

Simple Active Air Evacuation Procedure for Right Ventricular Failure Caused by Intracoronary Air Embolism

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In cardiac surgical cases such as valve replacement, right ventricular failure caused by intracoronary air embolism sometimes occurs after aortic declamping and during weaning from cardiopulmonary bypass (CPB). The details are reported of a de-airing method which involves simply rotating the arterial cannula towards the base of the heart, with no need for a particular circuit. This method was used in ten patients who, following open-heart surgery, suffered postoperative right ventricular failure due to air embolism

in the right coronary artery that did not respond to other de-airing methods. The technique resolved the problem in all patients, who were quickly weaned from CPB and ultimately discharged. Rotation of the arterial cannula may represent a simple means of resuscitating patients who have suffered right ventricular dysfunction that is unrelieved by other, conventional methods.

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Patients with mitral regurgitation (MR) secondary to ischemic cardiomyopathy pose a therapeutic challenge, as the long-term prognosis is poor (1) and is related directly to the degree of MR (2-4). This is especially the case for patients with a reduced left ventricular function (5). In the past, an increased operative In cardiac surgical cases such as valve replacement, ST elevation on electrocardiography and paradoxical contraction of the right ventricular free wall with bulging sometimes occurs after aortic declamping, or during weaning from cardiopulmonary bypass (CPB). In many cases, even though weaning from CPB may be possible, right heart failure can result in refractory hypotension and necessitate reinitiation of the CPB (1). A likely etiology for this complication is that, accompanying cardiac ejection, air retained in the left chambers enters the right coronary artery. In most cases, the intracoronary air-block is improved by prolonging the CPB; however, in rare cases the condition does not improve, and even after a patient has been weaned from CPB they can develop right ventricular failure that requires long-term mechanical support (2). In the present authors' experience, a simple rotation of the

arterial cannula can allow the resuscitation of patients who have suffered right ventricular dysfunction that is unrelieved by other, conventional methods.

Clinical material and methods

Among 2,288 open-heart surgeries conducted at the authors' department between January 2001 and May 2009, 10 patients (six men, four women) experienced postoperative right ventricular failure due to air embolism in the right coronary artery. All had undergone open-heart surgery for mitral valve disease under conventional conditions, namely CPB at the lowest body temperature of 32–34°C and blood cardioplegia. The mean aortic cross-clamp time was 49 ± 12 min. Carbon dioxide insufflation of the pericardial cavity was instituted before opening the heart in order to prevent air embolization, and pre-declamping air evacuation was conducted as a routine procedure. Before aortic declamping, antegrade terminal warm blood cardioplegia was infused through the aortic root for 5 min, after which the lung was inflated and intracardiac air vented through the aortic root cannula. After declamping, the heart was restarted, with sinus rhythm achieved in all patients. Following rewarming, weaning from CPB was possible initially, but early hypotension and right ventricular free wall paradoxical motion, accompanied by bulging, were noted. The central venous pressure was increased, but not the left

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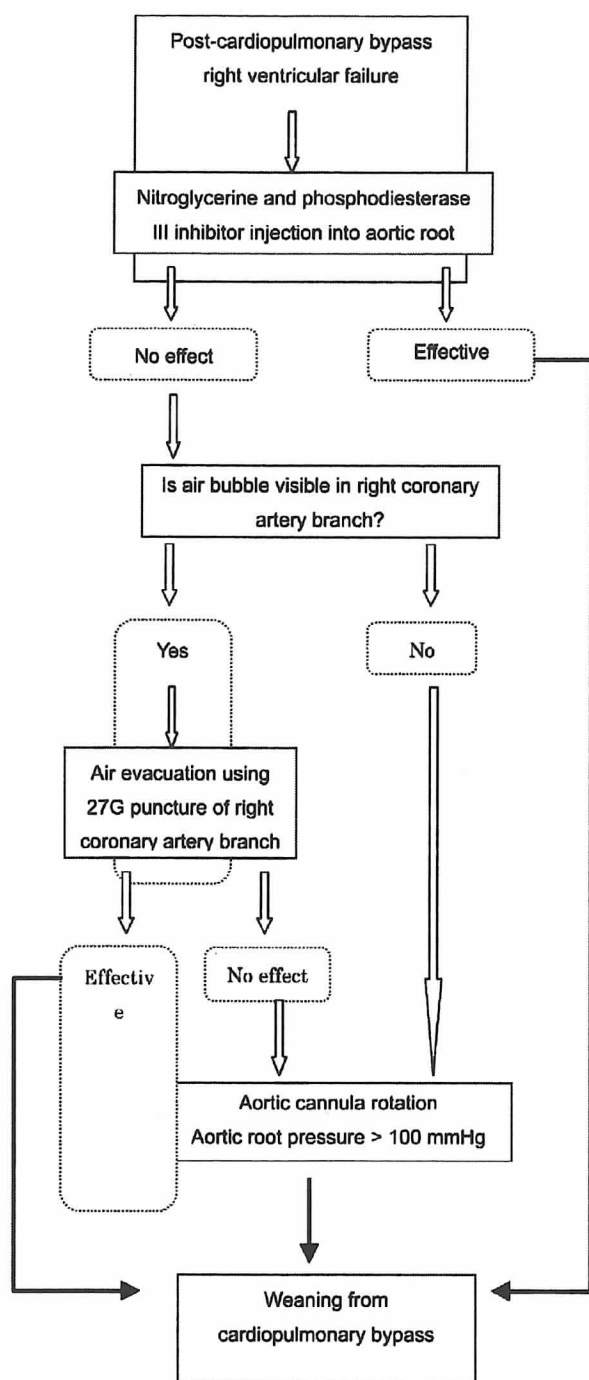


Figure 1: The 'bail-out' algorithm for the management of right ventricular failure caused by coronary air embolism.

atrial pressure, and the blood pressure remained low despite transesophageal echocardiography demonstrating good left ventricular function. Moreover, air bubbles were often observed in branches of the right coronary artery. Right ventricular failure due to intra-coronary air embolism was diagnosed (3), and the CPB

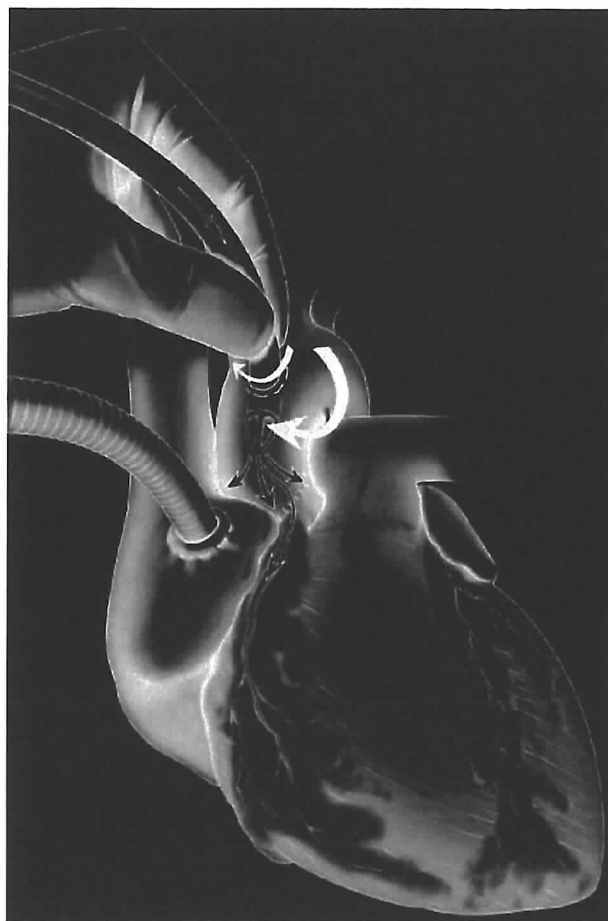


Figure 2: A simple active air evacuation procedure that involves rotating the aortic cannula toward the aortic root.

was reinstituted. Air evacuation from the coronary artery was attempted according to an algorithm (Fig. 1).

The aorta was first partially clamped with a soft clamp (3), after which nitroglycerine and a phosphodiesterase III inhibitor were administered from the base of the heart for the purpose of directly dilating the coronary artery. When an air bubble in the right ventricular branch of the coronary artery was visible, a 27 G needle was used to puncture the coronary arterial branch to vent the air and resolve the embolism. However, in these 10 patients all of the above-described maneuvers failed to improve the right ventricular function, and the following procedure was conducted to their resuscitation:

- The arterial cannula (24 Fr, Jostra) that had been inserted into the ascending aorta was rotated manually by 180° so that, instead of orienting peripherally, the cannula was pointing centrally. The pump was slowed briefly during rotation to prevent aortic wall injury.

- The pressure on the left side of the aortic root was monitored from the cardioplegia needle. When a pressure >100 mmHg was reached at the aortic root, blood was flushed toward the base of the aorta (Fig. 2).
- Flushing was conducted for a few seconds while monitoring the right ventricular free wall motion and electrocardiogram (ECG), and repeated if necessary. Two to three sessions of flushing were delivered until the wall motion and ECG findings were normalized, and weaning from CPB was again attempted.

In all patients, removal from CPB was possible (mean CPB time 100 ± 35 min), and the postoperative course was uneventful with no ECG abnormalities. All patients were eventually discharged.

Discussion

In valve surgeries and on-pump coronary artery bypass grafting, right ventricular failure - although rare - may occur during weaning from or discontinuation of CPB, as a result of air embolism in the right coronary artery (4). In most cases, the air dissolves naturally under prolonged CPB, and the embolism is resolved gradually via the micro-arteriovenous (AV) shunts (5,6) such that it poses no major clinical problem. In rare cases, however, right heart failure persists during weaning from CPB. While the incidence of this complication may be low, it has important consequences that include a prolonged CPB, persistent right heart failure, and even an increased risk of death. Fatal cases of right coronary air embolism have been reported, with the cause of death typically being myocardial infarction and heart failure (7,8).

Air bubbles of approximately 100 μ m diameter are trapped when entering the microcirculation, blocking the blood flow (9). Air embolism is commonly recognized by ECG findings of elevated ST segment in leads II and III, or AV block. Methods that are used conventionally to manage this condition include: (i) continuing CPB at a slightly higher perfusion pressure to drive air bubbles towards the periphery of the coronary artery (1); (ii) the administration of catecholamines to raise blood pressure aiming to flush out the air (1); and/or (iii) the administration of coronary vasodilators such as nitroglycerine, the aim being to flush the air to a more distal part of the artery (10) where it will be resolved via AV shunts that, purportedly, are present in arterioles (<100 μ m in diameter) (5,6). If air embolism occurs postoperatively, the air bubbles may also be removed using a vacuum extraction catheter (11).

The procedure to be taken if these conventional methods fail is unclear, however. Gadhinlajkar et al.

(12) reported the use of controlled perfusion as a 'bail-out' from the ventricular tachycardia/ventricular fibrillation storm after aortic valve replacement. Although this technique may be applicable to the management of right ventricular failure after valve surgery, it has several limitations. First, a separate circuit is required; second, there is a risk associated with additional aortic clamping; and third, the flow rate is difficult to set because of several factors, including the risk of myocardial damage due to hyperperfusion. Hence, this approach is unlikely to be applicable on a routine basis.

The 'bail-out' method involves simply rotating the arterial cannula toward the base of the heart, a maneuver which leads to a sufficient increase in blood pressure (>100 mmHg) being obtained at the aortic root. At the same time, an ample amount of blood is forced into the coronary artery, which facilitates flushing and the wash-out of any air bubbles. As the aorta is not clamped, there is no concern with regards to excessive pressure, and the flushing can be carried out repeatedly (for which a cannula with an L-shaped tip is technically easy to use). During rotation of the cannula, slowing of the pump is recommended to prevent aortic wall injury or aortic dissection.

In conclusion, a simple rotation of the arterial cannula may permit the resuscitation of patients who have suffered right ventricular dysfunction that is unrelieved by other, conventional methods. However, further studies must be conducted to provide scientific evidence supporting the effect of this procedure.

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