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Off-Pump Open Pulmonary Embolectomy for Patients with Major Pulmonary Embolism

Young Jo Sa,[1] Si Young Choi,[1] Jong Ho Lee,[1] Jong Beom Kwon,[1] Seok Whan Moon,[1,3,4] Keon Hyeon Jo,[1] Young Pil Wang,[1] Seok Chan Kim,[2] Pum Jun Kim, [2] Hae Ok Jung [2]

[1]Department of Thoracic and Cardiovascular Surgery, [2]Department of Internal Medicine, [3]Catholic High Performance Cell Therapy, [4]Institute of Cell & Tissue Engineering, College of Medicine, The Catholic University of Korea, Seoul, Republic of Korea

ABSTRACT

Acute major pulmonary artery embolism (AMPE) requires rapid diagnosis and early intensive treatment to optimize patient outcomes. Most patients with AMPE and hemodynamic instability need open pulmonary embolectomy (OPE). We modified the technique of OPE to include a minimally invasive procedure without the use of cardiopulmonary bypass (CPB). From March 1988 to April 2006, we performed OPE on a total of 12 patients (21 sides) with AMPE. Seven patients (13 sides) underwent conventional OPE with CPB and 5 patients underwent off-pump OPE (OPPE), 4 (8 sides) with AMPE and 1 with catheter embolus with thrombosis. In patients who underwent conventional OPE, there was 1 hospital death in a patient with severe right ventricle dysfunction and 2 significant cases of airway bleeding. In patients who underwent OPPE, there was 1 case of minimal airway bleeding. Mean systolic pulmonary artery pressure in conventional OPE and OPPE patients, respectively, decreased from 50.3 ± 14 mmHg and 35.4 ± 6.6 mmHg preoperatively to 41.7 ± 20 and 28 ± 3 mmHg postoperatively. During the long-term follow-up, there were 2 cancer-related deaths but no recurrence of PE. All surviving patients maintained functional class I (n = 10) or II (n = 1). Compared with conventional OPE, OPPE was effective for treating AMPE in our selected cases. Modification of conventional CPB and systemic full heparinization to minimal use of systemic heparinization without CPB may be helpful in treating selected patients with AMPE.

INTRODUCTION

Acute major pulmonary artery embolism (AMPE), defined as an occlusion of the PA that exceeds 50% of its cross-sectional area, causes acute or progressive hemodynamic deterioration if not properly treated. Therefore AMPE requires intensive and prompt management, such as thrombolytic therapy or open pulmonary embolectomy (OPE) [Stulz 1994; Goldhaber 1999; Kucher 2006]. A recently reported management algorithm for acute PE included early diagnosis, optimal treatment, and stratification of risk factors associated with long-term morbidity or mortality [Kasper 1997; Leacche 2005]. Modification of this algorithm may be needed, however, depending on patient hemodynamic status and comorbid conditions and available diagnosis or treatment facilities.

OPE had been considered a last resort for treating AMPE because of high postoperative morbidity and mortality, but early OPE has recently been advocated as a first-line treatment for AMPE because this procedure is associated with low mortality, less risk of major bleeding, and low incidence of recurrent PE [Schmid 1991; Kasper 1997; Yalamanchili 2004; Dauphine 2005; Leacche 2005]. With more rapid diagnosis, proper assessment of severity, and new surgical techniques, conventional OPE has continuously evolved, and minimally invasive modifications of this technique have shown favorable results in selected cases [Barbosa 1995; Sudo 1999; Ichimande 2000; Ashrafian 2003; Moon 2006]. We describe results for our selected cases, in which we used technical modifications to treat AMPE without cardiopulmonary support and with minimal use of systemic heparinization. We also present a review of literature on off-pump OPEs (OPPE).

MATERIALS AND METHODS

We retrospectively evaluated 12 patients who had undergone OPE for AMPE in our institution during the period from March 1988 to April 2006. Patient characteristics, diagnostic procedures, cause of PE, medical treatments, operative procedures, and postoperative morbidities were recorded and analyzed (Table 1). Heparin or thrombolytic therapy was contraindicated in some patients with recent craniectomy, major hepatectomy, or major abdominal trauma (liver and spleen injury). The remainder of the patients underwent anticoagulant or thrombolytic therapy. Single or repeated spiral chest computed tomography (CT) and lung perfusion scans were performed for diagnosis or assessment of treatments. Echocardiography was used to evaluate cardiac performance

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Correspondence: Seok Whan Moon, Department of Thoracic and Cardiovascular Surgery, Kangnam St. Mary Hospital, 505 Banpo-Dong, Socho-Ku, Seoul, Republic of Korea; 82-2-590-1442; fax: 82-2-594-8644 (e-mail: swmoon@catholic.ac.kr).

Table 1. Characteristics and Results of 12 Patients with Acute Massive or Submassive Pulmonary Embolism Who Underwent Open Pulmonary Embolectomy with or without CPB*

Patient No.	Age, y	Sex	Embolus Origin	Symptoms	RVD	Severity	Approach	CPB	NYHA Class	Filter	Complications	Comment
1	19	M	Leg	Hemoptysis, dyspnea	Yes	R, massive; L, submassive	Median sternotomy	Yes	II	+	Moderate AWB	Sports injury
2	54	F	Catheter	Catheter embolism	No	R, submassive	Median sternotomy	No	I	–		
3	74	F	Leg	Dyspnea	Yes	R, massive; L, submassive	Median sternotomy	Yes	II	–	Mild AWB	Natural death after 5 y
4	41	M	Leg	Dyspnea	Yes	R, massive; L, submassive	Median sternotomy	Yes	Died of RVF	–	Severe AWB	Subacute, major trauma
5	45	M	Leg	Hemoptysis	No	L, massive	Left thoracotomy	No	I	–		Femur fracture
6	40	M	leg	Syncope	Yes	R, massive; L, submassive	Median sternotomy	Yes	I	+		Mild leg trauma
7	20	F	leg	Dyspnea	Yes	R, massive	Median sternotomy	Yes	I	–		Major trauma
8	42	F	Leg	Dyspnea	Yes	R, :submassive; L, massive	Median sternotomy	Yes	I	+	Mild AWB	Protein C deficiency
9	70	F	Abdomen	Dyspnea	No	L, massive	Thoracotomy	No	I	–		Cancer death after 6 mo
10	35	M	Leg	Dyspnea	No	R, submassive; L, submassive	Thoracotomy, both	No	I	–		Subacute, sports injury
11	67	M	Leg	Syncope	Yes	R, submassive; L, massive	Clamp shell incision	No	I	+		Spine surgery
12	45	M	Leg	Dyspnea	Yes	R & L, massive	Clamp-shell incision	Yes	I	+	Phrenic palsy	Warm beating heart, craniectomy

*CPB indicates cardiopulmonary bypass; NYHA, New York Heart Association; IVC, inferior vena cava; RVD, right ventricle dysfunction; R, right; L, left; AWB, airway bleeding; RVF, right ventricle failure.

or to detect right ventricular dysfunction (RVD). Pulmonary artery angiography with insertion of an inferior vena cava (IVC) filter was performed when indicated.

Surgical Techniques

Seven patients with AMPE underwent OPE performed with conventional techniques: median sternotomy, systemic full heparinization, total cardiopulmonary bypass (CPB), moderate systemic hypothermia, cardioplegia, and intermittent circulatory arrest. Of the remaining 5 patients, 4 planned to undergo OPPE through a median sternotomy, anterolateral thoracotomy, or submammary transsternal bilateral thoracotomy on a nonemergent basis. This off-pump technique has been previously described [Moon 2006], but here we provide additional important details.

Before elective OPE, an IVC filter was inserted as needed to avoid recurrent PE intraoperatively or postoperatively. After administration of selective endobronchial anesthesia, we exposed the right or left or both pulmonary arteries through a median sternotomy, clam-shell thoracotomy, or sequential thoracotomy. The extrapericardial and intrapericardial major pulmonary arteries were exposed after dissection of both the right and left pulmonary hilum. Several snares were placed around the pulmonary vessels to allow for isolation (Figure 1). The proximal part of the affected pulmonary arteries was temporarily snared with a rubber tourniquet after systemic

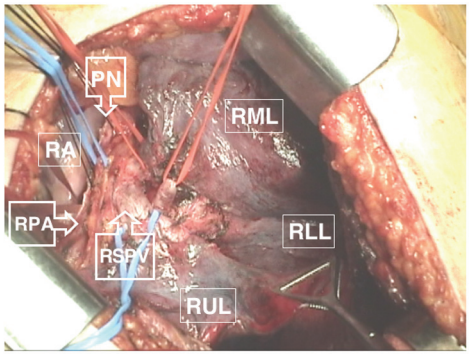

Figure 1. Right pulmonary artery (RPA) and vein and their branches to the right upper lobe (RUL), middle lobe (RML), and lower lobe (RLL) are mobilized for better exposure of the proximal and distal right pulmonary artery (RPA) following major and minor pulmonary fissures after anterolateral thoracotomy. PN indicates right phrenic nerve; RA, right atrium; RSPV, right superior pulmonary vein.

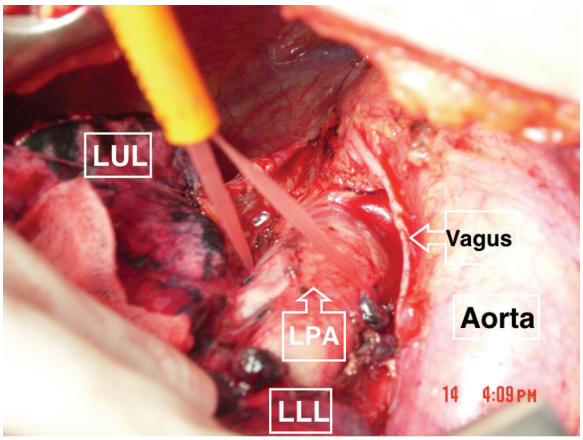

Figure 2. The left pulmonary artery (LPA) is mobilized and snared with umbilical tape for temporary compression after anterolateral thoracotomy. Pulmonary arteriotomy can be performed after compression of the PA. Vagus indicates vagus nerve; LUL, left upper lobe; LLL, left lower lobe.

partial heparinization (1 mg/kg) was obtained (Figure 2). Patients were monitored for changes in hemodynamic status and the pressure of the central pulmonary artery. After verification of no evidence of acute cardiac decompensation after snare tightening, the pulmonary arteriotomy was made, and the partially organized thrombi were encountered and removed with or without the aid of the embolectomy catheter (Figure 3). The pulmonary arteriotomy was closed with a 6-0 polypropylene suture and the rubber tourniquet was released. In case of bilateral PE, our attention was then turned to the other side of the pulmonary artery, and the embolectomy was performed in the same manner.

RESULTS

Twelve patients underwent OPE, 7 patients with and 5 without CPB; 7 OPE and 4 OPPE procedures were for treatment of AMPE, and 1 OPPE was for treatment of a catheter with thrombus. Five patients were men, and the average age was 46 years (range 19 to 74 years). All patients except 1 presented with dyspnea on exertion, chest pain, syncopal attack, hemoptysis, or combined symptoms. Chest CT scan, pulmonary artery angiography, lung perfusion-ventilation scanning, and echocardiography were used for diagnostic procedures or assessment of treatment. The emboli originated from leg veins (n = 10), hepatocellular carcinoma (n = 1), or catheter fracture (n = 1). PE was related to sports injury in 2 patients, major surgery or spine surgery in 4, major trauma in 3, protein C deficiency in 1, and schizophrenia in 1. In 8 patients, hemodynamic status stabilized with inotropic support or fluid resuscitation, but 3 patients remained hypotensive and tachycardic despite intensive care. Thrombolytic therapy and anticoagulants were initiated in 7 patients, but not in the 4 patients with catheter embolism, recent major liver surgery, recent craniectomy, or major abdominal trauma. Conventional OPE with total CPB, systemic full heparinization, and cardioplegia were performed in 7 patients who did not respond to medical treatments. In 1 patient with recent craniectomy and hypotension, OPE was performed with warm beating-heart CPB rather than off-pump because of intraoperative hemodynamic deterioration when the unilateral pulmonary artery was clamped. The remaining 5 patients, including 2 patients in whom thrombolytic therapy was contraindicated, underwent OPPE. Preoperative IVC filters were inserted preoperatively for 5 patients who had overt leg vein thrombosis.

Postoperative airway bleeding occurred in 3 patients: severe bleeding in 2 conventional OPE patients and minimal bleeding in 1 OPPE patient. Patients with thoracotomy suffered postoperative wound pain for as long as 6 or 12 months, compared with those with median sternotomy, who had less severe pain. One patient, who had right ventricle failure with severe pulmonary hypertension, died postoperatively, and 11 patients survived. During long-term follow-up, cancer-related death occurred in 2 patients, at 6 months and 3 years after OPPE. Patients with leg-vein thrombosis maintained long-term anticoagulation with warfarin or antiplatelet drugs.

In all 11 surviving patients, mean systolic pulmonary artery pressure in conventional OPE and OPPE, respectively, decreased from 50.3 ± 14 mmHg and 35.4 ± 6.6 mmHg preoperatively to 41.7 ± 20 and 28 ± 3 mmHg postoperatively. All survivors maintained functional class I or II during long-term follow-up (mean follow-up time, 102 months).

DISCUSSION

PE occurs in approximately 1% of hospitalized patients, and 5% to 10% of these cases are AMPE [Kasper 1997; Kucher 2006]. AMPE is clinically characterized by hemodynamic instability and is often associated with recent surgery or major trauma, congestive heart failure, venous thrombosis, or cancer [Goldhaber 1999; Kucher 2006]. If not diagnosed early and treated aggressively, AMPE results in progressive

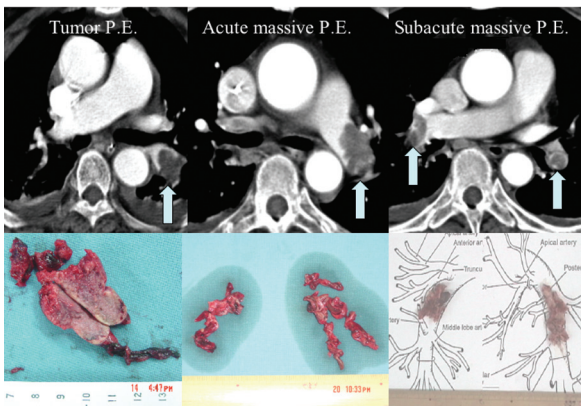

Figure 3. Representative chest computed tomographic findings and pulmonary embolus (PE) removed in 3 patients who underwent off-pump open pulmonary embolectomies. Arrows indicate emboli in the pulmonary arteries.

hemodynamic compromise with possible development of chronic PE with chronic pulmonary hypertension that may require more complicated thromboendarterctomy [Gulba 1994; Scheopf 2004].

Spiral CT is instrumental in early diagnosis and effective treatment assessment in AMPE, although invasive pulmonary angiography and lung perfusion scan are still used [Eng 2004; Schoepf 2004]. In addition to PE imaging, chest CT plays an important role in documentation of right ventricle (RV) enlargement, which predicts adverse clinical events in patients with acute PE. Echocardiography is not recommended as a routine imaging test to diagnose suspected PE, but it is useful at the bedside for identifying RV dysfunction (RVD) in AMPE in the presence of severe hemodynamic instability. RVD is predictive for decreased survival [Goldhaber 1999; Schoepf 2004; Kucher 2006] and requires intensive, aggressive treatment such as thrombolytic therapy or OPE to prevent cardiopulmonary collapse or chronic right heart dysfunction leading to pulmonary arterial hypertension. Decision-making regarding whether and when to perform OPE may be guided by echo-based RVD detection and patient monitoring for the presence of acute hemodynamic instability. Recent data support more liberal use of OPE, particularly in the presence of RVD before overwhelming hemodynamic collapse [Stulz 1994; Yalamanchili 2004].

Current strategies for management of AMPE depend largely on the degree of hemodynamic instability at presentation. Patients at low risk have good outcomes with intensive anticoagulant treatment alone, but higher-risk patients may require more aggressive intervention with thrombolytic therapy or embolectomy [Gulba 1994; Goldhaber 1999; Kucher 2006]. A recent study found that thrombolytic therapy was associated with higher rates of death, major hemorrhage, and recurrent PE than surgical treatment with OPE [Gulba 1994]. Moreover, thrombolytic therapy is contraindicated in up to 50% of patents because of recent major surgery, major trauma, or stroke [Kasper 1997].

The indications and timing of surgical intervention for AMPE remain controversial but crucial, because the best outcomes are achieved with surgery performed before the onset of overt cardiovascular collapse [Kucher 2006]. OPE has been associated with high surgical mortality rates of 30% to 70%, possibly because this procedure was reserved for AMPE patients with sudden severe hemodynamic instability or persistent massive PE despite intensive medical treatments [Clarke 1986; Meyer 1991; Schmid 1991]. Good results for OPE have been increasingly reported, however, with operative mortality <10% attributable to rapid diagnosis, early surgical timing before overt circulatory collapse, and multidisciplinary collaboration [Yalamanchili 2004; Leacche 2005]. Unlike other studies [Meyer 1991; Kasper 1997; Dauphine 2005], our study had more patients with submassive PE and stable hemodynamics with or without inotropic support. We believe that our improved survival rate may be attributable to early echo-based detection of RVD, early surgery before the development right heart failure or hemodynamic collapse, and collaborative management between physicians and surgeons. Early OPE with collaborative management plans may optimize OPE outcomes [Lancet 1999; Yalamanchili 2004; Leacche 2005].

OPE using median sternotomy, hypothermia, and intermittent circulatory arrest is generally accepted to be essential to the successful treatment of AMPE. Although CPB remains necessary for treating most patients with AMPE, prolonged CPB is likely to have adverse side effects [Meyer 1991; Schmid 1991], and some studies have found no advantage from the use of hypothermia and aortic cross clamping [Yalamanchili 2004; Leacche 2005]. Minimal or no use of CPB in OPE has been reported, although confined to selected cases with submassive PE or in emergent settings. OPPE may be selectively indicated for patients with submassive PE or hemorrhagic stroke, major trauma, or recent major surgery, situations in which systemic full heparinization is contraindicated (Table 2). If patients with AMPE show echo-based RVD despite medical treatments, this minimally invasive technique can be considered for treating submassive PE at an early stage to prevent progressive hemodynamic collapse or chronic pulmonary embolism. Otherwise more invasive techniques may be needed, such as prolonged CPB and PE with or without total circulatory arrest, despite the associated higher mortality and morbidity. Minimally invasive techniques are contraindicated, however, in patients with preoperative hemodynamic collapse. Moreover, OPPE should be converted to conventional CPB when hemodynamic instability occurs with pulmonary artery clamping in case of bilateral massive or submassive PE. Techniques can also be modified in accordance with the needs of individual patients and their hemodynamic status. In case of

Table 2. Review of Literature on Open Pulmonary Embolectomy without Cardiopulmonary Bypass*

Report	No. of Patients	Inflow Control	Results	Comment
[Vossschulte 1960]	35	Caval vein occlusion	20% Survived	All emergent cases
[Clarke 1985]	36	Caval vein occlusion	58% Survived‡	19 Emergent cases included
[Senning 1998]	1	Caval vein occlusion	Survived for 29 years	PE occurred after thoracotomy
[Barbosa 1995]	1	Clamping of PA	Survived	Thrombolytics contraindicated
[Ichimanda 2000]	1	Clamping of PA	Survived	Persistent embolus after thrombolytics
[Ashrafian 2003]	1	Clamping of PA	Survived	J-ministernotomy
[Hirle 2003]	1	Caval vein occlusion	Survived	Hemorrhagic stroke
[Moon 2006]	1	Clamping of PA	Survived	Clam-shell incision for both PE
This series	5	Clamping of PA	100% Survived	Both PE in 2 patients

*PA indicates pulmonary artery; PE, pulmonary embolism.

‡Eighty percent of patients without cardiac arrest survived open embolectomy, but 30% of patients with cardiac arrest survived postoperatively.

bilateral PE, the peripheral part of both the right and left peripheral arteries can be better exposed by a transsternal bilateral thoracotomy approach rather than median sternotomy [Moon 2006]. In an emergent setting, portable percutaneous cardiopulmonary support can save patients with circulatory collapse preoperatively, and may support the patient during surgery without conversion to conventional total CPB [Sudo 1999; Hseih 2001].

In conclusion, we believe that excellent results can be achieved with early OPE performed before the development of chronic severe pulmonary hypertension in patients with AMPE. The use of a less invasive technique, with the preoperative insertion of an IVC filter as needed and without the use of CPB, was effective in the treatment of our selected cases, patients who were hemodynamically stable with or without inotropic support and were able to avoid exposure to CPB-related high morbidity and mortality associated with conventional techniques.

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