Coronary Air Embolism During Coronary Angiography: A Systematic Review

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Abstract

Coronary air embolism (CARE) is a rare complication during transluminal coronary angiography or angioplasty and is almost always iatrogenic. CARE can cause significant morbidity and mortality as shown in animal studies. CARE is known to cause acute chest pain, hypotension, bradycardia, ST-segment elevation myocardial infarction (STEMI), and death. Multiple isolated case reports of CARE have been reported. We here present a systematic review of cases of CARE during transluminal coronary angiography or angioplasty. Multiple databases were searched to identify cases, the cases were thoroughly read and findings were tabulated. Our analysis revealed that CARE most often resulted in chest pain or loss of consciousness. Most of the patients developed bradycardia and hypotension. STEMI was the most common electrocardiography (EKG) finding and discrete vessel cut off was the most common angiographic finding. Coronary angiography technique including avoidance of air in the angiogram equipments by education of physicians and paramedical staff new to coronary angiography or angioplasty plays a vital role in prevention of CARE. Physicians should be aware of CARE as one of the cause of chest pain, hypotension, bradycardia, STEMI and arrhythmias during transluminal coronary angiography or angioplasty.

Keywords
Coronary Angiography; Air Embolism
Introduction

Coronary air embolism (CARE) is a rare complication from during transluminal coronary angiography or angioplasty. CARE is almost always iatrogenic, thus is preventable when caution i exercised. CARE can be asymptomatic or can cause chest pain, ST-segment elevation myocardial infarction (STEMI), arrhythmias, hypotension and death [1, 2]. CARE is associated with significant morbidity and mortality [1]. Various isolated cases reports of CARE during transluminal coronary angiography or angioplasty have been reported. Specific management guidelines for management of CARE during cardiac catheterization are lacking [1] and are derived based on individual physician experience. We here present the review of cases of transluminal coronary angiography or angioplasty CARE.

Methods

On November 28, 2017, a systematic search was conducted using Pubmed, Google Scholar, CINAHL, Cochrane CENTRAL and Web of Science databases. Studies listing the keywords “coronary air embolism, myocardial infarction, Non-ST segment myocardial infarction (MI) (NSTEMI), ST segment myocardial infarction (STEMI), coronary angiogram, coronary angioplasty” were used to identify cases of transluminal coronary angiography or angioplasty complicated by CARE. The reference list of each report was reviewed for potential additional cases. All cases were reviewed in detail. Data reviewed included demographic data, CV risk factors, electrocardiography (EKG) findings, troponin levels, associated triggering activity, transthoracic echocardiography, angiography, and management of air embolism when available.

Results

A total of 29 cases were identified [3–24] (Table 1). The mean age of the patients was 52±12 years, with 21 males (72%) and 8 females (28%). The prevalence of cardiovascular risk factors in these patients were: hypertension in 21%, diabetes in 14% and smoking in 24%. Elective cardiac catheterization was performed in 77% and emergent cardiac catheterization in 23%. CARE led to symptoms of chest pain in 84% and loss of consciousness in 16%. Air embolism affected single vessel in 76% and two-vessels in 24%. Right coronary artery (RCA) was affected in 31%, left anterior descending artery (LAD) 45%. In cases that developed air embolism in two-vessels (24%), the affected vessels were left anterior descending artery and left circumflex combined. Blood pressure was reported in 19 cases and 90% of the patients were hypotensive. 18 cases with reported heart rate of whom 73% were bradycardic, 12% developed sinus tachycardia, complete atrioventricular block in 5%, cardiac arrest in 1% and normal heart rate in 5%. Cardiopulmonary resuscitation was performed in 29% and 11% underwent intubation. EKG findings were reported in 25 cases: ST-segment elevation (STEMI) was reported in 68% and ST segment with T-wave inversion in 12%. Various interventions tried to manage air embolism were: aspiration (37.93%), verapamil (3.44%), nitroglycerine (13.79%), external cardiac massage (20.69%), streptokinase (3.45%) and no intervention (17.24%). Complete recovery of the patient was reported in 96%. Cardiopulmonary resuscitation and intubation was reported in 27.59%,
intubation alone in 10.34% and CPR alone in 10.34%. Death was reported in 3.45%. (Table 2).

Discussion
Coronary air embolism (CARE) is a rare complication of transluminal coronary angiography or angioplasty, the incidence of which varies on operators experience to perform the procedure and to detect the complication. The incidence with new trainees is reported at 0.19% and the total incidence is 0.27%, with most cases happening during the initial training months [23]. The incidence of CARE was more with percutaneous transluminal coronary angioplasty (PTCA) when compared to coronary angiogram (0.82 vs. 0.24) [25]. CARE can result in angiographic appearance of discrete vessel cut off due to vessel occlusion, no flow or slow flow phenomenon [26]. Small CARE only causes transient decrease in cardiac function while repeated small CARE or large CARE can cause significant decrease in cardiac contractility due to compromise in distal coronary arterial flow [27]. Mortality and symptomatology related to air embolism is dependent on the amount of air introduced into coronaries, number of vessels affected, baseline cardiac function of the patient and the vascular response such as vasospasm [1]. A canine model showed mortality of 28% with intracoronary air volume of 0.02 ml/kg [28] and a porcine model showed regional decrease in myocardial function with 2μl/kg of intracoronary air [29]. CARE can be asymptomatic or may manifest as chest pain, hypotension, myocardial infarction, and as arrhythmias such as bradycardia, conduction blocks, myocardial infarction, ventricular tachycardia, ventricular fibrillation and death [1, 2].

Air embolism during coronary angiography is almost always iatrogenic and may result from inadequately flushed catheters, introduction or withdrawal of balloon catheters and guidewires, rupture of the balloon, right to left air shunt due to intracardiac shunt, defective manifold systems, leaky equipments, and constant negative suction of self venting catheters that are left outside the body [1]. Every operator should receive training on prevention and management of CARE as it can be totally prevented by exercising caution [30]. Guidelines regarding management of coronary air embolism are largely lacking. Due to the associated morbidity and mortality the emphasis should be on prevention by thoroughly flushing cardiac catheterization equipments and carefully aspirating the catheters [1]. Various management strategies aimed at restoring blood flow in the affected coronary by resolving the air embolism are 100% oxygen to promote nitrogen diffusion, dissolving or passage of the air embolism by transient elevation of intra-atrial pressure by use of inotropes and intra-aortic balloon pump, forceful injection of saline or blood aiming to dissipate the intracoronary air, air aspiration using thrombectomy catheters and use of vasodilators (adenosine, calcium channel blockers and nitrates) to address coronary slow flow [1, 6]. These management strategies are derived from individual experience and guidelines for management of CARE are largely lacking. We have summarized etiopathogenesis and have based on our experience in Figures 1 and 2 respectively.

This systematic review is based on published cases hence is associated with selection bias which may be overcome by similar studies from large registries.
Conclusion

CARE is rare and preventable complication of transluminal coronary angiography or angioplasty. CARE often presents with chest pain and loss of consciousness on the table. CARE mostly affects single coronary artery and can cause bradycardia and hypotension. ST-segment elevation was the most common EKG finding. As CARE is almost always iatrogenic, train of physicians and paramedical staff new to cardiac catheterization plays a key role in prevention. Physicians should consider CARE as one of the differential diagnosis when patients develop chest pain, hypotension, and arrhythmias on the table.

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Figure 1:
Summary of Etiopathogenesis of Coronary Air Embolism
Figure 2:
Proposed Management of CARE

Management of coronary air embolism (CARE)

Early recognition of CARE is important to avoid catastrophic manifestations. Double guessing the possibility of CARE by taking additional angiographic views should be avoided when suspicion is high.

Hemodynamically stable

- Allow bleedback from the catheter to clear any residual air in the system

Hemodynamically unstable

1. Intravenous epinephrine bolus
2. Ascertain that catheterization system is air tight
3. Proximal CARE: Aspirate air via guide catheter
4. Distal CARE:
   a. Repeated injection of heparinized saline
   b. Use coronary microwire to disrupt and disperse CARE
   c. Aspirate air via catheter

Cardiac arrest at anytime: Initiate cardiopulmonary resuscitation as per ACLS (acute cardiac life support) protocol.

Supportive measures: Analgesia, nasal oxygen, intubation and mechanical ventilation, intravenous fluids and vasopressors as needed
Table 1:

Cases of Air Embolism Included in the Review

| Year of publication, author | Number of cases published |
|-----------------------------|---------------------------|
| Bentivoglio et al. [3]      | 1                         |
| Amar et al. [4]             | 1                         |
| Hadjimiltiades et al. [5]   | 1                         |
| Haraphongse et al. [6]      | 1                         |
| Antonellis et al. [7]       | 1                         |
| Inose et al. [8]            | 2                         |
| Hung et al. [9]             | 1                         |
| Patterson et al. [10]       | 1                         |
| Dib et al. [11]             | 1                         |
| Prasad et al. [11]          | 1                         |
| Yang et al. [12]            | 1                         |
| Kokolis et al. [13]         | 1                         |
| Celik et al. [14]           | 1                         |
| Natarajan et al. [15]       | 1                         |
| Rigatelli et al. [16]       | 1                         |
| Tedrick et al. [17]         | 6                         |
| Park et al. [18]            | 1                         |
| Maheshwari et al. [19]      | 1                         |
| Khouzam et al. [20]         | 1                         |
| Sinha et al. [21]           | 1                         |
| Yew et al. [22]             | 1                         |
| Suastika et al. [23]        | 1                         |
| Chand et al. [24]           | 1                         |
Table 2:

Summary of the Result

| Total number of cases | 29 |
|-----------------------|----|
| Mean Age              | 52 ± 12 years |
| Sex                   | Male 21 (72%)  
                           Female 8 (28%) |
| Coronary artery disease risk factors | Hypertension 6 (21%)  
                                      Diabetes 4 (14%)  
                                      Smoking 7 (24%) |
| Indication for cardiac catheterization, documented in 22 | Elective: 17 (77%)  
                                      Emergent: 5 (23%) |
| Patient developed, documented in 25 | Chest pain 21/25 (84%)  
                                      Loss of consciousness 4/25 (16%) |
| Number of vessels affected documented in 29 | Single vessel: 22/29 (76%)  
                                      Two vessels: 7/29 (24%) |
| Vessels affected | Right coronary artery 9 (31.09%)  
                                      Left anterior descending artery (LAD) and left circumflex (LCX) 7 (24.14%)  
                                      LAD 6 (20.69%)  
                                      Saphenous vein graft (SVG) 2 (6.9%)  
                                      Small Br of RCA 1 (3.45%)  
                                      Obtuse marginal branch of LAD 1 (3.45%)  
                                      Total patients in whom LAD was affected 13 (44.83%) |
| Blood pressure (BP) | BP reported in 19  
                                      Hypotension in 17 (89.5%) |
| Heart rate (HR): | HR documented in: 18  
                                      Bradycardia: 13 (72.22%)  
                                      Sinus tachycardia: 2 (11.11%)  
                                      Complete AV block: 1 (5.56%)  
                                      Cardiac arrest: 1 (5.56%)  
                                      No changes in: 1 (5.56%) |
| Patients who needed intubation | 3 (10.34%) |
| Patients who needed cardiopulmonary resuscitation (CPR) | 8 (27.59%) |
| Patients who needed intubation and CPR | 3 (10.34%) |
| EKG findings | ST segment elevation 17 (68%)  
                          ST segment depression with T wave inversion 3 (4.41%)  
                          Ventricular fibrillation 2 (8%)  
                          Second degree AV block, Mobitz type II 1 (4%)  
                          T wave inversion 1 (4%)  
                          Pulseless electrical activity 1 (4%) |
| Total number of cases | 29 |
|-----------------------|----|
| Various management strategies used | 100% Oxygen 13 (44.83%) |
|                       | Vasopressor 2 (41.4%) |
|                       | Aspiration of air bubble 11 (37.93%) |
|                       | External cardiac massage 6 (20.69%) |
|                       | Atropine 5 (17.24%) |
|                       | No intervention in 5 (17.24%) |
|                       | IV Fluids 3 (10.34%) |
|                       | Morphine 3 (10.34%) |
|                       | Temporary ventricular pacing 2 (6.9%) |
|                       | Sublingual nitroglycerin 2 (6.9%) |
|                       | Verapamil 1 (3.45%) |
|                       | Intravenous nitroglycerin 1 (3.45%) |
|                       | Intracoronary nitroglycerin 1 (3.45%) |
|                       | Verapamil 1 (3.45%) |
|                       | Streptokinase injection 1 (3.45%) |
| Death reported in     | 1 (3.45%) |