

Pulmonary Embolectomy for Acute Massive Pulmonary Embolism

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Background. Acute massive pulmonary embolism usually results in death if not diagnosed early and treated aggressively. Thrombolytic therapy and catheter embolectomy are increasingly used as definitive management. Emergent open embolectomy is often reserved as a last resort when less invasive methods have failed or the patient is in cardiopulmonary arrest.

Methods. We reviewed our experience with early open pulmonary embolectomy in patients with acute massive pulmonary embolism from January 1998 to February 2004.

Results. Eleven patients underwent early pulmonary embolectomy. Five (45%) patients were men, and the average age was 48 years. In 4 (36%) patients, a massive pulmonary embolism occurred after a surgical procedure or trauma. The remaining 7 patients had chronic medical diseases. The diagnosis was established primarily by

clinical findings along with spiral computerized tomography or transesophageal echocardiography. Eight (73%) patients survived and were discharged from the hospital. The 3 patients who died suffered cardiac arrest preoperatively and were taken to the operating room with cardiopulmonary resuscitation in progress. Only 1 patient survived after preoperative cardiac arrest.

Conclusions. Early open pulmonary embolectomy using cardiopulmonary bypass is an effective form of treatment for acute massive pulmonary embolism with excellent long-term results. Preoperative cardiac arrest is associated with a high mortality. Spiral computerized tomography and transesophageal echocardiography are important diagnostic tools.

(Ann Thorac Surg 2005;79:1240–4)

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Acute massive pulmonary embolism (AMPE) is life-threatening and usually results in death if not diagnosed early and treated aggressively. Despite increased emphasis on prophylaxis and the development of better diagnostic and therapeutic techniques, mortality associated with AMPE remains at about 30% [1–3]. AMPE comprises as many as one tenth of all cases of pulmonary embolism and is defined as an occlusion of the pulmonary artery that exceeds 50% of its cross-sectional area, resulting in progressive hemodynamic compromise [4–7]. The obstruction of the pulmonary artery to this degree initiates a cascade of physiologic events, which if not interrupted early, ultimately results in cardiac arrest and death in up to 70% of patients in the first hour [1, 5, 7].

Thrombolytic therapy and catheter thromboembolectomy have proven effective in restoring hemodynamic stability in patients with AMPE and have been increasingly used as definitive management of these patients [2, 8, 9]. However, these procedures are associated with an increased risk of hemorrhage, recurrent emboli, and failure to completely resolve the intraluminal thrombus, putting patients at higher risk to develop pulmonary hypertension [2, 3, 10].

On the other hand, advances in surgical and anesthetic techniques, along with the addition of cardiopulmonary bypass (CPB), have improved the survival and long-term

outcome of patients undergoing early open pulmonary embolectomy [1, 3, 4, 11]. Open embolectomy is often reserved for patients in extremis or when less invasive measures have failed, but its true role has not yet been well-characterized and is likely underestimated. This study analyzed the use of early open pulmonary embolectomy in patients with AMPE at an urban public hospital in Los Angeles over a 6-year period.

Material and Methods

A retrospective review was performed of all patients with AMPE who underwent emergency pulmonary embolectomy at Harbor-UCLA Medical Center from January 1998 to February 2004. Patient demographics, risk factors, modes of diagnosis, operative procedures, and postoperative morbidity and mortality were recorded and analyzed. The use of prophylactic measures, thrombolytics, and intracaval filters was also examined.

Surgical Technique

All operations were performed through a median sternotomy. After pericardiotomy and systemic heparinization, the ascending aorta and right atrial appendage were cannulated for the institution of CPB. A longitudinal incision was then made in the pulmonary artery, followed by removal of clot with ring forceps and vigorous irrigation of the pulmonary arterial tree. A choledochoscope was used to identify residual distal clots, which were then extracted. An inferior vena cava filter was

Accepted for publication Aug 30, 2004.

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Table 1. Characteristics and Outcomes of Patients with Acute Massive Pulmonary Embolism Who Underwent Open Pulmonary Embolectomy

Patient	Sex	Diagnosis	History of DVT	Imaging	Thrombolytics	Cardiac Arrest	CPB	Survival
54	M	Stroke within 60 days	No	CT, Angio	CI	No	53	Yes
53	M	Protein C deficiency	Yes	Angio	Yes	No	51	Yes
59	M	Lower GI bleed; history of stroke	No	BS V/Q, BS Echo	CI	Yes	62	Yes
41	F	POD 1 Cesarean section	No	TEE	Yes	Yes	^a	No
26	M	GSW to abd; POD 26 laparotomy	Yes	CT, TEE	CI	No	75	Yes
49	F	Locally advanced lung carcinoma	No	BS Echo, TEE	No	Yes	^a	No
60	F	Brain tumor; POD 35 resection	Yes	CT	CI	Yes	^a	No
46	F	Obese, smoker, Protein S deficiency	Yes	CT BS Echo	No	No	36	Yes
49	M	Elevated homocystine	No	CT, Angio, TEE	Yes	No	86	Yes
52	F	Advanced hepatocellular cancer	No	CT, BS Echo	No	No	45	Yes
44	F	GSW to chest; nonoperative	No	BS Echo, TEE	CI	No	70	Yes

^a Unable to come off bypass.

abd = abdomen; Angio = angiography; BS = bedside; CI = contraindicated; CPB = cardiopulmonary bypass in minutes; CT = spiral computerized tomography; DVT = deep venous thrombosis; Echo = echocardiography; F = female; GSW = gunshot wound; M = male; POD = post op day; TEE = transesophageal echocardiography; V/Q = ventilation/perfusion.

inserted by the interventional radiologists within 24 hours postoperatively in all patients.

Results

From January 1998 to February 2004, 11 patients with AMPE underwent early pulmonary embolectomy (Table 1). Five (45%) patients were men, and the average age was 48 years (range, 26 to 60 years). Three patients had undergone surgical procedures between 1 and 35 days prior, one of which was trauma related. One other patient suffered a gunshot wound to the chest that did not require operative intervention. Three patients had been diagnosed with cancer, one of which had recently under-

gone resection. Three other patients had documented hypercoagulable conditions, and 2 patients had a history of stroke with no identifiable hypercoagulable predispositions. Seven (64%) were inpatients at the time of symptom onset, and only 3 were receiving prophylaxis for venous thrombosis. Two patients were transferred from an outside facility after computerized tomography (CT) scans confirmed the diagnosis of pulmonary embolism. Four patients presented to the emergency room with acute onset of shortness of breath and chest pain.

Spiral CT of the chest with intravenous contrast (Fig 1) was the initial diagnostic study in 6 patients. Angiography was performed in 3 patients and was the only diagnostic study used in 1 patient. Eight patients underwent bedside echocardiography or intraoperative transesophageal echocardiography (TEE), or both. Bedside ventilation-perfusion scanning was performed in 1 patient and revealed evidence of pulmonary embolism, but evaluation by echocardiogram was still necessary before embolectomy. No patient was taken to the operating room on clinical suspicion alone.

Cardiac arrest occurred preoperatively in 4 patients, all of whom required intermittent cardiopulmonary resuscitation (CPR) en route to the operating room. The rest of the patients were hypotensive and tachycardic, and 4 required vasopressor support. Thrombolytic therapy was initiated in 3 patients before open embolectomy. Two of these patients had sudden worsening of respiratory failure after thrombolytic infusion and required an emergency embolectomy. The third patient's hemodynamic state showed no improvement and an urgent pulmonary embolectomy was performed. Thrombolytics were otherwise contraindicated in 5 patients because of recent trauma, stroke, surgery, and major gastrointestinal hemorrhage.

Eight (73%) patients survived and were discharged home. Three patients, who had suffered cardiac arrest

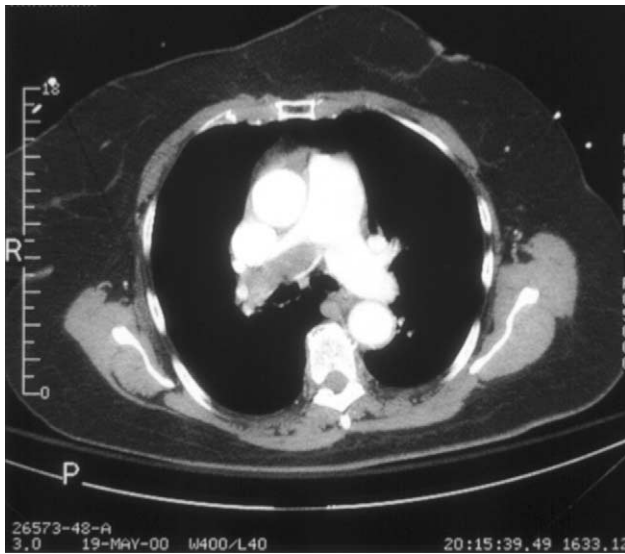


Fig 1. Spiral computed tomography shows a massive embolus in the right pulmonary artery.

Table 2. Mortality Rates in Earlier Studies of Open Pulmonary Embolectomy

Year	Author	Total	Deaths	Mortality %
1978	Tschirkov (Germany)	24	7	29
1981	Clark (England)	42	23	55
1981	Glassford (England)	20	8	40
1981	Bottzauw (Denmark)	23	6	26
1982	Mattox (US)	40	20	50
1985	Achatzy (Germany)	10	4	40
1986	Jaumin (France)	23	7	30
1988	Gray (England)	71	21	30
1990	Meyer (France)	96	36	38
1991	Boulafendis (US)	16	5	31
1991	Kieny (France)	134	21	16
1991	Schmid (Germany)	27	12	44
1991	Bauer (Switzerland)	44	11	25
1992	Meyns (Belgium)	30	6	20
1994	Stutz (Switzerland)	50	23	46
1995	Jakob (Germany)	25	6	24
1999	Doerge (Germany)	41	12	29
1999	Ullmann (Germany)	40	14	35
	Total	756	242	32

preoperatively, died intraoperatively after embolectomy when they could not be weaned off of CPB because of poorly contracting, dilated right ventricles. Only one (25%) of the 4 patients with cardiac arrest before operation survived. The average time on CPB was 60 minutes (range, 36 to 86 minutes) for patients able to be weaned off bypass. The mean systolic pulmonary arterial pressure was 63.3 mm Hg ± 11.8 mm Hg preoperatively and 33.7 mm Hg ± 9.1 mm Hg postoperatively.

Mean follow-up time was 9 months, and all discharged patients survived at least 30 days postoperatively. Seven (88%) of the patients discharged home were placed on long-term anticoagulation with warfarin. Anticoagulation was contraindicated in the eighth patient secondary to a recent major gastrointestinal bleed. One patient required operative drainage of a persistent wound hematoma 2 months postoperatively. Another patient suffered a myocardial infarction 1 month after surgery and required a second operation for repair of an atrial septal defect that was not seen on prior echocardiogram. The postoperative courses for 2 other patients were complicated by pneumonia in 1 and acute renal failure in the other, both of which resolved with medical management.

Comment

The pathophysiology of right ventricular failure secondary to pulmonary embolism was described in detail by Vlahakes and colleagues 20 years ago [12]. As the pulmonary arteries become obstructed, the increased afterload causes right ventricular strain and dilatation, making contractions increasingly difficult for the right ventricle. Displacement of the interventricular septum combined

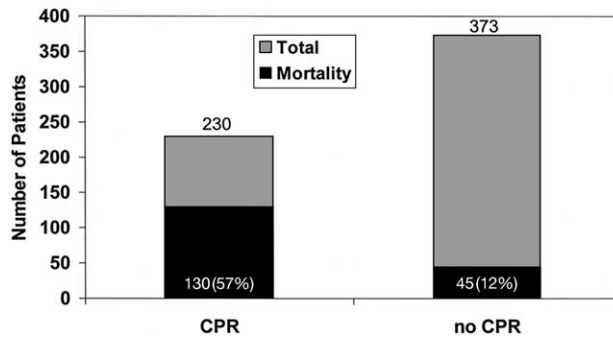


Fig 2. Total number of deaths reported in the literature in patients with acute massive pulmonary embolism with respect to the need for cardiopulmonary resuscitation (CPR).

with pulmonary vasoconstriction result in further decreases in cardiac output and blood oxygen content. As a result, the dilated, dysfunctional right ventricle becomes increasingly ischemic as its oxygen demand outweighs the supply. An endless cycle of poor coronary perfusion and worsening right ventricular failure will eventually lead to cardiac arrest and death. Interruption of this cycle by immediate and complete removal of the obstruction with normalization of right heart pressures is the only option for a good outcome.

Resumption of pulmonary artery flow has been accomplished successfully by open pulmonary embolectomy since the first reported case in 1924 [13]. However, less invasive strategies have become increasingly popular, and open embolectomy is often currently reserved for patients already in cardiac arrest or for those in which less invasive therapies are contraindicated or have failed. Despite an increasing proportion of the sickest patients undergoing open pulmonary embolectomy, mortality rates remain just above 30% for AMPE (Table 2) [1, 7, 11, 14-28]. Definitive restoration of pulmonary artery patency is accomplished and recurrence rates are low when intracaval filters are placed immediately after embolectomy. CPB offers additional benefit to the patient by restoring oxygenation and correcting hypothermia, acidemia, and electrolyte abnormalities to improve the stability of the heart postoperatively.

If preoperative cardiac arrest was avoided, survival after open pulmonary embolectomy in this series was 100%. Similar results are reported in the literature, with an overall mortality of 57% for patients requiring cardiopulmonary resuscitation compared with 12% for those who do not (Fig 2) [1, 15, 20-24, 26-28].

Thrombolytic agents target fibrin bonds and lyse organized clot to restore blood flow in arteries obstructed by thrombus. Although shown to be efficacious in the setting of AMPE, associated long-term morbidity may be high, and agents are contraindicated in up to 50% of patients because of recent surgery, trauma, stroke, hemorrhage, or cardiopulmonary resuscitation [2, 29]. Gulba and colleagues showed that patients treated with thrombolytics had higher rates of death, major hemorrhage, and recurrent embolism than their surgical counterparts [2].

Perhaps the greatest concern is the delay in definitive management that occurs when a trial of thrombolytics fails and the condition of the patient worsens. Emergency operative intervention in the face of recent thrombolytic infusion is significantly more challenging, and the risk of postoperative bleeding is increased. The use of antifibrinolytic agents and cryoprecipitate infusions along with meticulous surgical hemostasis can help to minimize hemorrhagic complications; however, overall blood loss can be significant.

Catheter thromboembolotomy is a minimally invasive technique where clot is removed by suction through a catheter inserted through the jugular or femoral vein into the pulmonary artery. Although successful management of AMPE has been reported, this advanced technique is not always readily available, and patients may be deemed too hemodynamically unstable to afford the time for preparation and repeated catheter insertions to remove massive clots. Only 5 have been performed at Harbor-UCLA Medical Center in the past 6 years. Furthermore, fragmentation of clot in the main pulmonary artery with distal showering of emboli to smaller inaccessible arteries may occur, and recurrence of the embolus is more common after this procedure than with open pulmonary embolotomy [2, 30]. Incomplete embolotomy has been shown in some patients to lead to pulmonary hypertension over time, which has been correlated with decreased overall survival [31, 32].

We propose the following algorithm for the indications of the discussed procedures in the setting of AMPE:

- Patients with a large thrombus demonstrated in the pulmonary artery, associated with hemodynamic instability requiring vasopressor support and evidence of impending right ventricular failure, should be promptly taken to the operating room for open embolotomy through a sternotomy.
- Patients with only mild hemodynamic instability and without evidence of severe right ventricular strain should be considered for thrombolytic therapy if no contraindications are present. Serial echocardiograms should be performed to evaluate for improvement. If thrombolytic therapy is contraindicated and catheter thrombectomy is readily available, then consideration for this technique is appropriate. However, in the instance that a patient with a large proximal thrombus is hemodynamically stable but cannot receive thrombolytics and catheter thrombectomy is not available, open embolotomy is then indicated.

In hemodynamically compromised patients, spiral CT and TEE are invaluable tools for diagnostic evaluation and choosing the appropriate therapeutic strategy [33-35]. Spiral CT is quick, noninvasive, and highly sensitive for the detection of an embolus in the proximal pulmonary arterial vasculature. Echocardiography is also quick and readily available and can be performed at the bedside or in the operating room. Right ventricular dilatation, abnormal right ventricular wall movement, a dilated pulmonary artery, and an increase in tricuspid regurgi-

tant velocity can be easily evaluated to accurately predict the degree of right ventricular failure. The finding of impending failure is an indication for open pulmonary embolotomy to avoid subsequent cardiac arrest, which is overwhelmingly fatal in this group of patients.

In conclusion, open pulmonary embolotomy is an immediate and definitive form of treatment for AMPE, with excellent long-term results. CPB is a vital component for the early resuscitation of these patients that increases the likelihood of a successful outcome. Open embolotomy before right ventricular ischemia and cardiac arrest ensues is imperative because preoperative cardiac arrest is associated with the highest mortality in patients with AMPE. Furthermore, bedside TEE and spiral CT are important noninvasive diagnostic tools that minimize a delay in diagnosis without compromising accuracy.

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