RETROGRADE PULMONARY PERFUSION FOR PULMONARY THROMBOEMBOLISM

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**Defects of conventional pulmonary embolectomy**

Options for the treatment of pulmonary embolism include medical management using thrombolytics, invasive procedures such as catheter pulmonary embolectomy and surgical embolectomy with or without cardiopulmonary bypass. Common view was that surgical pulmonary embolectomy should be reserved for those patients who are hemodynamically compromised but for whom thrombolytic treatment is contraindicated and for those who are so severely affected that the time required to attempt medical management is unacceptable (1,2).

The major argument against surgical embolectomy was the mortality associated with the procedure. The recently observed improvement in the results of surgical pulmonary embolectomy for massive pulmonary embolism has largely been credited to judicious selection of patients, rapid diagnosis and early surgery performed on hemodynamically stable patients (3-7). Reports state that results of open pulmonary embolectomy have improved, with mortality ranging from 8% to 27% (3-5). However, these series consisted primarily of patients who were not in critical condition at the time of surgery. Mortality rates remain high ranging from 30% to 45% when embolectomy for massive pulmonary embolism is performed on critically ill patients (3,8,9,10), reaching 60% when those patients have experienced cardiac arrest before procedure (8,9).

The causes of death in patients who undergo pulmonary embolectomy have been attributed to right heart failure secondary to persistent pulmonary hypertension, intraalveolar and interstitial pulmonary edema with normal left sided pressures, and massive parenchymal and intrabronchial haemorrhage. The common pathologic finding is pulmonary hemorrhagic infarction (8,11,12,13).

The extraction of clots from the distal branches of the pulmonary artery is commonly performed through an extended pulmonary arteryotomy by suction and the use of standard or gallbladder-stone
forceps, Fogarty catheters, or similar instruments, along with manual compression of the lungs as was advocated in the original report by Cooley and colleagues (14).

Mechanical injury to the pulmonary arterial wall by these means is thought to be responsible for the parenchymal and endobronchial bleeding (6,15,16). The danger of injury to distal vessels has prompted recommendations to avoid blind instrumentation and to limit extraction to visible clots.

Incomplete removal of thrombotic material lodged in the distal pulmonary arterial tree is considered an important cause of persistent pulmonary hypertension (17,18,19). Embolectomy performed through the main pulmonary artery may not be complete. There are reports of intraoperative pulmonary angioscopy carried out after embolectomy were residual thrombus were detected (20). The same has been seen in our patients during operation.

Surgical embolectomy in the patients who require resuscitation before surgical embolectomy or who are massaged onto cardiopulmonary bypass may be unsatisfactory because cardiac massage has displaced significant amounts of embolic material into the distal pulmonary arterial tree, where it may be inaccessible from a central pulmonary arteriotomy.

Scant attention has been devoted to the role of air embolism in causing these adverse, often fatal effects during pulmonary embolectomy. We have seen during intraoperative pulmonary angioscopy that peripheral pulmonary arteries are open during conventional pulmonary embolectomy and entrapped air remains into the peripheral arterial branches (picture 1). Experimental (21,22) and clinical (23,27) evidence indicates that pulmonary air embolism, release of endothelium-derived cytokines, damaging and occluding the microvasculature, with consequent pulmonary hypertension, pulmonary edema, and injury to the lung parenchyma. These findings are strikingly similar to those presented by critically ill patients who undergo pulmonary embolectomy. We believe, pulmonary air embolism can be considered a contributor to the negative outcomes in these patients.

Therefore, conventional pulmonary embolectomy fails to optimally evacuate the peripheral pulmonary arteries from thrombus and air and thus impedes recovery to preoperational pulmonary artery pressure. The severity of the obstructive syndrome depends upon the quantity of entrapped
air, which in turn, depends upon the ratio between the volume of air that has entered the pulmonary arterial system and the capability of the lungs to dissipate it through the alveoli. This renders more vulnerable those patients in whom there is a combination of negative factors: massive air embolism, peripheral migration of thrombotic material, right ventricular failure, and critical preoperative condition.

**Surgical Technique of the retrograde pulmonary perfusion**

The first clinical use of retrograde pulmonary embolectomy was reported in 1965 (28), however it has been used in a few isolated cases (29-33). Its absence from the literature suggests its use and potential benefits have not become widely known. The first report in which retrograde pulmonary perfusion was used as an adjunct to standard pulmonary embolectomy in consecutive series of patients was published by our group (19).

The retrograde pulmonary perfusion technique uses standard normothermic cardiopulmonary bypass with bicaval cannulation. The arterial line is connected to a Y connector (Picture 2). One branch of the connector is joined to the arterial cannula, which is inserted into the ascending aorta. The other branch of the connector is joined to a 20F clamped plastic cannula, which is inserted into the left atrium through a purse-string suture placed on the right upper pulmonary vein. After institution of cardiopulmonary bypass, cross-clamping of the aorta, and infusion of the cardioplegic solution, a longitudinal incision is made in the pulmonary artery trunk distal to the pulmonary valve and is extended into the proximal right and left pulmonary artery branches. The thrombotic material is extracted by means of forceps and suction. The right atrium and ventricle are then explored if necessary and all visible clots are removed. Then while the pulmonary artery is still open, the clamp on the left atrial cannula is released. Blood fills the left atrium and after few seconds the blood begins flowing into the pulmonary artery in a retrograde fashion. The mean pressure on the line is 20 mm.hg.. During reperfusion the left ventricle is compressed manually to avoid the flow from the
left atrium to the left ventricle. We continue retrograde perfusion from 5 to 7 minutes. At the end of retrograde perfusion, lungs are repeatedly inflated in order to mobilize any residual fragment of thrombotic material that may be lodged in the distal branches of the pulmonary artery and to facilitate the elimination of residual air bubbles. The clots are aspirated and all air is progressively eliminated from the pulmonary circulation. The pulmonary arteriotomy is then closed and left atrial cannula is disconnected from the arterial line and is used as a vent. The aorta is declamped, and the patient is weaned from cardiopulmonary bypass by standard method.

In our series, 25 consecutive patients with massive pulmonary embolism underwent pulmonary embolectomy by RPP. There were 6 critically ill patients who experienced cardiac arrest before or during operation. There were no in-hospital deaths. All patients were discharged from the hospital on anticoagulant therapy.

**Goals of the retrograde pulmonary perfusion**

During conventional pulmonary embolectomy pulmonary arterial branches are held open by the elastic parenchyma of the lung itself. Upon discontinuation of cardiopulmonary bypass and restoration of normal blood flow, the entrapped air is driven into the peripheral arterial branches, where it forms microbubbles that contribute to the obstruction of the circulation. Blood flow is obstructed further by the persistence of peripheral thrombi between the air bubbles and the alveolocapillary barrier. This thrombotic obstruction, in turn, impedes the air from reaching the alveoli, where it could be dissipated.

Retrograde pulmonary perfusion performed as an adjunct to pulmonary embolectomy appears to confer 2 benefits: it helps to flush out residual thrombotic material lodged in the distal pulmonary arterial branches, and prevents air embolism within the pulmonary artery. The technique is simple
and it appears effective in reducing the morbidity and death that have accompanied pulmonary embolectomy.

References


Images

Picture 1.

Pulmonary angioscopy performed during operation: peripheral pulmonary arteries remains open during conventional pulmonary embolectomy.
The arterial line is connected to a Y connector. One branch of the connector is joined to the arterial cannula, which is inserted into the ascending aorta. The other branch of the connector is joined to a 20F clamped plastic cannula, which is inserted into the left atrium through a purse-string suture placed on the right upper pulmonary vein.

Picture 2.