AN ORIGINAL AND SAFE DEAIRING PROCEDURE DURING CARDIOPULMONARY BYPASS

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Air embolism is always present as a risk in open-heart operations and can destroy an otherwise excellent surgical procedure. We describe here in an original method of deairing the left side chambers that we have used routinely since 1985. This technique consists of retrograde coronary sinus perfusion and left ventricular venting together with deairing.

Key words: Deairing, air embolism, open heart surgery

For a long time, air embolism has been a dreadful complication in patients undergoing cardiac surgery (1). Air embolism is always present as a risk in open-heart operations and can destroy an otherwise excellent surgical procedure. The incidence of systemic air embolism during cardiopulmonary bypass is estimated to be 0.1% (2). The most critical period for air embolism is the time immediately after declamping the aorta, in conjunction with the cessation of cardiopulmonary bypass (Table 1). Since the brain is clearly the most sensitive organ for air embolism, the complications resulting from the introduction of air into the systemic circulation are primarily manifested by neurologic injury, a particularly devastating complication physically and economically (3). A study of the arch and carotid artery anatomy shows how air preferentially passes first up to the right carotid artery resulting in a right hemisphere neurologic lesion with left hemiparetic sequelae. It would be almost impossible to get air into the left carotid artery yet spare the right carotid artery if the right carotid was occluded. Also the right external carotid artery most often lies in an anterior position over the internal carotid artery. Therefore, small amounts of air are often filtered by that system without sequelae.
Anatomically, the right coronary artery is the first branch anteriorly from the aorta. Air in the left sided cardiac chambers can embolize first to the right coronary artery, resulting in a heart block and/or right

ventricular dysfunction. Presently, the most common cause of significant coronary air embolism is the use of incorrect technique during the administration of cardioplegia.
Although the methodology of deairing varies among cardiovascular surgery centers, the need for air evacuation is accepted in routine open heart surgery and deairing procedures have been simplified. We describe herein a method of deairing the left side chambers that we have used routinely since 1985 in more than 7,000 cases over the last 15 years.

METHOD

Our original deairing procedure which is routinely performed is described as follows:
The arterial line is carefully deaired before connection the cardiopulmonary bypass. After placement of standard aortic and right atrial cannula/s, the right superior pulmonary vein is exposed and the vent cannula is introduced in to the left atrium through a purse string positioned at the base of the vein.
After performing the cardiac procedure, immediately before aortic or left atrial closure, the left atrial vent is turned off to allow slow filling of the heart with blood. The lungs are gently inflated to remove any air from the pulmonary veins into the left atrium. The needle for antegrade cardioplegia placed in the ascending aorta between the cross-clamp and the aortic valve is disconnected for draining the blood together with the bubbles from the aortic root. During the warming period oxygenated blood without additives from the pump filled the cardioplegia bag which is used for retrograde cardioplegia delivery system concomitantly. The volume of blood in the cardioplegia bag is determined by the volume of the cardiac chambers. Blood fills the left atrium, left ventricle and aorta through the right superior pulmonary vein with gravity, approximately 50 cm above the patient (Figure 1).
The operating table is tilted up and the patient is positioned in semi-Fowler status. The heart is gently squeezed, the sternal retractor is vibrated, and the left atrial appendage is

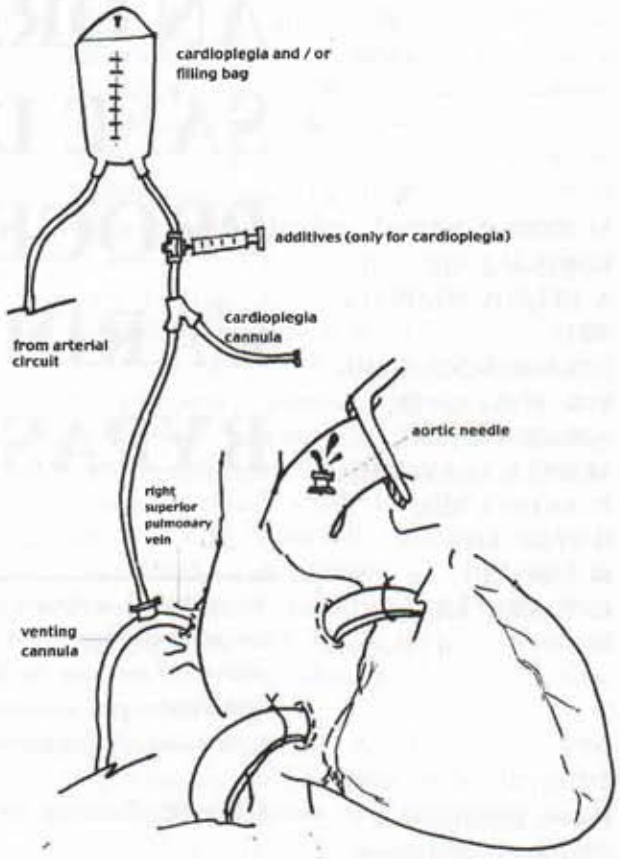

Figure 1. Schematic drawing of the deairing system.

invaginated manually. The patient is positioned in Trendelenburg status while the cerebral blood flow is interrupted by bilateral external pressure on the carotid arteries and finally the aortic cross-clamp is released.
After the evacuation of all floating bubbles through the ascending aorta, the aortic vent needle is withdrawn until the heart is ejecting well for about 10 minutes. The left atrial pressure is raised before the removal of the pulmonary vein vent. The patient is weaned from CPB without any embolic incident after deairing procedure.
Our technique is effective, physiologic and a practical way to lessen the risk of air embolism into the systemic circulation.
Intraoperative transesophageal echocardiography (TEE) monitoring of the patients undergoing mitral valve reconstruction demonstrated that the left sided cardiac

chambers have been completely free of apparent air bubbles on the release of aortic cross-clamp and return of cardiac activity by using this deairing method.

DISCUSSION

This technique containing retrograde coronary sinus perfusion and left ventricular venting together with deairing has many physiological and practical benefits by preventing massive air embolism to the coronary artery and also decompressing the left ventricle avoiding unnecessary complexity more than a direct left ventricular vent.

By the introduction of minimally invasive cardiac surgery procedures, our deairing method gained more importance. This technique can also be used for mitral and aortic valve surgery as a minimally invasive approach.

Former apical deairing technique is required dissection and manuplation of the left ventricular apex especially in redo cases. Our technique provides without relasing left ventricular walls and intersing needle at the apex and also eliminating of the grove ruptures or other bleeding complications.

Despite improvements in cardiac surgical technique, equipment and prevention methods, massive air embolism still occurs, demanding quick and accurate diagnosis and efficient therapeutic measures. The management of gross air embolism includes the recommendations below:

The arterial pump should be immediately stopped and the venous line should be clamped. The patient should be placed in a steep head-down position. The aortic cannula must be removed and the arterial circuit is purged of air. The arterial line is connected to the venous line to facilitate retrograde perfusion. Alternatively, the atrium can be cannulated separately. Retrograde perfusion at a flow rate of 1 to 2 L/min and at a temperature of 20°C is carried out with the flow directed up to the superior vena cava. This is continued for a few minutes with the suction system being used to retrieve blood exiting from the aortotomy. The anesthetist exerts pressure on the carotid arteries, and retrograde perfusion is continued until the arterial system is cleared of air.

Standard bypass is resumed with hypothermia, and attention is turned toward removing any air that may have entered the coronary system by pharmacological elevation of perfusion pressure and small-needle puncture of the distal coronary system. The operative cardiac procedure should be completed as quickly as possible. The patient should be ventilated using 100% oxygen.

The value of steroid therapy is unproven, but it may be beneficial. Hyperosmolar and diuretic therapy is mandatory. Hyperbaric oxygen is considered a specific therapy for air embolism because it is based on the mechanical compression of air bubbles according to Boyle's law: the volume of a gas is inversely proportional to the pressure to which it is exposed. Hence, compression to absolute 6 atmospheres will reduce the size of intravascular bubble to the one sixth of its original volume, which is 55% of its original diameter. This reduction helps relieve the vascular obstruction and restores perfusion.

Table 1. Sources of air embolism

1. Inattention to critical level of blood in the oxygenator
2. Malfunction of the oxygenator, breaking down integrity of lines or oxygenator
3. Unexpected resumption of heart beat
4. Reversal of vent or perfusion lines in pump head
5. Kinking proximal portion of the arterial line to pump head
6. Pressurized cardiotomy reservoir
7. Inappropriate arterial line filtration
8. Faulty technique during circulatory arrest
9. Retained air in the left atrial appendage, myocardial trabeculae, and pulmonary veins especially in redo cases.
10. Incomplete debubbling of the cardiopulmonary bypass system or the formation of bubbles due to an operating room solution gradient
11. Air via intravenous infusion especially in patients with congenital heart disease and any degree of right to left shunt
12. Partial occlusion of the aorta, nonoccluded coronary artery grafts.

Concomitantly, hyperbaric oxygen reduces the blood nitrogen partial pressure, increases the gradient between the bubbles and the blood, and accelerates bubble resorption. In addition, hyperbaric oxygen both increases ischemic brain tissue oxygenation and reduces brain edema by vasoconstriction (2).

According to some authors, cerebral emboli in open heart procedures are most likely to occur during the redistribution of blood from the heart-lung machine to the patient, when the heart is beginning to eject actively, despite careful standard deairing procedures. Meticulous deairing before declamping the aorta is strongly advocated. In addition, the filling of the heart through the right upper pulmonary vein is also very important and easily performed in minimally invasive cardiac surgery and also redo cases by not requiring LV wall release.

In conclusion, the potential risk for embolism from residual air in the left side of the heart is reduced by deairing system. We have been using the described method over the last 15 years and found our original deairing procedure to be effective, safe, practical and time consuming.

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