Surgical Embolectomy in Acute Massive Pulmonary Embolism

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Abstract

Background- Acute pulmonary embolism is a serious condition and despite diagnostic and therapeutic advances, mortality is still high. Anticoagulation, thrombolytic therapy, catheter embolectomy and open pulmonary embolectomy are therapeutic options. Surgical embolectomy was considered the management of last resort, but recent studies have shown the effectiveness of this therapeutic modality.

Methods- We reviewed our 7-year experience with pulmonary embolectomy in patients with acute massive pulmonary embolism from 1997 to 2004.

Results- Eleven patients underwent open embolectomy. Seven (63.6%) were male and the average age was 45.6. In 5 patients (45.4%), pulmonary embolism occurred after major surgery. Two patients were diagnosed with malignancy and spinal cord injury. No risk factor was detected in 4 patients. The diagnosis was made by spiral CT scan alone in 4 and by angiography in 7 patients. Cardiac arrest occurred in 3 patients pre-operatively. Two patients survived after pre-operative cardiac arrest.

Conclusion- Open pulmonary embolectomy is the most effective method of treatment of acute massive pulmonary embolism. CT scan is the best diagnostic modality and cardiac arrest is the worst prognostic factor. Less aggressive clot evacuation in patients who are diagnosed late seems to be effective in minimizing post-operative hemoptysis ***(Iranian Heart Journal 2007; 8 (1): 6-12)***.

Key words: massive pulmonary embolism ■ hemoptysis■ surgical embolectomy

Acute pulmonary embolism (PE) is considered a condition with high mortality. According to International Cooperation Pulmonary Embolism Registry (ICOPER) data published in 1999, 2454 patients with acute PE died within 90 days, most of which were attributed to recurrent PE.[1] Acute massive pulmonary embolism (AMPE) is described as an occlusion of the pulmonary artery that exceeds more than 50% of its cross-sectional area, resulting in hemodynamic compromise.[2-5]

Despite diagnostic and therapeutic advances, the rate of mortality due to AMPE remains as high as 30%.[6-8]

The mainstay of treatment of PE is anticoagulation with heparin. Other modalities include thrombolysis, catheter embolectomy and surgical embolectomy. Thrombolytic therapy, although effective, is associated with high rates of intracranial hemorrhage (3%).[1]

Catheter embolectomy, which can be performed at the time of pulmonary

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vasculature and increased risk of pulmonary hypertension.[9]

Surgical embolectomy was formerly proposed to be the last resort for management of PE. Recent studies have put a question mark on this belief and consider it as an early treatment modality.[10]

In this report, we discuss our 7-year experience with a series of 11 patients with AMPE who underwent emergency surgical pulmonary embolectomy.

Methods

Retrospectively, we reviewed all cases of AMPE who underwent emergency pulmonary embolectomy from 1997 to 2004. Their hospital records were reviewed for predisposing factors, time interval between the onset of symptoms and operation, pre-operative evaluation, patients' condition prior to surgery, operative technique, site of thrombi, morbidity and mortality.

Patient Population

There were 11 cases of AMPE who underwent open pulmonary embolectomy. Seven were male and the average age was 45.6 years (range: 33 to 72, Table I).

Table I. Patients' clinical variables.

No	Age	Sex	Predisposing Factor	Pre-op Evaluation	Site of Thrombus
1	35	M	Brain Surgery	Echo, Pulm Angio	RA, main PA & branches
2	40	M	-	Echo, Pulm Angio	main PA and branches
3	72	M	-	Echo	RA, main PA & branches
4	35	F	-	Echo, Pulm Angio	PA branches
5	56	M	CABG	Echo, Pulm Angio	PA branches
6	40	F	Abdominoplasty	Echo, Pulm Angio	main PA & branches
7	56	F	Malignancy	Echo, Pulm Angio	RA, small PA branches
8	52	M	CABG	-	main PA & branches
9	40	M	Spinal Cord War Injury	Echo, Spinal CT, Pulm Angio	PA branches
10	43	F	Aortic Dissection Surgery	Echo, Spinal CT	PA branches
11	33	M	-	Spinal CT	main PA & branches

Demographic data, pre-op data and intra-operative findings of patients with massive pulmonary embolism who underwent open pulmonary embolectomy. CABG, coronary artery bypass graft; PA, pulmonary artery; RA. right atrium, Spiral CT, Spiral computed tomography

In 5 patients (45.4%) the event occurred following a surgical intervention. Two of the patients (18.1%) had undergone coronary artery bypass grafting (CABG) within a few days; one brain surgery, one aortic dissection surgery, and one abdominoplasty.

Two others were diagnosed with malignancy and spinal cord injury. No risk factors were found in 4 patients. The average time interval between initiation of symptoms and operation was 4.3 days (range: a few hours to 14 days) (Table II).

Table II. Patients' clinical variables

ID	Time interval	Pre-op condition	Approach	IVC filter	Complication	Outcome
1	2 days	Shock State	Sternotomy	No	-	Survived
2	Few hours	Cardiac Massage	Sternotomy	Yes	-	Survived
3	7 days	Low Cardiac Output	Sternotomy	No	Massive Hemoptysis	Died
4	2 weeks	Dyspneic	Sternotomy	Yes	Renal Failure	Survived
5	6 days	Dyspneic	Re-sternotomy	No	-	Survived
6	Few hours	Cardiac Massage	Sternotomy	Yes	Brain Damage	Survived
7	4 days	Dyspneic	Sternotomy	Yes	-	Late Death
8	4 days	Cardiac Massage	Re-Sternotomy	-	Massive Hemoptysis	Died
9	3 days	Shock State	Sternotomy	No	Mild Hemoptysis	Survived
10	2 days	Dyspneic	Rt Thoracotomy	Yes	Mild Hemoptysis	Survived
11	Few hours	Dyspneic	Sternotomy	Yes	-	Survived

Other clinical variables and outcome of patients with massive pulmonary embolism who underwent open pulmonary embolectomy are depicted in Table II. The diagnosis was made by spinal CT scan in 3 patients, one of whom underwent pulmonary angiography for confirmation. Seven patients were diagnosed by pulmonary angiography alone. One of the patients was diagnosed intra-operatively. Echocardiography was done in 9 patients, which was indicative of embolism in all the patients. Cardiac arrest occurred pre-operatively in 3 patients, and they entered the operating room under continuous CPR. Two patients were in shock state, 5 were only dyspneic and one had low cardiac output pre-operatively. Post-operative complications were massive hemoptysis (2 patients), mild hemoptysis (2 patients), renal failure (1 patient) and brain damage (1 patient). Two patients died early on the operating table due to massive hemoptysis. These 2 patients suffered from symptoms of pulmonary embolism, especially dyspnea for 7 and 4 days (Table I). In the operating room, extensive embolectomy using forceps, Fogarty balloon catheters and lung compression was done. They developed massive hemoptysis soon after weaning off the cardiopulmonary bypass (CPB).

The last two patients, who had symptoms for relatively longer times (3 and 2 days), underwent less aggressive clot evacuation; they developed mild hemoptysis post-operatively.

Surgical Technique

All but one patient underwent sternotomy as the basic surgical approach. After pericardiotomy and full heparinization, the aorta and right atrium were cannulated, and cardiopulmonary bypass was instituted. In all the patients, the embolectomy was done on a beating heart without aortic cross clamping. The main pulmonary artery was opened longitudinally and retracted by army-navy retractors, especially to expose the right pulmonary artery beneath the ascending aorta. In two patients, we had to open the right pulmonary artery between the aorta and superior vena cava for better exposure. Removal of clots was done by Russian forceps and ring forceps in the main branches. Clots were removed from more distal branches by suction, Fogarty catheter and stone forceps (Fig. 1).

Fig. 1. The clot removed from the main pulmonary artery and its branches in one of the patients. Fragments are aligned to form the original shape.

The latter instrument is used by the urologists to remove stones from the urinary system and comes with different angulations (Fig. 2).

Fig. 2. Stone forceps are used to evacuate renal stones. Different tip angles ease the evacuation of clots with minimal risk of fragmentation.

We found this instrument to be a very useful device for gentle extraction of trapped particles of clot in medium-sized pulmonary artery (PA) branches. Irrigation and external lung compression were also used as assisting maneuvers. These maneuvers are only occasionally seen to be useful. Special care was taken not to damage the already infarcted loose tissue in the distal pulmonary branches. In one patient who had an operation for aortic dissection 1 month prior to embolectomy, we preferred to use the left thoracotomy approach to avoid obvious troublesome adhesions. CPB was instituted via the femoral artery and vein in this patient, and the main pulmonary artery was easily approached though the left thorax with good exposure. In 6 patients, IVC filter was inserted perioperatively either by the surgeon or the cardiologist.

Results

Nine (81.8%) of the patients survived the operation and were discharged from the hospital. Two mortalities occurred in our study, both in the operating room and because of massive hemoptysis after weaning off CPB. One of these patients entered the operating room on CPR and the other one with very low cardiac output. A third death occurred one month after surgery due to renal failure. The patient was diagnosed with widespread malignancy and peritoneal seeding prior to death. In addition to the 3 mentioned patients, 2 patients developed mild hemoptysis with good recovery during hospital stay and no sequelae. One other patient suffered from hypoxic brain damage, which led to vegetative state. Follow- ups were complete for 6 of the 8 survived patients. None of them faced hemodynamic problems. Only one patient, for whom an inferior vena caval filter was inserted, developed repeated deep vein thromboses (DVT) in the left lower extremity during the 3-year follow-up. It gradually improved to chronic organized thrombus and sustained edema of that extremity.

Discussion

Massive pulmonary embolism (PE) is defined as the entrapment of a large embolus within the pulmonary artery. If shock is induced, the mortality risk rises three- to seven-fold; the majority of deaths occur within one hour of presentation.[11] As the pulmonary arteries become obstructed, the increased afterload causes right ventricular strain and dilatation, hypokinesis, tricuspid regurgitation with annular dilatation of the tricuspid valve and ultimately right ventricular failure.[12-13] Pressure overload, however, causes leftward shift of the interventricular septum, and together with pulmonary vasoconstriction, results in decreased cardiac output and reduced blood oxygen content and finally, right ventricular ischemia, cardiac arrest and death.[14] Resumption of pulmonary artery flow is the only way to interrupt this fatal cascade. There is a wide consensus to use thrombolytics in massive PE, but controversy arises because the effect on improvement of mortality has not yet been conclusively proven.[8,13,15] However, these agents are contraindicated in up to 50% of patients because of recent surgery, trauma, stroke, hemorrhage or cardiopulmonary resuscitation (CPR).[16] According to ICOPER survey, thrombolytic-treated patients had an intracranial hemorrhage rate of 3%[1], which is a matter of great concern. Gulba and colleagues showed that patients treated with thrombolytics had higher rates of death, major hemorrhage and recurrent embolism than their surgical counterparts.[7] Overall, thrombolytic therapy should be given very cautiously to patients who are not probable candidates of open embolectomy. Catheter embolectomy is a minimally invasive technique that can be performed during contrast pulmonary angiography. Clot is removed by suction through the jugular or femoral veins into the pulmonary artery.[9] Although a success rate of 80% is reported,[9,17] available catheters tend to fragment the embolus with distal showering of emboli to smaller, inaccessible arterial branches and cause further pulmonary hypertension. Recurrence of embolus is more common in this method than with open pulmonary embolectomy.[18] Indications for surgical embolectomy are now beyond traditional ones, such as failed medical therapy and contraindications to thrombolytics. Right ventricular dysfunction without shock, for example, is believed to be a reasonable indication for surgery, because as pulmonary artery to right ventricle (PA-RV) pressure increases, the right ventricle might ultimately fail.[10]

In the past, open pulmonary embolectomy was the treatment of last resort for patients with PE due to its high mortality rate. The average morbidity from different series between 1982 and 1999 is about 30%.[8] The approach has changed over time and many centers are reporting open embolectomy as an integral part of their treatment algorithm for massive and submassive PE.[10] A decrease of mortality of open pulmonary embolectomy from 57% in 1960s[19] to 6% in 2005[10] is proof to this fact. Nonetheless, open pulmonary embolectomy is an immediate and definitive form of treatment for acute massive PE, with excellent long-term results and should not be considered merely as a last resort.[14,20]

Few studies are available comparing medical versus surgical management of PE. In a non-randomized comparison of surgical and medical treatment in hemodynamically compromised patients with massive PE, the medical group had an increased mortality rate, increased number of hemorrhagic events and a high rate of recurrent PE.[7] It is proved in several studies that patients who enter the operating room on CPR have significantly higher mortality rates, compared to no CPR (73.7% vs. 20%).[21] CPR is additionally divided into continuous and intermittent type. The mortality of the former is 80% vs. 40% of the latter.[22] There are two possible reasons for poor prognosis of patients with CPR prior to surgery. First, there may be established organ dysfunction due to prolonged pre-operative hypotension and second, surgical embolectomy after massage may be unsatisfactory because cardiac massage has displaced a significant amount of embolic material into the distal pulmonary arterial tree, where it might be inaccessible.[18]

Massive hemoptysis was a major complication in this series of patients and caused 2 deaths. Both of these patients were diagnosed with delay (7 and 4 days from initial symptoms). Our explanation for this complication is that the clots in these patients had moved further peripherally and eventually had caused infarction in the lung parenchyma, due to delayed diagnosis. This part of the lung becomes more susceptible to bleeding. Before beginning the operation, as the clots were fixed in place, no hemoptysis occurred. However, when we tried to remove the clots from the distal branches aggressively using Fogarty catheter and lung compression, the patient developed hemoptysis as soon as he was weaned from CPB. This means that the connections between capillaries and alveoli, which were produced due to parenchymal infarction, were filled with clots and we manually opened these connections. Consequently, bleeding into the respiratory system occurred. We applied this theory to the management of the last 2 patients who were diagnosed late (2 and 3 days). We exerted less aggressive clot evacuation, which resulted in mild hemoptysis post-operatively. So, it appears reasonable to use less aggressive methods of clot removal from the peripheral vasculature in lately diagnosed cases to minimize the risk of massive hemoptysis. We also raise the idea of using "stone forceps" (Fig. 2) for clot evacuation instead of ring forceps. This instrument, used by urologists to remove renal stones, has different sizes and tip angulations. This allows the surgeon to access more distant clots with a lower risk of fragmentation. Lack of transesophageal echocardiography (TEE) in the operating room for evaluating residual clots after embolectomy was a limitation to our study. However, we assessed the amount of clot remaining by comparison of PA pressure after embolectomy with normal PA pressure. As most cases are acute PE,

adequate clot removal should result in near normal PA pressure, and pressures over normal means that some peripheral clots are still in place.
Sternotomy is considered the best approach for pulmonary embolectomy. Occasionally, due to prior surgeries on the thorax and the resultant adhesion formation in the pericardium, as well as the urgency to reach the PA, this approach is not feasible. We present our experience with one such case that was operated on for aortic dissection and was approached with a left thoracotomy incision. After femoro-femoral cannulation, the left thorax was accessed. Main PA was easily characterized beneath pericardium and incised. This was much faster than dissecting adhesions through a sternotomy.
In conclusion, open pulmonary embolectomy is the most effective way of treatment of AMPE and should not be left as the last option. It provides excellent outcome, both in short and long terms. Spiral CT scan is the best diagnostic modality because it is highly available and non-invasive. Cardiac arrest is the worst prognostic factor, especially if performed continuously prior to operation. Less aggressive clot evacuation in patients who are diagnosed late seems to be a good practice and effective for minimizing post-operative hemoptysis.

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