Surgical embolectomy in the management of massive and sub-massive pulmonary embolism: The results of 30 consecutive ill patients

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Short Communication

Abstract

BACKGROUND: Despite the improvement in the diagnosis and treatment of acute pulmonary embolism, it is yet a common clinical problem. The actual role of open embolectomy has not been well understood. The present report aimed to extrapolate the outcome of early open pulmonary embolectomy in a number of patients with acute (sub) massive pulmonary embolism (AMPE/ASMPE).

METHODS: A prospective study was performed on 30 patients who underwent emergency embolectomy at Ghaem Hospital, Mashhad, Iran during January 2005 to November 2012. All patients with an indication for pulmonary embolectomy according to recent American Heart Association guideline were enrolled in this study. Echocardiographic features, pulmonary artery pressure, and right ventricular (RV) diameter were recorded. The patients were followed up monthly by two cardiologists.

RESULTS: Indications for operation in descending order consisted of contraindication for fibrinolytic therapy (30%), failure to respond to fibrinolysis (26.66%), cardiopulmonary arrest (20%), patent foramen ovale (20%), right atrium clot (10%), and cardiogenic shock (10%). Mean pulmonary artery pressures were 52.26 ± 6.54 and 29.43 ± 2.87 mmHg before and after the operation, respectively (P < 0.0001). RV function and diameter improved significantly after surgery (P < 0.0001 and < 0.0001, respectively). Complete follow-up was performed in all surviving patients. All patients survived the operation, except one who died 2 days after surgery due to profound hypotension.

CONCLUSION: Short and long-term outcomes of early open embolectomy seemed to be satisfactory in high-risk patients presenting high clot burden in central pulmonary arteries. This study demonstrated that pulmonary embolectomy may play a promising role in the management of AMPE and ASMPE and recommended for future clinical trials.

Keywords: Echocardiography, Fibrinolysis, Embolectomy, Thromboembolism, Pulmonary, Treatment Outcome

Introduction

Acute massive pulmonary embolism (AMPE) is an acute and disastrous process with high mortality rates in spite of recent diagnosis and therapy advances. The main criteria in categorizing AMPE are widespread thrombosis, affecting at least half of the pulmonary artery bed. Patients with AMPE may develop cardiogenic shock, systemic hypotension and multi-organ failure. Patients with acute sub massive pulmonary embolism (ASMPE) present with increase in troponin, pro-brain natriuretic peptide (pro-BNP), or BNP levels as well as moderate to severe right ventricular (RV) dysfunction and enlargement. More than one-third of the pulmonary vascular bed is usually obstructed in ASMPE. If there is no previous history of cardiopulmonary diseases, patients may be hemodynamically stable.[1]

The management strategy in AMPE and ASMPE depend upon the conditions of the patients

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and has been controversial in some situations. Therapeutic methods include: thrombolytic agents, catheter-based thrombus fragmentation or aspiration and surgical embolectomy. The two former procedures may fail to resolve thrombotic materials adequately causing persistent pulmonary hypertension. In addition, fibrinolytic agents increase the risk of bleeding and catheter embolectomy procedure is limited due to mechanical hemolysis and micro or macro emboli.[1-3]

Due to building up experiences of surgeons and improvement of surgical and anesthetic techniques, surgical embolectomy with cardiopulmonary bypass has reemerged as an effective therapy. The present report aimed to provide an extrapolation of the outcome of early open pulmonary embolectomy in a number of patients with AMPE and ASMPE over an 8-year period in Ghaem Hospital, Mashhad, Iran.

Materials and Methods

A prospective study was performed on 30 consecutive patients with AMPE and ASMPE who underwent emergency pulmonary embolectomy at Ghaem Hospital during January 2005-November 2012. The hospital is considered as a referral and specialized educational hospital where the patients are referred from around cities for surgical embolectomy. Written informed consent was obtained from each patient. The patients were followed with routine monthly visits to the cardiologist.

Patients with AMPE and ASMPE who satisfied the indications for surgical embolectomy were included in this study. According to recent American Heart Association (AHA) guideline indications for surgical embolectomy included a central or para-central (sub) massive embolism with one of the following situations: cardio-respiratory arrest, thrombus in the right heart, large patent foramen ovale (PFO), failure to respond to thrombolytic therapy, and absolute contraindications for thrombolytic therapy.[4,5]

Based on local hospital policies and low costs, streptokinase was chosen as the thrombolytic agent. Thrombolytic therapy failure was defined as: sustained systolic blood pressure below 90 mmHg, refractory shock, RV dysfunction which persisted for more than 36 h, and residual pulmonary vascular obstruction > 30% at the 10th days after thrombolysis on right heart catheterization or multidetector computed tomographic (CT) pulmonary angiography.[6] In the case of failure to

thrombolytic therapy, surgical embolectomy was performed within 72 h of the initial thrombolysis.

Absolute contraindications to thrombolytic therapy included the following: (1) prior intra cranial hemorrhage, (2) ischemic stroke (between 3 h and 3 months), (3) aortic dissection, (4) intracranial disease e.g. neoplasm, arteriovenous malformations, etc. (5) head injury < 3 months ago, (6) bleeding disorder.

Based on recent AHA guideline, indications for fibrinolytic therapy in acute pulmonary embolism were regarded as follows: (1) patients with acute (< 14 days) massive pulmonary embolism and acceptable risk of bleeding complications (Class IIa), (2) in some situation it may be considered for patients with ASMPE judged to have high risk condition such as new hemodynamic instability, presence of major myocardial necrosis, which was defined with elevated serum troponin level, high level of N-terminal pro-BNP or BNP, or presence of severe RV enlargement on echocardiography/CT scan and low risk of bleeding complications (Class IIb).[4]

Based on the mentioned criteria the patients enrolled in the study and their demographic information, initial presentation and symptoms, risk factors, methods of diagnosis, localization of thrombotic material, indication for operation, mortality, and morbidity were recorded and analyzed. The exclusion criteria included the patients with severe co-morbidities, and those who did not consent to surgery or did not refer for follow-up.

The main diagnostic tool was CT pulmonary angiography. Echocardiography was also performed by one cardiologist, but patients were followed by two cardiologists. Standard two-dimensional (2D) and Doppler transthoracic echocardiographic (TTE) studies were performed using the Vivid 3 and Vivid 7 with a 3.2 MHz transducer in left lateral position. RV diameter was measured on 2D and pulmonary systolic pressure was estimated by adding a trans-tricuspid gradient to the right atrial (RA) pressure. The RA pressure was also estimated by the respiratory motion of the inferior vena cava seen on 2D echocardiogram. The presence or absence of PFO was evaluated by contrast echocardiography. The proximal parts of the inferior and superior vena cava were searched for thrombus using echocardiogram. Bed side transesophageal echocardiography (TEE) was the initial diagnostic tool in 11 patients. Troponin levels were evaluated, and color Doppler ultrasonography was also performed in all patients.

Depending on the patient's condition surgical embolectomy was performed in the 1st h up to 72 h after diagnosis. Each patient was operated with a unique technique. Depending on patient's situation, general anesthesia was induced with ketamine or etomidate and patients were intubated. After connecting appropriate monitoring devices and placing electrocardiographic electrodes, a vertical median sternotomy was performed, and cannulae were inserted into the ascending aorta and both vena cava. The cannulae inserted into the ascending aorta was used to deliver antegrade cardioplegia and for later air aspiration. Cardiopulmonary bypass was established, and cooling was initiated. The aorta was clamped, and the cold cardioplegic solution was infused through the aortic root. After cardiac arrest, longitudinal arteriotomy of the main pulmonary artery was performed; the incision was extended onto the left and right branches and the clots were removed by forceps and assisting suction. To avoid additional damage to the lung parenchyma, lung massage was not performed. In seven patients, RA was incised, and the PFO was repaired in 6, and RA clot was removed in 3 patients. After removing the thrombotic materials, the pulmonary arteriotomy site and RA incision were sutured with continuous No.5-0 polypropylene sutures. Coronary artery bypass grafting (CABG) was required in 2 patients. After rewarming and evacuating air from cardiac chambers, patients were weaned off cardiopulmonary bypass.

We aimed to evaluate early mortality, systolic pulmonary artery pressure (SPAP), RV dysfunction and bleeding complications during hospitalization and to compare echocardiographic data before and after surgery. Late mortality, new presentation of symptoms and warfarin therapy complications were also recorded.

Absolute number and percentage were computed to describe non-numeric data. Data were expressed as mean ± standard deviation for continuous variables. The echocardiographic parameters had a normal distribution, and paired-sample t-test was used to test for significant difference between these parameters before and after surgery. Data analyses were performed using SPSS software for Windows (version 11.5, SPSS Inc., Chicago, IL, USA). $P < 0.0500$ was considered significant for all data analyses.

Results

Thirty patients who underwent surgical embolectomy for AMPE and ASMPE enrolled in our study from January 2005 to November 2012.

This study included 13 men and 17 women whose mean age was 56.1 years (range, 23-83 years). Baseline patients' characteristics are summarized in table 1. One patient underwent cardiopulmonary resuscitation twice, one in the emergency room and another in the operating room. The indications for operation are summarized in table 1 (some patients had more than one indication for operation). One patient was an 83-year-old man who had a large clot in his RA, which slightly passed through the PFO to the left atrium.

The mean cardiopulmonary bypass time was 43 min (range, 20-64 min), and the mean aortic cross clamp time was 32 min (range, 15-60 min). All patients survived the operation. Heparin therapy was started 4 h after operation and warfarin therapy was initiated on the 2nd day post operation. Target international normalization ratio was between 2.0 and 3.0. The median length of stay was 7 days (range, 5-10 days). 29 patients were discharged and placed on long term anticoagulation therapy with warfarin.

One patient was a 73-year-old man who died 2 days after surgery; he had undergone CABG 2 months before admission for acute pulmonary emboli. He had pulmonary hypertension and RV dysfunction before his CABG and had presented with dyspnea and mild hemoptysis 7 weeks after CABG. He was treated with fibrinolysis; however, open embolectomy was performed due to unstable hemodynamic conditions. Two days after surgery, he was complicated by profound hypotension which was unresponsive to medical treatment.

Post operation echocardiography was performed in all patients. Mean SPAP and RV diameter reduced significantly after surgery and RV function also improved ($P < 0.0001$). Pre- and post-operational echocardiographic data are presented in table 2. The median and mean follow-up duration was 45 and 42 months respectively (range, 3-94 months). In patients' follow-up, 10 cases (33.33%) with warfarin toxicity, 2 cases (6.66%) with gastrointestinal bleeding, and 5 cases (16.66) with pneumonia were diagnosed, all of which improved with medical treatment. No recurrent embolus was observed. Two patients (6.66%) died later due to cancer metastasis. There were not new patients' symptoms.

Discussion

Despite improvement in the diagnosis and treatment of acute pulmonary embolism, it is yet a common clinical problem. If obstruction of the pulmonary artery vascular bed is > 50%, estimated

Table 1. Patient characteristics and indications for operation

Patient characteristics	n (%)
Sign and symptom	
Dyspnea	30 (100.0)
Cardiac arrest	6 (20.0)
Hypotension	6 (20.0)
Syncope	4 (13.3)
Faintness	5 (16.6)
Hemoptysis	1 (3.3)
Localizations of thrombi	
Main pulmonary artery	10 (33.3)
Left pulmonary artery	18 (60.0)
Right pulmonary artery	16 (53.3)
RA	3 (10.0)
Inferior vena cava	4 (13.3)
Indications for operation	
Cardiopulmonary arrest	6 (20.0)
Failure to respond to fibrinolysis	
Sustained systolic blood pressure below 90 mmHg	4 (13.3)
Residual pulmonary vascular obstruction > 30%	3 (10.0)
Persistent RV dysfunction and pulmonary hypertension	1 (3.3)
Contraindication for fibrinolysis	
Prior brain surgery	4 (13.3)
Recent orthopedic surgery	4 (13.3)
Recent ischemic stroke	1 (3.3)
Right atrium clot	
ASMPE with huge RA clot	2 (6.7)
ASMPE with a large clot in RA passing through the PFO	1 (3.3)
PFO	
Large PFO with RA clot	3 (10.0)
Prior brain surgery with PFO	1 (3.3)
Cardiopulmonary arrest with PFO	1 (3.3)
Only large PFO	1 (3.3)
Cardiogenic shock with maximum inotropic agent	3 (10.0)

ASMPE: Acute sub-massive pulmonary embolism; PFO: Patent foramen ovale; RA: Right atrium, RV: Right ventricular

Table 2. Comparison between the echocardiographic parameters (mean ± SD) before and after operation

Parameter	Time		P*
	Preoperational (mean ± SD)	Post operational (mean ± SD)	
RV diameter (mm)	39.83 ± 4.42	33.70 ± 2.33	
TAPSE (mm)	12.20 ± 2.60	18.93 ± 1.41	< 0.0001
SPAP (mmHg)	52.26 ± 6.54	29.43 ± 2.87	

* Paired-sample t-test; RV: Right ventricular; TAPSE; Tricuspid annular plane systolic excursion; SPAP: Systolic pulmonary artery pressure; SD: Standard deviation

mortality rate of patients approaches 50% and if the patient requires vasopressor therapy, the mortality rate increases to 70%. If hemodynamic deterioration continues, mortality rate approaches 100%.[1] In acute pulmonary embolism, pulmonary vascular resistance and RV after load suddenly increase, resulting in RV dilation and strain and subsequent difficulty in contraction. Ventricular pressure overload shifts the interventricular septum leftward, with resultant under-filling of the left ventricle, declining cardiac output and systolic arterial pressure, and consequently decreases coronary blood flow. The combination of high RV wall tension and myocardial O_2 demand with coronary hypoperfusion cause RV ischemia and further RV dysfunction. Perpetuation of this vicious cycle leads to circulatory collapse, and death. Interruption of this cycle by immediate and complete removal of clots is the only option for good prognosis.

According to recent guidelines, fibrinolytic therapy is strongly recommended in high-risk patients presenting with cardiogenic shock or hypotension, unless major contraindications exist. However, some

studies reported that it did not reduce mortality rates.[1,7] Due to major bleeding risk, thrombolytic therapy remain controversial in normotensive high-risk patients. Women also have a 27% risk of major bleeding compared to 15% in men.[7]

Other options for acute pulmonary emboli treatment is catheter based techniques. It is applied when there are contraindications for fibrinolysis and surgery is impossible or not available. However this technique has some adverse effects including: pericardial effusion and tamponade, pulmonary hemorrhage, dissection of aorta, and distal embolization. After hemodynamic improvement, the procedure should be stopped, regardless of angiographic result. In some situations thrombolytic therapy and catheter embolectomy fail to resolve thrombi adequately. The clots may then undergo organization and incomplete recanalization and incorporate into the vascular bed. This process leads to persistent pulmonary hypertension and RV dysfunction, which appears to be a significant contributor to poor prognosis. Open pulmonary embolectomy is a definitive treatment; in which clot-debulking is usually complete and rapid improvement of the pulmonary artery pressure and RV function is achieved. The true role of open embolectomy has not been well established.[8,9] In the past, surgical embolectomy was the last therapeutic option and only performed on patients with cardiopulmonary arrest, failure to respond to fibrinolysis, or contraindication for fibrinolysis. Ahmed et al.[10] indicated that surgical outcome was significantly improved with early surgery (< 24 h from presentation) compared to delayed surgery (> 24 h). Hence the approach to massive and submassive embolism has been recently modified and open embolectomy is performed in many centers with little adverse outcome. The mortality rates of this procedure have decreased from 57% in 1960 to 6% in 2005.[11,12]

Few available studies have compared surgical versus medical management. In a non-randomized comparison of medical and surgical treatment, the medically treated patients had a higher mortality rate.[1] Our study demonstrated that early surgical intervention in patients presenting with high clot burden in central pulmonary arteries and with evidence of RV enlargement/dysfunction showed satisfactory short and long-term results. These findings were also compatible with other studies.[2,10,11,13-15] The patients had a significant decrease in pulmonary artery pressure and an improvement in RV function.

It is advised that indications for open embolectomy should be extended so that high-risk patients with severe RV dysfunction or hypotension and high centrally located clot burden, be considered for surgery before cardiac arrest and severe RV failure. It seems that TTE and TEE are non-invasive and available diagnostic tools suitable for risk stratification and the diagnosis of RV dysfunction or enlargement, and severe pulmonary hypertension. These disorders might be considered as prodromes of cardiac arrest.

In our study, one patient died after surgery. It was assumed that this early death was largely attributed to previous pulmonary hypertension, severe RV dysfunction and delayed surgery. The degree of hemodynamic compromise and pervious cardiopulmonary disease are probably the most powerful predictors of in-hospital death.

Conclusion

Integrated approach to acute pulmonary embolism and rapid diagnosis followed by early intervention, are essential. The present study suggests the short and long term outcomes of early open embolectomy be satisfactory in high-risk patients presenting high clot burden in central pulmonary arteries. However, a randomized study comparing surgical embolectomy and fibrinolytic therapy might confirm the role of embolectomy in such patients. This study demonstrated that pulmonary embolectomy may play a promising role in the management of AMPE and ASMPE and is recommended for future clinical trials.

Limitations
It was acknowledged that the number of patients was limited and no control group (non-surgical management) was available for comparison. The limitation was due to the nature of the study and the relatively rare cases of AMPE and ASMPE.

Acknowledgments

Conflict of Interests

Authors have no conflict of interests.

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