 520-626-1859; Fax: +1 520-621-2919; E-mail: klee@shc.arizona.edu

1573-403X/18 $58.00+.00

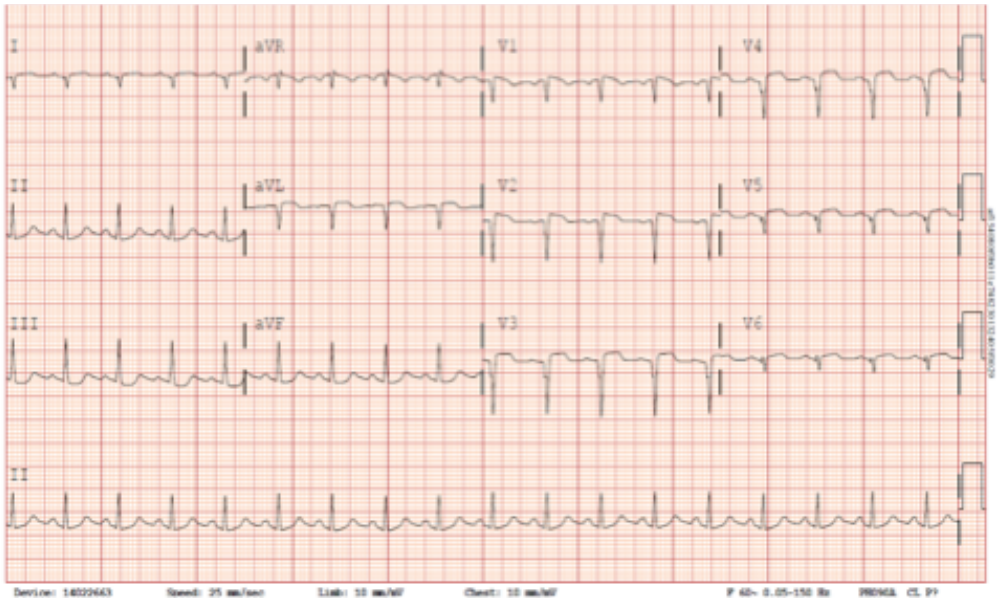

Fig. (1). Post resuscitation ECG showing V2-V5 ST elevation with Q waves.

presentation) after Return of Spontaneous Circulation (ROSC) to determine if acute ST elevation is present (Fig. **1**) in post arrest patients [9, 10]. The 2015 updated guidelines also place a new emphasis on performing a pre-hospital ECG as well as the need for and timing of hospital notification (both Class I recommendations). A major study published since the 2010 evidence review confirmed the importance of acquiring a 12-lead ECG for patients with possible ACS as early as possible in the pre-hospital setting [11]. This is reiterating what prior recommendations have stated which is that when STEMI is diagnosed in the pre-hospital setting, pre-arrival notice should be provided to the hospital as well as pre-hospital activation of the catheterization laboratory [11]. This should be extended to patients with ROSC in the field who are found to have STEMI on ECG.

While the post-arrest ECG is important, it should be noted that prior studies have shown that clinical and ECG criteria can be unreliable in recognizing coronary ischemia in cardiac arrest. In a study of 435 patients with OHCA, who all underwent coronary angiography, almost 70% of patients did not have ST-elevation on ECG post-resuscitation. However, 58% of these patients had at least 1 significant coronary lesion during coronary angiography (negative predictive value =42%) [7]. Furthermore, in Kern *et al*.'s study of 247 post-cardiac arrest patients with no evidence of STEMI on ECG who underwent early angiography, 33% had an occluded culprit vessel [8]. The benefit of routine coronary angiography for all OHCA patients even if they do not have electrocardiographic evidence of a STEMI is, therefore, a subject that demands further, ongoing investigation.

One should also be aware of possible confounding factors that could result in false-positives. Some conditions that can present with ST elevations, such as a left ventricular aneurysm or pericarditis, can make correct diagnosis difficult. Although, these conditions are less likely to appear as the cause of out-of-hospital cardiac arrest [11].

Another consideration is what the presenting rhythm was during the cardiac arrest. While post-arrest STEMI on ECG is a clear indication to take a patient to the cath lab, a patient who presents with ventricular tachycardia (VT) or ventricular fibrillation (VF) may need to be considered as a potential STEMI equivalent. Yannopoulos *et al*., theorized that a large percentage of patients presenting with VT/VF have ischemic heart disease as the etiology for their cardiac arrest regardless of the presence or absence of ST elevation on the post-resuscitation ECG [12]. Their prospective registry study looked at 315 patients who were resuscitated from VT/VF and transferred alive to the emergency room regardless of STEMI being found on the post-arrest ECG. Of those, 231 (73.3%) were taken to the cath lab per the Minnesota Resuscitation Consortium protocol while 84 (26.6%) were not taken to the cath lab (protocol deviations). The consortium protocol consists of pre-hospital CPR, therapeutic hypothermia, emergency cardiac catheterization and, when indicated, coronary revascularization. Of the 231 patients who followed the protocol, 121 (52%) underwent PCI, and 15 (7%) underwent coronary artery bypass graft. Of patients taken to the cath lab, 151 (65%) survived with good neurological outcome [12]. This underscores the importance and provides further support to the AHA recommendation to consider coronary angiography and possible intervention after resuscitated OHCA even in the absence of ST-elevation, in the presence of coma, or in conjunction with hypothermia [11].

3. TIMING AND BENEFITS OF EARLY ANGIOGRAPHY

If ST elevation is present on the post-arrest ECG, it is recommended to carry out urgent coronary angiography with immediate revascularization of any infarct-related artery in post-cardiac arrest patients [9] (Figs. **2-4**). Numerous studies validated the importance of coronary angiography post-arrest including the PROCAT trial. This study showed that in post-cardiac arrest patients who were thought to have a cardiac etiology for their arrest taken for coronary angiography, a coronary artery lesion that is feasible for emergency treatment was found in 96% of patients with ST elevation and in

58% of patients without ST elevation [7]. Furthermore, in the INTCAR-Cardiology database of 746 comatose post-cardiac arrest patients, an occluded culprit vessel was found in 74.3% of STEMI patients with the LAD and RCA vessels most commonly affected [8].

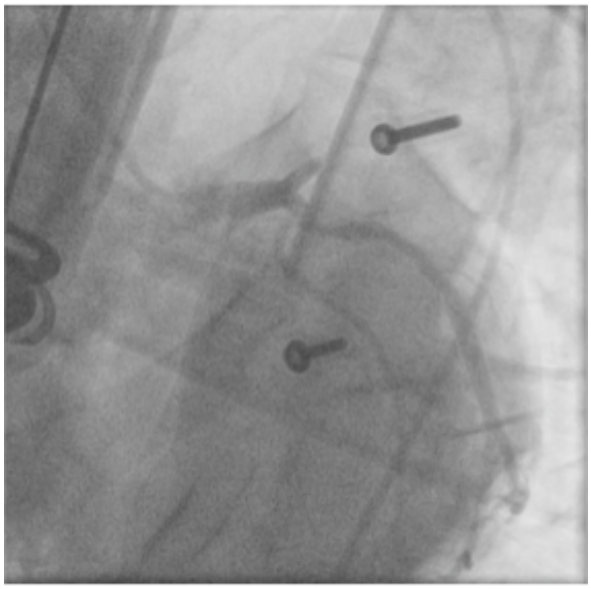

Fig. (2). Post arrest angiogram showing acutely totally occluded proximal left anterior descending coronary artery with LUCAS device in place.

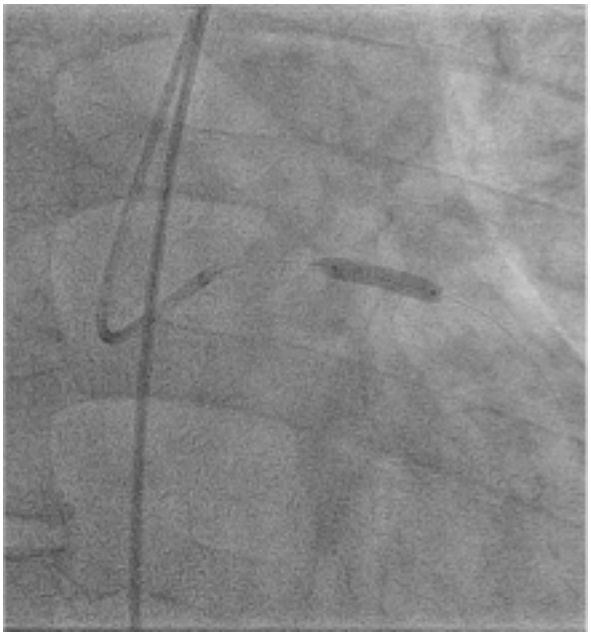

Fig. (3). Drug eluting stent deployment in proximal left anterior descending artery.

Several observational studies evaluating the association between coronary angiography, survival and functional outcomes in post-cardiac arrest patients resulted in updates to the 2015 AHA Guideline Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. The 2015 International Liaison Committee on Resuscitation (ILCOR)

Fig. (4). Angiogram showing patent left anterior descending coronary artery post percutaneous coronary intervention with drug eluting stent placement.

combined with the AHA performed systematic reviews that analyzed urgent coronary angiography for patients post cardiac arrest. This resulted in a modification to the recommended timing of coronary angiography stating that it should be performed emergently (rather than later in the hospital stay or not at all) for OHCA patients who are suspected of having a cardiac etiology of cardiac arrest and ST elevation on ECG, making this a Class 1 recommendation [9]. Although immediate coronary angiography timing was not uniform amongst the several studies analyzed, all studies concluded that immediate angiography is defined as a procedure completed on the same day as the cardiac arrest, in contrast to later in the patient's hospital stay. The 2015 guidelines took into account 15 observational studies that reported improved survival to hospital discharge associated with immediate coronary angiography in patients with ST elevation after cardiac arrest [13-27]. In particular, one study looking at mortality rates as well as neurologic outcomes in cardiac arrest patients who received early coronary angiography ($\leq$ 6 hours) were compared to control groups who either did not receive cardiac catheterization or received angiography > 6 hours after hospital admission [22]. Results of the 240 patients with OHCA showed that early angiography (defined as the procedure performed within the initial 6 hours) was found to result in higher survival rate compared to patients receiving no catheterization or after 6 hours [22].

The improved survival rates were due to several benefits attributed to early catheterization. One of those benefits was the timely ability to assess coronary anatomy, since early recognition of coronary versus non-coronary etiologies of cardiac arrest in select patients can result in the identification of the appropriate therapeutic strategy [22]. Furthermore, many post-cardiac arrest patients may require emergent hemodynamic support with an intra-aortic balloon pump or percutaneous ventricular assist device throughout the post-arrest period. This would allow patients to be identified early on in regards to who could require surgery for bypass graft-

ing, a left ventricular assist device, or ECMO after cardiac catheterization [21]. If these resources are unavailable, early angiography can help identify patients promptly who will require a higher level of care necessitating transfer to another healthcare facility (Fig. **5**). This can potentially help mitigate ischemia, prevent secondary organ injury and determine prognosis. In addition to mortality and early diagnostic benefits, several observational studies also showed improved favorable neurologic outcomes attributed to early coronary angiography in post-cardiac arrest patient with STEMI [1, 13-31]. The 2015 AHA guidelines, therefore, state that coronary angiography is reasonable in post-cardiac arrest patients when indicated regardless of whether the patient is comatose or awake (Class IIa recommendation) [9].

Fig. (5). Example of LUCAS device being used in the catheterization lab.

Prior consensus statements have argued that public reporting of post-procedure mortalities creates an incentive to avoid emergency coronary angiography in comatose patients who are at higher risk of death as a result of poor neurologic recovery [6]. However, the likelihood of neurologic recovery cannot be decided accurately prior to emergency cardiovascular interventions being performed. Therefore, appropriate decision making regarding cardiovascular interventions should be made separate from the assessment of neurologic prognosis [6].

4. CULPRIT ONLY *VS.* MULTI-VESSEL PCI

Currently under debate is the pursuit of single culprit vessel only PCI vs multi-vessel or complete revascularization in patients presenting post-cardiac arrest with STEMI and multi-vessel CAD. Patients with global cardiac ischemia due to multi-vessel CAD can be prone to cardiac arrest and STEMI making the determination of the appropriate treatment strategy vital. Mylotte *et al*., performed an observational study that compared single vessel *vs*. multi-vessel PCI among patients presenting with STEMI who also had cardiogenic shock and successfully resuscitated cardiac arrest [32]. This study showed that of the169 patients who presented with these inclusion criteria and multi- vessel CAD, six-month survival was significantly greater in those who underwent multi- vessel primary PCI compared to those who had a culprit-only intervention (43.9% *vs*. 20.4%, p=0.0017) [32].

This survival benefit was attributed to a significant decrease in the composite endpoint of repeat cardiac arrest, shock and death in the multi-vessel primary PCI group (50.0% vs. 68.0%, p=0.024) [32]. However, the recently published CULPRIT-SHOCK study showed that among patients with cardiogenic shock, STEMI and multi-vessel CAD (but not cardiac arrest) the 30-day risk of a composite of death was lower among those who initially underwent PCI of the culprit lesion only than among those who underwent immediate multi-vessel PCI [33]. At this time there are no specific guidelines pertaining to culprit only vs multi-vessel PCI in post cardiac arrest patients with STEMI and multi-vessel CAD necessitating the need for further study. The optimum revascularization strategy at this time should be determined on an individual basis.

5. LIMITATIONS OF CURRENT EVIDENCE

The inherent shortcomings of observational studies looking at early cardiac catheterization for post-cardiac arrest patients must be noted particularly given the possibility of selection bias. There is a growing concern that early coronary angiography is selectively administered to those with a good prognosis for neurological recovery. Given the small size and retrospective studies that were used, observational studies are limited in being able to account for selection bias.

Although randomized trials have shown better outcomes with early coronary angiography and revascularization in the STEMI population [34], there are multiple factors to consider when applying these findings to the cardiac arrest population. One important factor to consider is that cardiac arrest patients were excluded from randomized trials of early revascularization in STEMI leading to clinical ambiguity [28]. Also, given the high false negative rates of 12-lead ECGs post-arrest, diagnosing a STEMI in resuscitated patients can be difficult [28]. Furthermore, some physicians may wish to withhold invasive procedures such as coronary angiography in cardiac arrest patients with uncertain potential for neurological recovery. Finally, based on the available data and shortage of randomized trials, it is difficult to compare PCI vs thrombolysis outcomes in comatose survivors with STEMI.

Thus, in the current era of public reporting, interventional cardiologists may be disinclined to recommend coronary angiography to cardiac arrest patients due to their potentially high risk of mortality [6]. Proposals for excluding coronary angiography outcomes in this high-risk group for future reporting to prevent withholding of necessary procedures are under consideration. Without prospective randomized trials, evidence for early coronary angiography in cardiac arrest patients comes from observational studies only [18-24]. The dearth of randomized trials poses a significant limitation in assessing the evidence-based benefit of early angiography and PCI. Despite these limitations, a majority of studies up to this point have found that early coronary angiography is associated with improved survival to discharge [18, 20].

6. POOR PATIENT PROGNOSTIC FACTORS

A difficult but important consideration physicians may have to take into account is how to approach patients who have been successfully resuscitated post-cardiac arrest with STEMI.

The presence of multiple adverse resuscitation factors that negatively affects the procedural risk to survival benefit ratio of PCI can potentially identify patients that will gain the least from coronary intervention. This should be assessed prior to deciding to proceed with coronary angiography.

It is important to emphasize that revascularization of the infarct artery by PCI and potential reductions in adverse cardiac events may not be acceptable if there is poor neurological function [12].

An important unfavorable predictor is un-witnessed arrest with an extended period of time without systemic circulation prior to the resuscitation effort. This prolonged time of presumed systemic hypo-perfusion has been associated with a decreased survival-to-discharge rate. Similarly, no bystander CPR or longer than 30 minutes to ROSC are factors that are also associated with decreased survival to discharge rates [29]. Furthermore, patients over the age of 85 years old and patients with end-stage renal disease also have poor survival rates [29]. Physical exam findings consistent with absent brainstem reflexes, such as lack of spontaneous breathing as well as pupillary, corneal and cough reflexes and absence of motor response with pain stimulation (Glasgow Coma Scale motor response of **1)** are also predictors of poor outcome [35]. Laboratory values of patients after OHCA who had worse outcomes included higher lactate levels (>80 mg/dL) and lower pH levels (<7.05). Although both lab values were associated with poor outcomes, pH level was a better prognostic indicator of neurological outcome than lactate levels [36]. Regarding the presenting rhythm, results from the Prehospital Myocardial Infarction Registry (PREMIR) showed that higher mortality rates were found in patients presenting with asystole or pulseless electric activity [37]. This was opposed to VF and VT heart rhythms which were associated with better survival rates comparatively. It also showed that other independent predictors of mortality were needed for endotracheal intubation and older age.

In patients with one or more of these aforementioned unfavorable features, the benefit to futility ratio of taking patients to the catheterization laboratory should be carefully considered. Rab T *et al.*, offer a structured algorithm to help guide providers with how to identify appropriate care for all comatose survivors of cardiac arrest with and without STEMI and to recognize patients who are unlikely to receive significant benefit from an early invasive approach [30].

7. HYPOTHERMIA WITH PCI

Using both systemic mild therapeutic hypothermia as well as an invasive interventional approach on the successfully resuscitated post-cardiac arrest STEMI patient is also important when feasible. The AHA 2015 Post-Cardiac Arrest Care Guideline for CPR and Emergency Cardiovascular Care make it a class 1 recommendation for comatose adults with STEMI after OHCA due to VF and /or pulseless VT to undergo therapeutic hypothermia with targeted temperature management (TTM) targeting and maintaining a constant temperature between 32 and 36 ºC [9, 10]. Mooney *et al.*, showed that among patients with ROSC after OHCA and STEMI, those treated with both hypothermia and coronary angiography with or without PCI had an overall survival rate of 65%, with 92% of survivors having good neurological recovery [14]. Delaying hypothermia initiation resulted in worse outcomes, given that every hour of delay the risk of death increased by 20% [34].

CONCLUSION

To summarize, both the European Society of Cardiology and the combined entity of the American College of Cardiology Foundation and the AHA have published STEMI guidelines recommending immediate coronary angiography and percutaneous coronary intervention when indicated, for resuscitated OHCA patients whose subsequent ECGs show STEMI [9, 28, 31]. These guidelines also emphasize the need for an organized approach to post-resuscitation care, including transfer to centers capable of performing therapeutic hypothermia and PCI.

A 12-lead ECG should be obtained as soon as possible after ROSC to determine whether acute ST elevation is present (Class 1 Recommendation) [9, 28, 31]. Coronary angiography should be performed emergently (rather than later in the hospital stay or not at all) for OHCA patients with suspected cardiac etiology of arrest and ST elevation on ECG (Class I) [9, 28, 31]. Coronary angiography is reasonable in post-cardiac arrest patients for whom coronary angiography is indicated regardless of whether the patient is comatose or awake (Class IIa, LOE C-LD), although patients with several unfavorable features may require further consideration before being taken for angiography [9, 28, 31]. While most patients with cardiac arrest benefit from urgent targeted temperature management, invasive angiography, and culprit lesion revascularization, selected patients with multiple unfavorable factors should be carefully evaluated for these measures given the high likelihood of futility [9].

Independent predictors of mortality and poor prognosis were need for endotracheal intubation, older age, unwitnessed arrest, prolonged time period without CPR and time to ROSC. Ventricular fibrillation and ventricular tachycardia as initial heart rhythms were associated with improved survival [30, 37]. One can use a proposed algorithm to help identify comatose survivors of cardiac arrest with and without STEMI who might benefit from an early invasive approach vs those survivors who are unlikely to receive substantial benefit [30].

LIST OF ABBREVIATIONS

ACS	=	Acute Coronary Syndromes
AHA	=	American Heart Association
CAD	=	Coronary Artery Disease
ECG	=	Electrocardiogram
OHCA	=	Out-of-hospital cardiac arrest
PCI	=	Percutaneous Coronary Intervention
ROSC	=	Return of Spontaneous Circulation

STEMI	=	ST Elevation Myocardial Infarction
TTM	=	Targeted Temperature Management
VF	=	Ventricular Fibrillation
VT	=	Ventricular Tachycardia

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Declared none.

REFERENCES

[1] Girotra S, Nallamothu BK, Spertus JA, *et al*. Trends in survival after in-hospital cardiac arrest. N Engl J Med 2012; 367(20): 1912-20.

[2] Sans S, Kesteloot H, Kromhout D. The burden of cardiovascular diseases mortality in Europe. Task force of the European society of cardiology on cardiovascular mortality and morbidity statistics in Europe. Eur Heart J 1997; 18(12): 1231-48.

[3] Mozaffarian D, Benjamin EJ, Go AS, *et al*. Heart disease and stroke statistics--2015 update: A report from the American Heart Association. Circulation 2015; 131(4): e29-322.

[4] Chan PS, McNally B, Tang F, Kellermann A, Group CS. Recent trends in survival from out-of-hospital cardiac arrest in the United States. Circulation 2014; 130(21): 1876-82.

[5] Wissenberg M, Lippert FK, Folke F, *et al*. Association of national initiatives to improve cardiac arrest management with rates of bystander intervention and patient survival after out-of-hospital cardiac arrest. JAMA 2013; 310(13): 1377-84.

[6] Peberdy MA, Donnino MW, Callaway CW, *et al*. Impact of percutaneous coronary intervention performance reporting on cardiac resuscitation centers: A scientific statement from the American Heart Association. Circulation 2013; 128(7): 762-73.

[7] Dumas F, Cariou A, Manzo-Silberman S, *et al*. Immediate percutaneous coronary intervention is associated with better survival after out-of-hospital cardiac arrest: Insights from the PROCAT (Parisian Region Out of hospital Cardiac ArresT) registry. Circ Cardiovasc Interv 2010; 3(3): 200-7.

[8] Kern KB, Lotun K, Patel N, *et al*. Outcomes of comatose cardiac arrest survivors with and without ST-segment elevation myocardial infarction: Importance of coronary angiography. JACC Cardiovasc Interv 2015; 8(8): 1031-40.

[9] Neumar RW, Shuster M, Callaway CW, *et al*. Part 1: Executive summary: 2015 American Heart Association Guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation 2015; 132(18 Suppl 2): S315-67.

[10] Peberdy MA, Callaway CW, Neumar RW, *et al*. Part 9: Post-cardiac arrest care: 2010 American Heart Association Guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation 2010; 122(18 Suppl 3): S768-86.

[11] Quinn T, Johnsen S, Gale CP, *et al*. Effects of prehospital 12-lead ECG on processes of care and mortality in acute coronary syndrome: A linked cohort study from the Myocardial Ischaemia National Audit Project. Heart 2014; 100(12): 944-50.

[12] Garcia S, Drexel T, Bekwelem W, *et al*. Early access to the cardiac catheterization laboratory for patients resuscitated from cardiac arrest due to a shockable rhythm: The Minnesota resuscitation consortium twin cities unified protocol. J Am Heart Assoc 2016; 5(1): pii: e002670.

[13] Hollenbeck RD, McPherson JA, Mooney MR, *et al*. Early cardiac catheterization is associated with improved survival in comatose survivors of cardiac arrest without STEMI. Resuscitation 2014; 85(1): 88-95.

[14] Mooney MR, Unger BT, Boland LL, *et al*. Therapeutic hypothermia after out-of-hospital cardiac arrest: Evaluation of a regional system to increase access to cooling. Circulation 2011; 124(2): 206-14.

[15] Gräsner JT, Meybohm P, Lefering R, *et al*. ROSC after cardiac arrest--the RACA score to predict outcome after out-of-hospital cardiac arrest. Eur Heart J 2011; 32(13): 1649-56.

[16] Cronier P, Vignon P, Bouferrache K, *et al*. Impact of routine percutaneous coronary intervention after out-of-hospital cardiac arrest due to ventricular fibrillation. Crit Care 2011; 15(3): R122.

[17] Bulut S, Aengevaeren WR, Luijten HJ, Verheugt FW. Successful out-of-hospital cardiopulmonary resuscitation: What is the optimal in-hospital treatment strategy? Resuscitation 2000; 47(2): 155-61.

[18] Bro-Jeppesen J, Kjaergaard J, Wanscher M, *et al*. Emergency coronary angiography in comatose cardiac arrest patients: Do real-life experiences support the guidelines? Eur Heart J Acute Cardiovasc Care 2012; 1(4): 291-301.

[19] Aurore A, Jabre P, Liot P, Margenet A, Lecarpentier E, Combes X. Predictive factors for positive coronary angiography in out-of-hospital cardiac arrest patients. Eur J Emerg Med 2011; 18(2): 73-6.

[20] Nanjayya VB, Nayyar V. Immediate coronary angiogram in comatose survivors of out-of-hospital cardiac arrest--an Australian study. Resuscitation 2012; 83(6): 699-704.

[21] Reynolds JC, Callaway CW, El Khoudary SR, Moore CG, Alvarez RJ, Rittenberger JC. Coronary angiography predicts improved outcome following cardiac arrest: Propensity-adjusted analysis. J Intensive Care Med 2009; 24(3): 179-86.

[22] Strote JA, Maynard C, Olsufka M, *et al*. Comparison of role of early (less than six hours) to later (more than six hours) or no cardiac catheterization after resuscitation from out-of-hospital cardiac arrest. Am J Cardiol 2012; 109(4): 451-4.

[23] Tømte O, Andersen G, Jacobsen D, Drægni T, Auestad B, Sunde K. Strong and weak aspects of an established post-resuscitation treatment protocol-A five-year observational study. Resuscitation 2011; 82(9): 1186-93.

[24] Waldo SW, Armstrong EJ, Kulkarni A, *et al*. Comparison of clinical characteristics and outcomes of cardiac arrest survivors having versus not having coronary angiography. Am J Cardiol 2013; 111(9): 1253-8.

[25] Nielsen N, Hovdenes J, Nilsson F, *et al*. Outcome, timing and adverse events in therapeutic hypothermia after out-of-hospital cardiac arrest. Acta Anaesthesiol Scand 2009; 53(7): 926-34.

[26] Werling M, Thorén AB, Axelsson C, Herlitz J. Treatment and outcome in post-resuscitation care after out-of-hospital cardiac arrest when a modern therapeutic approach was introduced. Resuscitation 2007; 73(1): 40-5.

[27] Zanuttini D, Armellini I, Nucifora G, *et al*. Impact of emergency coronary angiography on in-hospital outcome of unconscious survivors after out-of-hospital cardiac arrest. Am J Cardiol 2012; 110(12): 1723-8.

[28] O'Gara PT, Kushner FG, Ascheim DD, *et al*. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: Executive summary: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines: Developed in collaboration with the American College of Emergency Physicians and Society for Cardiovascular Angiography and Interventions. Catheter Cardiovasc Interv 2013; 82(1): E1-27.

[29] Spaulding CM, Joly LM, Rosenberg A, *et al*. Immediate coronary angiography in survivors of out-of-hospital cardiac arrest. N Engl J Med 1997; 336(23): 1629-33.

[30] Rab T, Kern KB, Tamis-Holland JE, *et al*. Cardiac arrest: A treatment algorithm for emergent invasive cardiac procedures in the resuscitated comatose patient. J Am Coll Cardiol 2015; 66(1): 62-73.

[31] Noc M, Fajadet J, Lassen JF, *et al*. Invasive coronary treatment strategies for out-of-hospital cardiac arrest: a consensus statement from the European association for percutaneous cardiovascular interventions (EAPCI)/stent for life (SFL) groups. EuroIntervention 2014; 10(1): 31-7.

[32] Mylotte D, Morice MC, Eltchaninoff H, *et al*. Primary percutaneous coronary intervention in patients with acute myocardial infarction, resuscitated cardiac arrest, and cardiogenic shock: The role of primary multivessel revascularization. JACC Cardiovasc Interv 2013; 6(2): 115-25.

[33] Thiele H, Akin I, Sandri M, *et al*. PCI strategies in patients with acute myocardial infarction and cardiogenic shock. N Engl J Med 2017; 377(25): 2419-32.

[34] Girotra S, Chan PS, Bradley SM. Post-resuscitation care following out-of-hospital and in-hospital cardiac arrest. Heart 2015; 101(24): 1943-9.

[35] Martinell L, Nielsen N, Herlitz J, *et al*. Early predictors of poor outcome after out-of-hospital cardiac arrest. Crit Care 2017; 21(1): 96.

[36] Momiyama Y, Yamada W, Miyata K, *et al*. Prognostic values of blood pH and lactate levels in patients resuscitated from out-of-hospital cardiac arrest. Acute Med Surg 2017; 4(1): 25-30.

[37] Koeth O, Nibbe L, Arntz HR, *et al*. Fate of patients with prehospital resuscitation for ST-elevation myocardial infarction and a high rate of early reperfusion therapy (results from the PREMIR [Prehospital Myocardial Infarction Registry]). Am J Cardiol 2012; 109(12): 1733-7.